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Growth and fruiting of *Ribes magellanicum* in Tierra del Fuego, Argentina

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Abstract *Ribes magellanicum* is a Patagonian deciduous shrub, with globose berries, purple at maturity, which can be eaten fresh or used in marmalades and syrups. The aim of this work was to study the shoot growth and fruiting of *R. magellanicum* in plants growing naturally near Ushuaia city, Tierra del Fuego, Argentina, as a first step towards its later domestication. Shoot growth was significantly higher in the northern exposures compared with the southern exposures, as well as in the upper half of the plants in comparison with the lower ones. Fruit production per shoot was significantly higher in 2004 compared with 2003. North-west and south-west exposures favored fruit production, whereas the best values were found in the upper half of the plants and in long shoots compared to the lower half of the plants and the short shoots, respectively. *R. magellanicum* plants growing naturally near Ushuaia city, formed c. 900 shoots per plant at the end of the growing season in 2003, whereas nearly 500 fruiting shoots with 595 racemes and 3000 fruits with a weight of 331 g were formed. Sixty-five percent of the fruiting shoots were in the upper half of the plants. These results are the first antecedents on growth and fruiting of *R. magellanicum* in Austral Patagonia and are relevant for its later domestication.

Keywords small fruits; native species; Patagonia; fruiting

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INTRODUCTION

Over the past years, an increasing interest has been shown in intensive horticulture in Argentinean Patagonia. This is because of its diversity in soils and climate and, mainly, in the possibility of producing crops out of season with the Northern Hemisphere (Vater & Arena 2002). Moreover, the industrial demand for berries is well known, and in particular for *Ribes* species, which are cultivated for several uses. The most important uses of the fruit are in preserves, juice, and teas (Hummer & Barney 2002), the extraction of anthocyanins from *R. nigrum* fruits with considerable health benefits (Lister et al. 2002), and the extraction of oils in highly unsaturated fatty acids from the seeds (del Castillo et al. 2002). The main economically important crop groupings include black currants, red and white currants, gooseberries, hybrid berries, and ornamentals. However, the search for new species of the genus to introduce them to commercial culture is no less important.

The *Ribes* L. genus (Grossulariaceae), the currants and gooseberries, includes more than 150 described species of shrubs which are native throughout northern Europe, Asia, North America, and in mountainous areas of South America and north-west Africa (Brennan 1996). Only c. 10 or 12 of these species comprise the primary gene pool from which domesticated currants and gooseberries were developed. In Patagonia, there are four species and varieties (Correa 1984). *R. magellanicum* Poiret, commonly named "parrilla" is found in forest clearings and wood margins of *Nothofagus pumilio*, from Neuquen (37°S) to Tierra del Fuego (Moore 1983; Correa 1984; Brion et al. 1988) and is often found together with *Berberis buxifolia*. *R. magellanicum* is a deciduous, erect shrub up to 4 m high, with reddish brown, fissured bark on older branches, racemes with 20 or more yellow to reddish flowers, and globose berries, purple at maturity (Moore 1983), with an ornamental value. Its berries can be eaten fresh or used in marmalades and syrups (Correa 1984). Also, the fruits are a source of anthocyanins (Arena & Vater 2005).

R. magellanicum can be propagated by hardwood cuttings (Arena et al. 1996) and through *in vitro* tissue culture (Arena & Martínez Pastur 1995). However, there are no reports on growth and fruit production of *R. magellanicum*.

The aim of this work was to study the shoot growth and fruiting of *R. magellanicum* in plants growing naturally near Ushuaia city, Tierra del Fuego, Argentina, as a first step towards its later domestication.

MATERIAL AND METHODS

Geographic situation and climatic site description

The studied area is located near Ushuaia city, 54°48′S, 68°19′W (Tierra del Fuego, Argentina). Climatic data on maximal, minimal, and mean daily temperatures (°C), mean ambient relative humidity (%), and total rainfall (mm) were recorded by the Meteorological Station at Centro Austral de Investigaciones Científicas from September to March for the 2002/03 and 2003/04 seasons (Table 1).

Plant material description

Twenty *R. magellanicum* plants growing naturally in *Nothofagus* forest clearings were chosen for this study. The plant mean height was 1.85 m (SD 0.30 m), whereas the mean perimeter was 5.17 m (SD 1.43 m). Plants higher than 2.40 m and smaller than 1.50 m were discarded. All the plants were in the adult phase and formed flowers and fruits (Fig. 1, 2) when they were selected. The same plants were evaluated in both growing seasons.

Shoot growth and fruit production

Shoot growth and fruit production variables were analysed according to the following factors: shrub exposure (north-east, north-west, south-east, and south-west), height position (upper and lower half), and shoot type (short (until 1 cm length) and long (longer than 1 cm length)). The following shoot growth variables were analysed during the last week of February in 2003 in all the plant shoots: shoot length, total shoot number, and total shoot production (shoot length × total shoot number), in their absolute and relative values (%) (percentage of the total of the plant).

The fruit production variables analysed during fruit ripening in February 2003 and 2004 in all the plant fruiting shoots were: fruiting shoot length,

Fig. 1 Adult plant of *Ribes magellanicum* with flowers, growing near Ushuaia city, Tierra del Fuego, Argentina.

Table 1 Maximal daily temperatures (MAT), minimal daily temperatures (MIT), mean daily temperatures (MET) (°C), mean ambient relative humidity (MEH) (%), and total rainfall (TRA) (mm) were recorded by the Meteorological Station at Centro Austral de Investigaciones Científicas, Argentina, from September to March for the 2002/03 and 2003/04 seasons.

Growing season	MAT	MIT	MET	MEH	TRA
2002/03	11.33	4.47	7.50	73.64	282.40
2003/04	12.12	5.36	8.36	77.33	281.10

Fig. 2 Fruits of *Ribes magellanicum* formed in naturally growing plants near Ushuaia city, Tierra del Fuego, Argentina.

raceme number per shoot, fruit number per shoot, fruit weight per shoot, fruit number per raceme, raceme weight, and mean fruit weight. Also, total fruit shoot number, raceme number, fruit number, and fruit weight in their absolute and relative values (%) (percentage of the total of the plant), were measured considering the described factors.

Statistical analysis

The statistical validity of the results was obtained through the analysis of variance by the Fisher and Tukey tests, with a significant level of $P < 0.05$.

RESULTS

Shoot growth

Shoot length was significantly affected by the shrub exposure and shoot type, being significantly higher in north-west and north-east exposures compared with the southern exposures (Table 2). The long shoots attained near 11 cm length on average, whereas those characterised as short were of 1 cm. The factors studied did not significantly affect the total shoot number either in its absolute values or in its relative values. However, total shoot production was significantly higher in the upper half than in the lower half of the plant and in long shoots compared with short shoots. Shoot production was slightly higher in the northern exposures and highest in the upper half and in long shoots.

Fruit production

The factors studied influenced most of the fruit production variables when considering the shoot as the experimental unit (Table 3). All the variables were higher in 2004 than in 2003, with the exception of the raceme number per shoot which did not vary significantly. The highest increments were found in the raceme weight and in the fruit weight (near 100% and 88%, respectively) in 2004 compared with 2003. In the north-west exposure fruiting shoot length was maximum, whereas fruit number, fruit weight, raceme fruit number, and raceme weight were significantly higher in west exposures compared with east exposures. However, mean fruit weight was maximal in the north-east exposure. In the upper half of the plants, fruit shoot length, raceme number, fruit number and fruit weight per shoot were significantly higher than in the lower half of the plants. The fruit shoots considered as long reached nearly 8 cm length, and all the studied variables were significantly higher in these long shoots than in the short shoots.

Fruit production per plant was significantly higher in 2004 compared with 2003 (943.42 and 331.43 g respectively (data not shown)) when analysing the fruit production variables considering the plant as the experimental unit. On the other hand, only height position and shoot type affected the studied variables (Table 4). In the upper half of the plants, a higher number of fruiting shoots, racemes, and fruits were formed, as well as a higher fruit weight, although this variable did not vary significantly in its absolute values. Also, a higher number of short fruiting shoots were found, with the highest number of racemes, fruits, and fruit weight.

DISCUSSION AND CONCLUSIONS

The higher fruit production per shoot in 2004 compared with 2003 could be because of the temperature differences, with the temperature 0.86°C higher in 2004 than in 2003. Particularly in January and February, mean temperature differences between both years were of 1.4 and 1.7°C, respectively. The total rainfall at the end of the growing season in 2004

Table 2 Analysis of variance for shoot length (SL) (cm), total shoot number (SN), and total shoot production (SP) (cm), in their absolute and relative values (%) (percentage with respect to the total plant), at different shrub exposure, height position, and shoot type of *Ribes magellanicum* plants growing naturally near Ushuaia city, Tierra del Fuego, Argentina. SL variable was analysed through a multifactorial analysis, whereas SN and SP were analysed considering the studied factors individually, during the 2002/03 growing season. Number of shoots measured (*n*) was 7112. Significance of main effects of the variance analysis: SL = Shrub exposure: 0.0000, Height position: 0.3177, Type: 0.0000, Interaction (Shrub exposure × Height position × type): 0.0032. SN = Shrub exposure: 0.9553, Height position: 0.2869; Type: 0.5981; SN% = Shrub exposure: 0.7275, Height position: 0.0937; Type: 0.6574; SP = Shrub exposure: 0.8983, Height position: 0.4733, Type: 0.0013; SP% = Shrub exposure: 0.4206, Height position: 0.0041; Type: 0.0000. Means followed by different letters for each factor and in each column mean significant differences through Tukey test at $P < 0.05$.

	SL	SN	SN (%)	SP	SP (%)
Shrub exposure					
North-east	6.42ab	234.25	27.04	1471.25	27.96
North-west	6.95	221.62	25.65	1596.13	26.25
South-east	5.73bc	207.37	22.34	1258.50	21.08
South-west	5.45c	225.87	24.94	1362.50	24.68
Height position					
Upper	6.03	483.12	53.68	3159.13	57.10a
Lower	6.25	406.00	46.31	2529.25	42.89b
Type					
Short	1.00b	419.37	48.12	462.50b	10.84b
Long	11.28a	469.75	51.87	5225.88a	89.15a

Table 3 Multifactorial analysis for fruiting shoot length (FSL) (cm), raceme number per shoot (IN), fruit number per shoot (FN), fruit weight per shoot (FW) (g), raceme fruit number (IFN), raceme weight (IW) (g), mean fruit weight (MFW) (g), at different year, shrub exposure, height position, and shoot type of *Ribes magellanicum* plants growing naturally near Ushuaia city, Tierra del Fuego, Argentina. Number of fruiting shoots measured (*n*) was 4889. Significance of main effects of the variance analysis: FSL = Year: 0.0044, Shrub exposure: 0.0000, Height position: 0.0000, Type: 0.0000, Interaction: 0.0000; IN = Year: 0.8270, Shrub exposure: 0.3093, Height position: 0.0000, Type: 0.0000, Interaction: 0.0000; FN = Year: 0.0000, Shrub exposure: 0.0000, Height position: 0.0022, Type: 0.0000, Interaction: 0.0000; FW = Year: 0.0000, Shrub exposure: 0.0000, Height position: 0.0100, Type: 0.0000, Interaction: 0.0062; IFN = Year: 0.0000, Shrub exposure: 0.0000, Height position: 0.0092, Type: 0.0000, Interaction: 0.3493; IW = Year: 0.0000, Shrub exposure: 0.0000, Height position: 0.0048, Type: 0.0000, Interaction: 0.1733; MFW = Year: 0.0000, Shrub exposure: 0.0053, Height position: 0.1006, Type: 0.0000, Interaction: 0.0004. Means followed by different letters for each factor and in each column mean significant differences through Tukey test at $P < 0.05$. Interaction: Year × Shrub exposure × Height position × Type.

	FSL	IN	FN	FW	IFN	IW	MFW
Year							
2003	4.49b	1.42	8.48b	0.98b	5.54b	0.63b	0.10b
2004	4.81a	1.41	11.89a	1.85a	8.48	1.31a	0.15a
Shrub exposure							
NE	4.24c	1.40	8.81b	1.20b	6.48c	0.89c	0.14a
NW	5.42a	1.44	11.33a	1.60a	7.32b	1.01b	0.12bc
SE	4.26c	1.44	9.26b	1.20b	6.27c	0.79d	0.12c
SW	4.68b	1.39	11.34a	1.67a	7.96a	1.18a	0.13ab
Height position							
Upper	5.05a	1.55a	10.71a	1.48a	6.74	0.92	0.13
Lower	4.25b	1.28b	9.66b	1.35b	7.27	1.01	0.12
Type							
Short	1.00a	1.00b	6.28b	0.83b	6.28b	0.83b	0.11b
Long	8.3b	1.84a	14.08a	2.00a	7.74a	1.11a	0.14a

Table 4 Analysis of variance for total fruiting shoot number (FSN), raceme number (IN), fruit number (FN), and fruit weight (FW) in their absolute and relative values (%) (percentage with respect to the total plant), at different shrub exposure, height position, and shoot type of *Ribes magellanicum* plants growing naturally near Ushuaia city, Tierra del Fuego, Argentina. Variables were analysed during the 2002/03 growing season, considering the studied factors individually. Significance of main effects of the variance analysis: FSN = Shrub exposure: 0.8228, Height position: 0.0298, Type: 0.0009; FSN% = Shrub exposure: 0.7254, Height position: 0.0001, Type: 0.0000; IN = Shrub exposure: 0.8451, Height position: 0.0481, Type: 0.0045; IN% = Shrub exposure: 0.7137, Height position: 0.0005, Type: 0.0000; FN = Shrub exposure: 0.9893, Height position: 0.2088, Type: 0.1596; FN% = Shrub exposure: 0.8013, Height position: 0.0062, Type: 0.0000; FW = Shrub exposure: 0.9850, Height position: 0.2387, Type: 0.2261; FW% = Shrub exposure: 0.8157, Height position: 0.0094, Type: 0.0000. Means followed by different letters for each factor and in each column mean significant differences through Tukey test at $P < 0.05$.

	FSN	FSN (%)	IN	IN (%)	FN	FN (%)	FW	FW (%)
Shrub exposure								
NE	146.00	28.73	161.25	28.39	775.62	27.06	78.65	26.68
NW	102.00	19.40	131.00	19.50	772.85	20.10	87.78	20.43
SE	140.37	26.76	176.00	26.39	852.14	26.06	97.75	25.34
SW	113.87	25.09	134.42	25.70	678.42	26.77	77.85	27.53
Height position								
Upper	356.12a	68.23a	437.50a	68.07a	2185.13	64.82a	241.81	65.07a
Lower	146.12b	31.76b	157.87b	31.92b	796.37	35.17b	89.62	34.92b
Type								
Short	447.12a	85.44a	440.25a	78.81a	2059.88	76.15a	220.90	76.22a
Long	55.12b	14.55b	102.25b	21.18b	699.50	23.84b	83.34	23.77b

was similar to that of 2003. However, total rainfall in January 2004 was lower than in 2003 (50 versus 80 mm). These phenomena are coincident with those observed for *Berberis buxifolia* at Ushuaia (Arena et al. 2003), where higher temperatures and lower precipitation from October to January could advance the phenological phases in this fruit species. However, the periodicity in reproductive growth or biennial bearing is well known in fruit trees (Kramer & Kozlowski 1979) and is related to plant physiology as endogenous growth regulators or nutrients (Vozmediano 1982).

The higher shoot growth observed in the northern exposure compared with the southern exposures, and the similar behaviour observed in the total shoot number and total shoot production in such exposures, can be explained by a longer exposure to the sun and consequently to high light intensity. These results are coincident with the observations of other shrubs of native fruit species of Patagonia, as in *Berberis heterophylla* (Arena et al. 2001) and *B. buxifolia* (Arena et al. 2003).

The higher fruiting shoot growth in the north-west, and the higher number and weight of fruits per shoot and per raceme in the north-west and south-west compared with the north-east and south-east, can be related to the particular characteristics of the studied site, where this population is naturally protected from the west winds by a mountain slope. This may explain the higher values of the studied variables in the south-west. The productive variables in their absolute values, as in its relative values, were not affected by the exposure.

The higher values found in the upper half of the plants compared with the lower half could be explained by increased light intensity (Vozmediano 1982), and are coincident with those observed in *Berberis* species (Arena et al. 2001, 2003). The influence of sunlight on berry production and berry composition has been well documented (Toldam-Andersen & Hansen 1993; Dokoozlian & Kliewer 1996; Bergqvist et al. 2001). Shading reduced fruit set and yield in *Ericaceae* species (Patten & Wang 1994; Roper et al. 1995) and in *Malus domestica* (Doud & Ferree 1980). Also, shade effects have been studied on sour cherry (*Prunus cerasus*) showing maturing and colouring depending on light conditions and fruit location on the tree (Predieri & Dris 2006).

The number of shoots with a length higher than 1 cm was similar to those considered as short. In the analysis of the fruit production variables per shoot, the higher values were found in the longer shoots. This could be related to a more favorable source-sink relation in terms of nutrients in the longer shoots compared with the short ones. However, the 85% of the fruiting shoots were short shoots and these

produced 75% of the fruit. These findings must be taken into account when cultural practices are chosen for domestication.

Ribes magellanicum plants growing naturally near Ushuaia city, Tierra del Fuego, formed c. 900 shoots per plant at the end on the growing season in 2003, varying between 500 and 1100 shoots. These plants formed nearly 500 fruiting shoots, whereas 595 racemes with near 3000 fruits with a weight of 331 g were formed. Sixty-five percent of the fruiting shoots were grown in the upper half of the plants. These results are the first antecedents on growth and fruiting of *R. magellanicum* in Austral Patagonia and are relevant for its later domestication.

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