ΦYTON
REVISTA INTERNACIONAL DE BOTÁNICA EXPERIMENTAL
INTERNATIONAL JOURNAL OF EXPERIMENTAL BOTANY
FUNDACION ROMULO RAGGIO
Gaspar Campos 861, 1638 Vicente López (BA), Argentina
www.revistaphyton.fund-romuloraggio.org.ar

Sustainable management and use of a medicinal emblematic plant in Chile: *Buddleja globosa* Hope

Manejo y uso sustentable de una planta medicinal emblemática de Chile: *Buddleja globosa* Hope

Wilckens P[1], MP Fernández[2], M Gómez[1], I Peña[3], G Montenegro[1]

Abstract. *Buddleja globosa* Hope is a well-known native, medicinal plant because of its digestive and cicatrizing properties. Due to the increasing domestic and international demand, *B. globosa* abundance and distribution in Chile has resulted in the intensive exploitation of the plant's natural habitat, without consideration of the plant's regenerative capacity. The main objective of this research was to establish the *B. globosa* growth cycle and model its regeneration cycle. This would allow for more productive, efficient and sustainable use and management of this species, thus ensuring its long-term conservation. We selected two study sites, one wild and another one cultivated. In each one, ten individuals were marked as control treatments, for further observations, in order to quantify the monthly growth dynamics. Fifteen plants selected at random were marked in each site under study to know the regeneration rates with three pruning methods: apical, medium and basal (5 plants per treatment). The results showed significant differences between the control and management treatments on plants grown in the valley, and among the wild plants of the mountains. The biomass growth rates achieved in the treatments of pruning, and the period that those were maximum at both sites, allows us to recommend harvesting of *B. globosa* under a medium pruning management in January for the valley. For the mountain zones, it is suggested to conduct a partial apical-type harvest in December: this would allow that a part of the plant achieves the end of the flowering stage, which will contribute to seed dispersal and natural reproduction of the species.

Keywords: Biomass; Growth cycle; Medicinal resource; Regeneration rate; Sustainable use.

Resumen. *Buddleja globosa* Hope es una especie medicinal nativa ampliamente conocida por sus propiedades cicatrizantes y digestivas. Las demandas del mercado interno y externo así como su amplia distribución a lo largo del país han incentivado una utilización intensiva desde su hábitat natural, desconociéndose su capacidad de regeneración vegetativa frente a los sistemas de cosecha de biomasa utilizados por los hierbateros. Esta investigación tiene como objetivo general establecer el ciclo de crecimiento y un modelo de regeneración de la especie que permita un manejo productivo y un uso sustentable para su conservación en el tiempo. Se seleccionaron dos sitios de estudio, uno silvestre y otro cultivado. En cada uno se marcaron 10 plantas controles, para cuantificar, a través de varias observaciones, la dinámica estacional del crecimiento. Para conocer las tasas de regeneración se utilizaron 15 plantas tratamientos con tres métodos de cosecha; apical, media y basal (5 plantas por tratamiento). Los resultados mostraron diferencias significativas entre controles y tratamientos en las plantas cultivadas en el valle y entre las plantas silvestres de la cordillera. Las tasas de crecimiento de biomasa alcanzada en los tratamientos de poda y el periodo en que estas se hacen máximas en ambos sitios, nos permite recomendar una cosecha de *B. globosa* bajo un manejo de podas medias en el mes de enero para el valle. Para las zonas de cordillera se sugiere una cosecha parcial con poda apical en diciembre que permita que una parte de la planta logre la finalización de la fase de floración, para la dispersión de semillas y reproducción natural de la especie.

Palabras clave: Biomasa; Ciclo de crecimiento; Recurso medicinal; Tasa de regeneración; Uso sustentable.

Pontificia Universidad Católica de Chile. Facultad de Agronomía e Ingeniería Forestal.
[1] Departamento de Ciencias Vegetales.
[2] Departamento de Ecosistemas y Medio Ambiente.
[3] Departamento de Ciencias Animales.
Avda. Vicuña Mackenna 4860, Macul, Santiago, Chile. Phone: (56) 02 3545726; Phone-fax: (56) 02 3544154.
Address Correspondence to: Paulina Wilckens, *e-mail:* pwilckensr@uc.cl, paulinawilckens@gmail.com
Recibido / Received 30.VI.2011. Aceptado / Accepted 10.I.2013.
This research was financed by the Project QC008 of Foundation COPEC-UC.

INTRODUCTION

Plant taxa existing to a national level are estimated in 5739 (Marticorena, 1990; Cubillos & León, 1995). Around 10% of them present some medicinal uses (Massardo & Rozzi, 1996). These numbers somehow express the interest for medicinal plants in the country, which may be approached from three wide and diverse dimensions. One of these dimensions comes from ethnobotany (Araya-Presaet al., 2003).

Another dimension is phytochemistry. Pharmacological studies become relevant as the active principles of plants are isolated and identified, presenting curative records based on knowledge transference of their properties by ethnical groups and local communities (Montenegro et al., 1994; Ladio & Lozada, 2004). Main studies related to medicinal uses have been carried out from an ethnobotanical and chemical point of view (Muñoz et al., 1981).

A third approach, which is the core of this research, deals with the ecology and conservation of medicinal species that are especially important, taking into account that 5.4% of the native species present conservation problems (Benoit, 1989; Squeo et al., 2001).

The existence of different types of pressure and magnitude have been identified as causes of the non-sustainable harvest practices and/or the overexploitation of the wild resources, without management plans and use regulations for their potential extraction. These actions cause an alteration or reduction of biodiversity, which modifies the specific density, composition and distribution of the plant communities. The most immediate effect is the reduction of the number of populations to a level that hinders the genetic flow and, therefore, the natural regeneration of the species, causing problems of local extinctions through time (Primack et al., 2001).

For a plan of sustainable development of vegetal species, it is extremely important to consider their biology, growth form (Montenegro et al., 2003), and the plant architecture, which are genetically determined for each species, but vary within a specific range of the phenotypical plasticity (Perreta & Vegetti, 2005).

Several species may tolerate the extraction of some biomass, which is regenerated if the apical or axillary renewal buds or epicormic buds are maintained on the plants. The study of regeneration mechanisms, specifically the location and activity of renewal buds, their growth dynamics, and the way and season when they shoot, allow determining essential regeneration patterns for elaborating management plans for species of medicinal interest (Montenegro et al., 2003).

Once the phenology, architecture and way of natural species regeneration are known, it may be determined when and how the harvest must be made to diminish the impact provoked.

One form to determine the period with the higher increase of removable biomass may be through the progressive analysis of the increased foliar area or biomass using a non-destructive method, based on the relation between leaf length and the area or biomass acquired by the leaf through time (Montenegro et al., 2003).

Climatic factors are another important group of elements that must be considered in the development of the vegetal structures. Within these elements, temperatures and water availability have an essential role for biomass generation (Cabrera, 2004).

There are no standards or regulations ruling the extraction of plants of medicinal use at a domestic level. Very little has been issued to protect specific species. There is no general law protecting all medicinal species with conservation problems (Lara et al., 2003).

Thus, we face (1) limitations of a system protecting Chilean medicinal species, (2) a characteristic traditional and informal market, where it is difficult to identify the actors and processes involved, (3) the absence of measures allowing a sustainable extraction of the species, and (4) the lack of regulations related to the quality of the commercialized material and its certified origin (Fernández, 1998).

Along the characteristics of the domestic market, there is a gradual and external pressure that makes evident the importance of (1) regulating their utilization and use, and (2) elaborating conservation policies of medicinal plants.

The *Buddleja* genus (Buddlejaceae) is composed by around 100 species concentrated mainly in the Southern areas of Asia, Africa and America. Several of these species are related with types of mountain vegetation and other species develop in dry climates (Aguilar-Rodríguez & Terrazas, 2001).

In Chile, two species are recognized, *Buddleja globosa* Hope and *Buddleja suaveolens* Kunth & Bouché (Marticorena & Quezada, 1985). A third species called *Buddleja araucana* Phil. has been described in Chile and Argentina (Prina et al., 2003).

B. globosa grows in Chile, Peru and Argentina. It is distributed in the country in humid and sunny sectors of the Andes Mountains, from the IV to the X Region. It is one of the most used species in popular Chilean medicine. It has been traditionally used for its diuretic, anti-inflammatory, antiseptic, and healing properties and for curing digestive ulcers (Montenegro, 2000), with varied uses like compresses, infusion, powders and ointments (Hougton, 2003; Muñoz et al., 2004; Backhouse et al., 2008).

Some of the properties ascribed to the species are explained by the presence of a large amount of secondary compounds, like terpens, flavonoids and saponines, among others. Some hemostatic and diuretic properties are acknowledged (Hougton, 2003; Muñoz et al., 2004), as well as analgesic, anti-inflammatory and antioxidant properties whose extracts have been tested *in vitro* and *in vivo* experiments (Backhouse et al., 2008).

Popular acknowledgement of its multiple medicinal properties has led to an intensive harvest from its natural habitat for commercial purposes, causing an overutilization of the resource, and a wide heterogeneity of the harvested material (Jeldres, 2002).

The position of the renewal buds in *B. globosa,* and its growth dynamics, growth rate and regeneration after harvesting should be determined, as well as the time that the plant will need to regenerate the harvested biomass.

Our objectives were to (1) determine the growth cycle of *B. globosa,* (2) create a regeneration model which allows a productive management and sustainable use through time, (3) quantify the growth dynamics and biomass regeneration, and (4) identify the effects from the harvest methods used by harvesters.

MATERIALS AND METHODS

Study sites. This research was made during June 2008 to April 2009 at two study sites:

Cordillera site. Located in the central foothills, commune of Lo Barnechea, Los Maitenes sector (33° 17' 12" S; 70° 20' 06" W), at 1966 m.a.s.l., where the species was growing naturally. This site, called Cordillera from now on, shows a high mountain Mediterranean climate. From May to September, precipitations occur mainly as snow. Total annual precipitation varies from 715 mm (in the low mountain zones) to 913 mm (in the highest zones) (Santibáñez & Uribe, 1990). Mean temperatures for the period of study are presented in Table 1.

According to information for the community of Yerba Loca, a sector that is similar to the study place (located at the Northwest site, at half hillside, with representative vegetation, and 1859 m.a.s.l.) presents a soil with a silty clay structure, imperfect drainage, high humidity and depth, and apparent laminar type erosion.

Table 1. Mean temperatures (°C) for the Cordillera and Valley. 2008/2009
Tabla 1. Promedio de temperaturas (°C) en la Cordillera y Valle. 2008/2009

	Mean temperatures (°C)	
Treatment	Cordillera	Valley
Sept. 2008	7.7	11.6
Oct. 2008	9.7	14.5
Nov. 2008	13.5	18.3
Dec. 2008	15.5	20
Jan. 2009	16.9	21.6
Feb. 2009	16.2	20.4
Mar. 2009	16.7	19.3
Apr. 2009	15.8	15.7
May 2009	10.7	12
Average	13.6	17.0
Total	122.7	153.4

Valley site. Located in the central valley of the Metropolitan Area of Santiago, in the commune of María Pinto (33° 31' 42" S; 71° 13' 55" W), at 200 meters m.a.s.l., where the species was cultivated with a weekly irrigation system. This site, called Valley from now on, presents a semiarid Mediterranean climate. The water regime is characterized by an annual mean precipitation of 454 mm, with a water deficit of 952 mm and a dry period of eight months (Santibáñez & Uribe, 1990).

The soils of María Pinto are described as clay loam and sandy clay loam, presenting high susceptibility to erosion, as well as low fertility. The granitic components allow a rapid external drainage, decreasing in lower horizons due to its high quartz concentration (Peralta, 1976).

The mean temperature data for the Cordillera site were provided by the Environmental and Climatologic Department of Minera La Disputada, from the Meteorogical Central in Paso Marchant (2175 m.a.s.l.). For the Valley site, the climate data are from the Meteorogical Central of Chile, Central of Pudahuel, which was selected because it is close to the cultivation zone.

Study material. *Cordillera*. It corresponds to the altitudinal vegetation floor defined as Sub Andean bush (1500-2000 meters m.a.s.l.). It is characterized by a predominant arborescent bush composed by *Kageneckia angustifolia, Guindilia trinervis, Colliguaja integerrima, Haplopappus illinitus, Baccharis rhomboidalis* ssp *truncata* and *Schinus montanus*. *Escallonia myrtoidea* is found in more humid sectors (Muñoz et al., 2000).

Buddleja globosa is found mainly in humid gorges protected from wind and associated with species like *Colliguaja salicifolia, Corynabutilon ceratocarpum, Ephedra chilensis, Guindilia trinervis, Senecio eruciformis*, and *Valeriana stricta,* among others.

Valley. The samples of *B. globosa* were found arranged in the field at a distance of 1.5 x 1.5 m. The samples were planted in 2005 from grounded cuttings in polyethylene bags.

Survey to harvesters. A face to face survey type was applied (Sandhusen, 2003),with open questions to a sample of 10 harvesters of the Metropolitan Area and other zones of Chile, to identify the (1) harvester(s), (2) harvest zones of *B. globosa*, (3) harvest season, (4) collection methods and (5) eligibility of biomass retrieval.

A questionnaire was applied to three groups of interest: (1) 5 harvesters in the Market of Medicinal Herbs of Santiago, (2) 1 harvester (Mr. Luis Núñez) in the Ethnobotanics Meeting held in the commune of Peñalolén, and (3) 4 harvesters in the Indigenous Fair and sale points of medicinal herbs in the commune of Pica, Region of Tarapacá.

The harvester of the *B. globosa* populations at Los Andes foothills, Mr. Núñez, provided information obtained by surveys in the commune of Lo Barnechea, Los Maitenes sector. Three excursions were made to the harvest sites, and one to the supply markets, to verify *in situ* the harvest methods used and their commercialization forms.

Five populations of *B. globosa* were identified, and located in gorges with different orientations and heights: "Los Maitenes" at 1966 m.a.s.l.; "Los Chacayes" at 2211 m.a.s.l.; "La Planchada" at 1962 m.a.s.l., and "other populations" expressed by Population 1 and Population 2, located at "Los Maitenes Bajos" sector, with heights close to 1000 m.a.s.l.

Phenology and architecture. A monthly record was made on the species phenology and architecture, in 10 individuals chosen at random, used as control in both zones. The origin and location of each organ in the plant were observed, as well as the season and duration of development. This knowledge would be useful for providing management recommendations on sustainable harvest practices.

The monthly record of the evolution of the vegetative organs was summarized in a figure of the growth cycle and modular scheme following the symbology of Orshan (1989) and the FreeHand Macromedia Program.

Growth dynamics and biomass quantification. According to the methodology described by Montenegro et al. (1979, 1993, 2001) in each zone of study, ten individuals were selected as control treatments, which were marked for further observations to quantify the monthly growth dynamics. Two branches apparently healthy were marked in each plant at level of the last leaf formed during the previous growth period. After growth was initiated, the length of the whole branch, and each leaf appearing on the stem recently formed, were measured. The syleptic shoots emerging from axillary buds growing in that year were included in the measurements as they appeared.

At the beginning and end of the growth period, 300 different-size leaves were harvested in each zone from diverse bushes. They were measured and weighted (length and dry weight). These values were necessary to determine a correlation factor between length and biomass. The particular biomass of each growing leaf on the marked branches was estimated with information, allowing the estimation of leaf biomass per shoot at monthly intervals.

Regeneration and harvest. Fifteen plants selected at random were marked in each study site to know the regeneration rates. On early August 2008, three pruning methods were applied: apical, medium and basal (5 plants per treatment). Each pruning consisted on a transversal cut with pruning shears at different heights, at 20 cm from the soil level for the basal pruning, 20 cm from the plant apex for the apical pruning, and at medium height of the plant for the mean pruning.

The same methodology for measuring leaves described previously was used. At the beginning and the end of the growth period, 25 leaves from different specimens were harvested in each zone to determine the correlation factor between length and leaf biomass.

Data analysis. A linear relation of the data on leaf length and weight was determined, and a linear regression of the type y= bx was parameterized, where y= biomass (dry weight) (g), b= regeneration rate (g/cm) and x= leaf length (cm). The equation obtained was used to estimate the total biomass of each branch and plant of *B. globosa.*

In order to determine the potential growth for the species, represented by the growth rate, a fitted second degree polynomial model was estimated to represent growth better, determined by: $y = a + bx + cx^2$ where: y = biomass (g), x = time, x^2 = time^2, b = growth rate (g/cm), c = rate de decrement (g/cm). Values of 1 to 7 were assigned to the quantitative variables of time; each value corresponded to a month of growth, corresponding each value to each month of the growth cycle, when the measurement was made (October = 1, November = 2, ..., April = 7).

In order to determine the level of significance between the regression line obtained for both the control and the different treatments, a t- test of Student was made, with a SAS Statistics program. Therefore, the biomass data of the branches observed during the whole growth period were used. Subsequently, a test of statistical significance was obtained for the growth and decrement rates.

To determine whether the harvest methods were carried out in periods of maximum yields, the maximum periods of biomass were obtained through an equation fit:

$$Y_m - y = e^{b(x-c)} \quad \text{therefore: } Y_m = \frac{+b}{-2c}$$

where Y_m= maximum biomass per plant (dry weight in grams), y = biomass of the specific month (dry weight in grams), x = monthly period of measurement (1, 2 …7), b = growth rate (g/cm), c = decrement rate (g/cm).

A test of statistical significance was also obtained for these maximum values with the SAS Statistics programs.

Once the type of treatment generating the highest biomass was identified, and the growth and regeneration rates, and the harvest periods when biomass was higher were known, these data were contrasted with the dates and modalities of *B. globosa* pruning at the Cordillera site.

RESULTS

Description of seasons and harvest methods of natural populations. The harvests were made by the harvester Luis Núñez during the whole year.

The first harvests were made between September and October in the population “La Planchada” (1962 m.a.s.l.) and subsequently, the plants were harvested in the communities “Los Maitenes” (1966 m.a.s.l.) and “Los Chacayes” (2211 m.a.s.l.) since November.

Therefore, the regeneration of the plants harvested at the beginning of the growth period allowed a second harvest between March and April. In the case of plants located at higher altitudes, the regeneration was slower, which produced a non-selective harvest of shorter apical stems than those harvested at lower altitudes.

Population 1 and Population 2 helped to supply the demand of fresh *B. globosa* material during the winter months, season when extreme climate conditions did not allow access to the natural populations located at higher altitudes.

The harvest system used by the harvester consisted on an apical pruning in mature plants, which consisted on the manual tipping of the apical portion of the plant. Depending on the harvest season, the tippings measured between 15 cm long in winter to 30 and 40 cm long in spring and summer, respectively. The procedure consisted on breaking the branch by hand at the desired height, and detach them until bundles composed by approximately 20 twigs are formed. A sack of approximately 55 pounds (dry weight) is completed with 30 to 40 bundles (dry weight).

The 5 harvest populations were rotated according to the year season: the shortest populations were used in winter, and then the highest populations were used depending on the environmental conditions, number of harvests made and regeneration degree of the biomass extracted in the previous season. In general, the number of visits to each site was 5 to 6 times a year. The harvest was carried out by only one person, and the *B. globosa* populations were unknown or unreachable to other harvesters.

Phenology and architecture. According to the classification of life forms by Raunkiaer (1934), the *B. globosa* species corresponds to evergreen microphanerophyte of up to 3 meters high with opposite, sessil and decussate leaves.

Only one modular type responsible of the species architecture was found. This type corresponded to dolicoblast, with apical reproductive bud. The dolicoblasts originated from axillary buds from other dolicoblasts of the previous year or the same year.

Development of syleptic branches were observed in the Valley. In the plants of Cordillera, the dolicoblasts could not

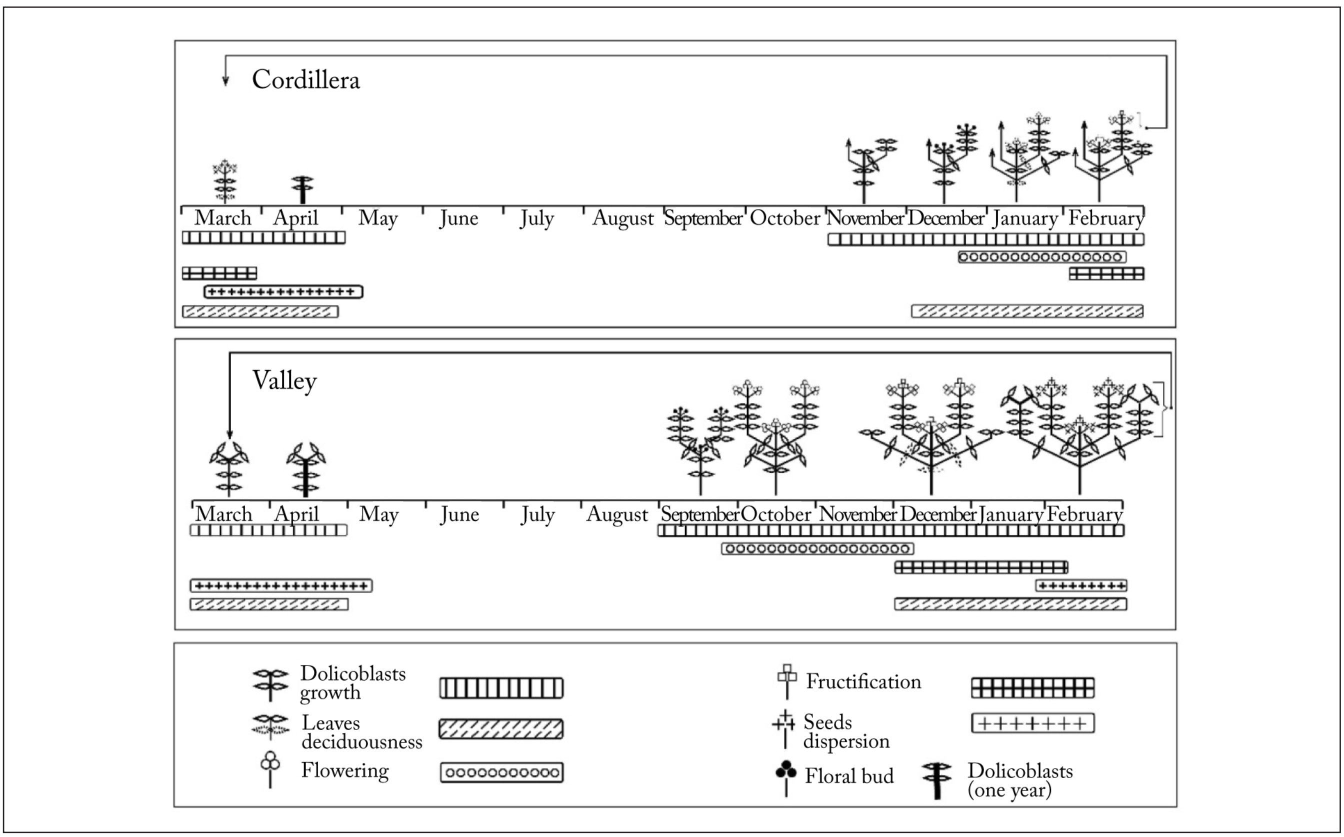

Fig. 1. Phenomorfological cycle of *B. Globosa* in the Cordillera and Valley.
Fig. 1. Ciclo fenomorfológico de *B. globosa* en la Cordillera y Valle.

develop those branches, presenting less ramification than those in the Valley.

The phenological stages corresponded to dolicoblasts growth, flowering, fructification, seeds dispersion, leaf abscission and a winter latent-state, where the plant did not manifest notorious growth. Differences were observed in the duration of each of these phases between the two zones. In the Cordillera, the growth stage was later and shorter than in the Valley, extending to 6 months, since November 2008 until April 2009 (and a resting period of 6 months, since May to October). In the Valley, the growth cycle lasted 8 months since the beginning of the development of dolicoblasts and foliar structures in September, until the decrement period ended in April (and a resting of 4 months, between May and August) (Fig. 1).

The beginning of the phenological stages in the Valley did not present between one to three months in advance. Flowering was between the end of September and the end of November in the Valley. However, it occurred between the end of December and the end of January in the Cordillera. Fructification in the Valley occurred between December and January and seed dispersion occurred between February and April. In the Cordillera, fruits appeared between February and March, and seed dispersion occurred between March and April. Leaf abscission occurred between December and April at both sites.

Table 2. Growth rates, decrement rates and maximum biomass periods per branch in the Cordillera and Valley. 2008/2009.
Tabla 2. Tasas de crecimiento, tasas de decrecimiento y máximos periodos de biomasa por rama en la Cordillera y Valle 2008/2009.

	Maximum biomass period (p>0.0297)		**Growth rate (g/cm) (p>0.0366)**		**Decrement rate (g/cm) (p>0.0094)**	
Treatment	Cordillera	Valley	Cordillera	Valley	Cordillera	Valley
Basal	A 4.19 a	B 5.65 ab	A 0.95 b	B 8.42 ab	A -0.11 b	B -0.75 b
Apical	A 3.95 ab	A 4.19 b	A 2.45 ab	A 5.91 b	A -0.30 ab	A -0.53 a
Medium	A 3.82 b	A 4.87 b	A 1.97 b	B 10.7 a	A -0.26 b	B -1.07 b
Control	A 3.35 b	B 5.81 a	A 4.03 a	B 6.71 b	A -0.58 a	A -0.59 ab

Different upper case letters in the same row mean significant differences between zones, and different lower case letters in the same column indicate significant differences between treatments. The maximum biomass periods correspond to the months of measurement (October = 1, November = 2… Abril = 7). n = 48 plants.
Letras mayúsculas diferentes en la misma fila indican diferencias significativas entre zonas, y letras minúsculas diferentes en una misma columna indican diferencias significativas entre tratamientos. Los máximos períodos de biomasa corresponden a los meses de medición (Octubre = 1, noviembre = 2,………. abril = 7). n =48 plantas.

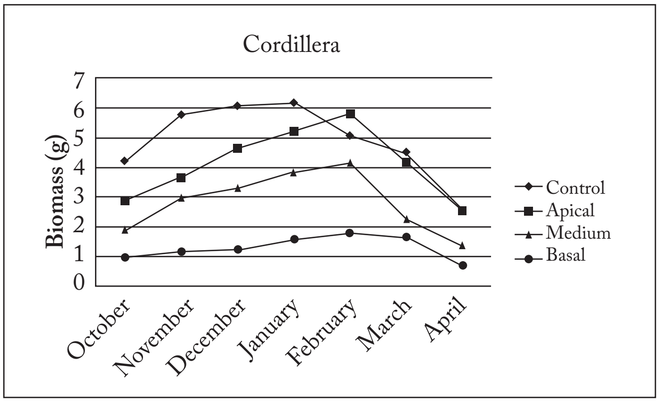

Fig. 2. Monthly biomass in the control and treatments in the Cordillera during the 2008/2009 growing season; ●= Basal pruning ■= Apical pruning ▲= Mean pruning ◆= Control. Each curve shows the biomass averages obtained for the control treatment and pruning treatments in *B. globosa* at both sites.
Fig.2. Dinámica de crecimiento mensual en controles y tratamientos en la Cordillera durante temporada 2008/2009; ●= Basal ■= Apical ▲= Poda Media ◆= Control. Cada curva muestra los promedios de biomasa obtenidos por controles y tratamientos de poda en *B. globosa* en ambos sitios.

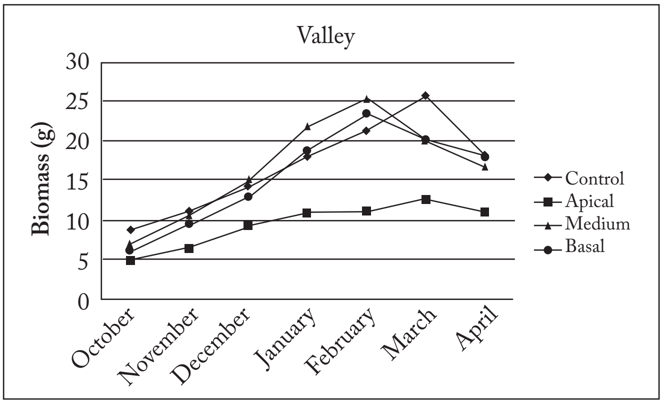

Fig. 3. Monthly biomass in the control and treatments in the Valley during the 2008/2009 growing season; ●= Basal pruning ■= Apical pruning ▲= Mean pruning ◆= Control. Each curve shows the biomass averages obtained for the control treatment and pruning treatments in *B. globosa* at both sites.
Fig.3. Dinámica de crecimiento mensual en controles y tratamientos en el Valle durante temporada 2008/2009; ●= Basal ■= Apical ▲= Poda Media ◆= Control. Cada curva muestra los promedios de biomasa obtenidos por controles y tratamientos de poda en *B. globosa* en ambos sitios.

Growth dynamics and biomass quantification. The same coefficient was obtained to estimate the biomass for both study sites, corresponding to 0.0273, with $R^2 = 0.96$.

The inter- and intra-zone analyses of growth, decrement rates and maximum periods of biomass showed significant statistical differences. Regarding the biomass quantification, there was not a significant interaction due to the absence of repeated zones.

The inter-zone analysis showed growth rates significantly lower in the Cordillera than in the Valley, not only between control treatments but also between the mean and basal pruning treatments. In the control treatments, the plants in the Cordillera reached growth rates of 4.0% in relation to those of 6.7% in the Valley. In the treatments, the mean pruning reached a regeneration rate of 1.97% in the Cordillera and 10.7% in the Valley, while values for the basal pruning were 0.95% and 8.42%, respectively (Table 2). These differences may be observed graphically in Figures 2 and 3.

The decrement rates did not show significant differences ($p>0.05$) between the control treatments at both sites; however, treatments of mean and basal pruning showed, significantly higher decrement rates in the Valley than in the Cordillera.

The intra-zone analysis of the growth rates in the Cordillera reflected significant differences between the control treatment and the treatments of basal and mean pruning. However, significant differences were not found between treatments at this location (Table 2).

Unlikely, the modal of mean pruning in the Valley showed significant differences in both the control treatment and the apical pruning treatment.

The maximum periods of harvest in the Cordillera were obtained in December in both the control and the apical and mean pruning treatments. In the Valley, this period was obtained in February for the control treatment, and in January for the mean and apical pruning treatments. This showed an advancement of the period of biomass maximization in the Cordillera in relation to the basal pruning (Table 2).

Table 3. Final biomass average per branch (g) in the Cordillera and Valley. 2008/2009.
Tabla 3. Promedio final de biomasa por rama (g) en la Cordillera y Valle. 2008/2009.

	Biomass (dry weight in g)	
Treatment	**Cordillera**	**Valley**
Basal	0.80 b	18.0 ab
Apical	2.51 a	10.9 b
Medium	1.32 b	16.7 b
Control	2.51 ab	18.3 b

Different lower case letters in the same column indicate significant differences among treatments. n =48 plants.
Letras minúsculas diferentes en una misma columna indican diferencias significativas entre tratamientos. n=48 plantas.

A final average biomass for the study period was 2.51 g per branch in the Cordillera, and 18.3 g per branch in the Valley (Table 3). If an average of 10 branches per plant is estimated in the Cordillera, and 25 branches per plant in the Valley, values increase to 25 g of dry weight per plant in the Cordillera, and to 450 g of dry weight per plant in the Valley. These values per plant could not be statistically tested because there were no replicates for the site effects.

DISCUSSION

The system used by the harvester responded to the pressure of permanent demand of fresh material more than obtaining the maximum possible biomass in one or two time periods. The harvest system is less efficient in the months when the biomass does not reach its maximum levels, which was observed in the lower twig lengths harvested before and after December.

The modality of *B. globosa* harvest, made apically and rotatively all through the year, appears less harmful than those modalities eliminating completely the reproduction organs. Records provided by Montenegro et al. (2001) in their study on *Chorizante vaginata,* plant commercialized in the markets because of its medicinal properties, indicate a type of harvest made preferably from the roots of the plant. As in the case of *Echinopsis chiloensis,* cactaceae columnar used as "rainstick", it is also indicated an extraction of the stems from the base, hindering its vegetative reproduction (Montenegro et al., 1999).

Rotation of *B. globosa* populations responded to the need of providing the plants the necessary time for regeneration of the extracted biomass. This would allow to satisfy the market needs individually to the harvester, and allow the natural regeneration of the species.

The results of modular type and origin of the dolicoblasts coincide with the results by Potocnjack (2003), in his observational study on *B. globosa*.

Unlike the plants of the Cordillera, the dolicoblasts in the Valley developed syleptic branches. This phenomorphological manifestation would represent a response of the species to adequate climatic conditions and a longer growing period in the Valley.

The survival of the species in zones with high mountain Mediterranean climate would restrict growth and reproduction to the seasons of spring and summer when the soil humidity is abundant (Arroyo et al., 1981; Cabrera et al., 2004). Unlike the water restrictions of the natural populations, the individuals in the cultivation site received weekly irrigation, which might help to explain the differences in growth.

Observations of the field in the Valley show that the environmental conditions might induce a constant tissue regeneration of the plant. This high regenerative capacity of the species might be explained by the distribution of the renewal buds observed along the whole stem, both basally and apically. This result is reinforced by those obtained by Doll et al. (2003) as they reached grounding of 75% of the apical stakes obtained from plant stems.

The differences in the growth and decrement rates obtained from the inter-zone analysis suggest an effect from the environmental conditions in the zone on the growth dynamics of the species. Growth rates in the control treatment were lower in the Cordillera than in the Valley. There were also higher growth and decrement rates in the mean and basal pruning treatments in the Valley.

Some studies propose that low winter temperatures and summer droughts are the more limiting factors of photosynthesis under Mediterranean conditions. The optimal temperature determined for photosynthesis in this region during the study period varies between 20 and 30 °C (Gulías et al., 2004). The mean monthly temperatures in the Cordillera vary between 7.7 to 16.9 °C, while those in the Valley vary between 11 and 21.6 °C (Table 1).

The differences in the growth dynamics obtained in the intrazone analysis, characterized by similar regenerative responses in presence of the different pruning modalities in the Cordillera, and positive responses in the regeneration rates in the mean and basal pruning treatments in the Valley, may be attributed to higher levels of plant water stress in the Cordillera. This was unlike the Valley plants, which received weekly irrigation.

In this regard, lower levels of photosynthesis have been found in plants subjected to biotic stresses under field conditions compared with values found under controlled conditions (Gulias et al., 2004). This might help to explain the differences between the plants of the Cordillera and the Valley. Additionally, growth rate of the apical pruning was most similar to the control treatment in the Cordillera; this might be due to a less intensive stress exerted on them in relation to the other treatments. However, further studies would be necessary to support these appreciations.

Determination of the maximum periods of biomass accumulation suggests that harvesting should be done in December in control plants, and in January in those plants that received apical pruning at the Cordillera. In the Valley, on the other hand, these maximum periods occur in February on control plants and plants pruned basally, and in January on mean pruned plants (Table 2). These maximum harvest periods coincide or are close to the period when each zone reaches the maximum mean temperatures, obtained in January (16.9 °C) in the Cordillera and in February (20.4 °C) in the Valley (Table 1) which supports the relation between the maximum accumulation period of biomass production and temperature.

The differences among the maximum biomass periods obtained because of the pruning effect are feasible to explain as a stimulus exerted by pruning in the Valley, advancing the period of biomass maximization (e.g., the case of mean pruning). In the Cordillera, a delayed period of biomass maximization in the basal pruning treatment was observed as an effect of the pruning, probably derived of an intense pruning stress.

From the sustainable point of view these maximum periods must coincide with the most favourable periods for the plant, which are determined by those allowing a complete development of the phases of the growth cycle of the species.

Accomplishing the conditions conducive to natural regeneration is essential to maintain the minimum genetic diversity required for preserving the species at the Cordillera (Lohengrin et al., 1999).

Regardless of inexistent statistical significance differences in the biomass records, it was noticeable the difference in the magnitude of the biomass accumulated at the end of the growth period in the plants of the Valley compared to those at the Cordillera (Table 3). The high plant biomass accumulation in the Valley was most likely related to a better water supply and temperatures at this site.

The environmental characteristics in the Cordillera seem to restrict the regenerative capacity of *B. globosa*, where the different pruning treatments provided lower both rates and growth dynamics than values for these parameters in the Valley.

Therefore, to diminish the pressures on the wild populations at the Cordillera, the cultivation of *B. globosa* is recommended under a management of mean prunings, made in February during the first year of growth, and in January during the following years. The basal pruning is recommended only to renew the vegetative structures, and the apical pruning as an alternative second harvest of apical shoots after the mean pruning is made in January, and before the winter vegetative resting period in April.

For the Cordillera, management plans for *B. globosa* should be based on the response of the species to the environmental conditions. A partial apical-type harvest is recommended which allows that some parts of any plant end the phases of the growth cycle, especially the seed dispersion process, to aid the natural reproduction of the species.

The optimal harvest period for maximization of the biomass in the Cordillera was December. However, this is inappropriate because the market needs a continuous availability of fresh material, which imposes a permanent harvest method, which is less efficient but sustainable.

ACKNOWLEDGEMENTS

We thank the financial support from the Project QC 008 of Foundation COPEC-UC.

REFERENCES

Aguilar-Rodríguez, S. & T. Terrazas (2001). Anatomía de la madera de *Buddleja* L. (Buddlejaceae): análisis fenético. *Madera y Bosques* 7: 63-85.

Araya-Presa, J., F. Squeo, L. Barrientos, E. Belmonte, M. Mamani & G. Arancio (2003). Manual de plantas y canciones Aymara. Proyecto Explora-Conicyt. Universidad de La Serena. Chile. 39 p.

Arroyo, M.K., J. Armesto & C. Villagrán (1981). Plant phenological patterns in the high Andean Cordillera of central Chile. *The Journal of Ecology* 69: 205-223.

Backhouse, N., L. Rosales, C. Apablaza, L. Goity, S. Erazo, R. Negrete, C. Theodoluz, J. Rodríguez & C. Delporte (2008). Analgesic, anti-inflammatory and antioxidant properties of *Buddleja globosa*, Buddlejaceae. *Journal of Ethnopharmacology*116: 263-269.

Benoit, I.L. (1989). Libro rojo de la flora terrestre de Chile. Ministerio de Agricultura. CONAF, Chile. 157 p.

Cabrera, H.M., T. Rioseco & M.T.K. Arroyo (2004). Eco fisiología y distribución frente a múltiples estrés en plantas de zonas con climas mediterráneos. In: Cabrera H.M. (ed.), pp. 267-285. Fisiología Ecológica en Plantas. Mecanismos y Respuestas a Estrés en los Ecosistemas. Ediciones Universitarias de Valparaíso, Chile. 285 p.

Cubillos, A. & P. León (1995). Informe Nacional para la Conferencia Técnica Internacional de la FAO sobre los Recursos Fitogenéticos (Leipzig). Santiago, Chile. 108 p.

Doll, U., H. Vogel, P. Jeldres & M. Muñoz (2003).Estudios de propagación vegetativa en *B. globosa* (*Buddleja globosa*). *Revista Latinoamericana de Ciencias de la Agricultura* 30: 211-216.

Fernández, M.P. (1998). Plantas medicinales. In: Campos. J. (ed.), pp. 29-38. Productos Forestales no Madereros en Chile. Dirección de productos forestales FAO. Serie Forestal Nº10. 59 p.

Gulías, J., J. Galmés, J. Cifre, H. Medrano & J. Flexas (2004). Ecofisiología de la fotosíntesis y la eficiencia en el uso del agua en la vegetación de la cuenca mediterránea. In: Cabrera H.M. (ed.), pp.157-171. Fisiología Ecológica en Plantas. Mecanismos y Respuestas a Estrés en los Ecosistemas. Ediciones Universitarias de Valparaíso, Chile. 285 p.

Houghton, P. (2003). *Buddleja globosa*: A medicinal plant of Chile, their chemistry, biological activity and traditional uses. *Boletín Latinoamericano y del Caribe de Plantas Medicinales y Aromáticas* 2: 36-41.

Jeldres, P. (2002). Exploring diversity and the potential for domestication in *Buddleja globosa*. Hope a medicinal plant from Chile. Thesis M.Sc., Agr.Georg-August Universität, Göttingen, Germany. 60 p.

Ladio, A.H. & M. Lozada (2004). Patterns of use and knowledge of wild edible plants from distinct ecological environments: A case study of a Mapuche community from NW Patagonia. *Biodiversity and Conservation* 13: 1153-1173.

Lara, A., D. Soto, J. Armesto, P. Donoso, C. Wernli, L. Nahuelhual & F. Squeo (2003). Componentes científicos clave para una política nacional sobre usos, servicios y conservación de los bosques nativos chilenos. Universidad Austral de Chile. Iniciativa Científica Milenio de Mideplan. Valdivia, Chile. 134 p.

Lohengrin, A., C. Cavieres, C. Papic & C. Castor (1999). Variación altitudinal en los síndromes de dispersión de semillas de la vegetación andina de la cuenca del río Molina, Chile central (33°S). *Gayana Botánica* 56: 115-123.

Marticorena, C. & M. Quezada (1985). Catálogo de la flora vascular de Chile. *Gayana Botánica* 42:1-2.

Marticorena, C. (1990). Contribución a la estadística de la flora vascular de Chile. *Gayana Botánica* 47:85-113.

Massardo, F. & R. Rozzi (1996). Usos medicinales de la flora nativa chilena. Valoración de la biodiversidad. *Ambiente y Desarrollo* 12: 76-78.

Montenegro, G., M.E. Aljaro & J. Kummerow (1979). Growth dynamics of Chilean matorral shrubs. *Botanical Gazzette* 140: 114-119.

Montenegro, G. (1987). Quantification of mediterranean plant phenology and growth. In: J.D.Tenhunen, O. Catarino, L. Langeand and W.C. Oechel (eds), pp. 469-488. Plant Response to Stress: Functional Analysis in Mediterranean Ecosystems. Springer-Verlag, Berlin, Germany. 668 p.

Montenegro, G. & R. Ginocchio (1993). Modular interpretation of architecture in shrubs species. *Anais da Academia Brasileira de Ciencias* 65: 189-202.

Montenegro, G., M. Gómez, L. Iturriaga & B. Timmermann (1994). Potencialidad de la flora nativa chilena como fuente de productos naturales de uso medicinal. *Rojasiana* 2: 49-66.

Montenegro, G., D. Atala, M. Gómez, V. Martínez, L. Iturriaga, P. Echeñique, A.M. Mujica & B.N. Timmerman (1999). Impacto de la producción de "palos de agua" sobre *Echinopsis chiloensis* en Chile. *Ciencia e Investigación Agraria* 26: 67-73.

Montenegro, G. (2000). Chile: Nuestra flora útil. Guía de plantas de uso apícola en medicina folklórica, artesanal y ornamental. Ediciones Universidad Católica de Chile. 267 p.

Montenegro, G., G. Patrick, P. Echenique, M. Gómez & B.N. Timmermann (2001). Mechanisms toward a sustainable use of *Chorizanthe vaginata* Benth, var. maritima Remy: A medicinal plant from Chile. *Phyton, International Journal of Experimental Botany* 70: 91-106.

Montenegro, G., M. Gómez, A.M. Mujica & B. Timmermann (2003). Theoretical models for regeneration of medicinal plants and their application in sustainable wild-harvesting. In: J. Lemons, R. Víctor and D. Schaffer (eds), pp. 275-290. Conserving Biodiversity in Arid Regions. Kluwer Academic Publishers, The Netherlands. 495 p.

Muñoz, M., E. Barrera & I. Meza (1981). El uso medicinal y alimenticio de plantas nativas y naturalizadas en Chile. *Boletín del Museo Nacional de Historia Natural* 33: 1-91.

Muñoz, M., A. Moreira-Muñoz, C. Villagrán & F. Luebert (2000). Caracterización florística y pisos de vegetación en los Andes de Santiago, Chile central. *Boletín del Museo Nacional de Historia Natural* 49: 9-50.

Muñoz, O., M. Montes & T. Wilkomirsky (2004). Plantas medicinales de uso en Chile. *Química y Farmacología* **7:** 63-85.

Orshan, G. (1989). Plant Pheno morphological studies in Mediterranean ecosystems. Kluwer Academic Publishers, The Netherlands. 416 p.

Peralta, M. (1976). Uso, Clasificación y Conservación de suelos. Editorial del Servicio Agrícola y Ganadero, Santiago, Chile. 340 p.

Perreta, M.G. & A.C. Vegetti (2005). Patrones estructurales en las plantas vasculares: Una revisión. *Gayana Botánica* 62: 9-19.

Potocnjack, D. (2003). Arquitectura y modelos de regeneración en plantas medicinales comercializadas en Chile. Tesis de Magister. Facultad de Agronomía e Ingeniería Forestal Pontificia Universidad Católica de Chile. 52 p.

Primack, R. (2001). Problemas de las poblaciones pequeñas. In: E. Primack, R. Rozzi, P. Feinsinger, R. Dirzo and F. Massardo (eds), pp. 363-383. Fundamentos de Conservación Biológica. Perspectivas latinoamericanas. Fondo de Cultura Económica, México. 797 p.

Prina, A.O., G.L. Alfonso & W.A. Muiño (2003). Diversidad de la flora vascular del distrito fito geográfico de la Payenia, Argentina. *Chloris Chilensis* Año 6(1). http:www.chlorischile.cl

Raunkiaer, C. (1934). Life forms and terrestrial plant geography. Clarendon Press. Oxford University. 137 p.
Sandhusen, R.L. (2003). Mercadotecnia. Editorial CECSA, México. 660 p.
Santibáñez, F. & J.M. Uribe (1990). Atlas agroclimático de Chile, regiones V y Metropolitana, Universidad de Chile. Facultad de Ciencias Agrarias y Forestales. Laboratorio de Agroclimatología, Santiago, Chile. 66 p.
Squeo, F., G. Arancio & J.R. Gutiérrez (2001). Libro rojo de la flora nativa y de los sitios prioritarios para su conservación. Región de Coquimbo. Ediciones Universidad de La Serena. 372 p.