Influence of clay soil on two *Leucospermum* cultivars planted directly or grafted on clay-soil resistant rootstock. Study of Na and micronutrient nutrition.

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INTRODUCTION

General view of the plot in the third year of cultivation (2009)

General view of the plot under study the first year of cultivation. July 2006

Cultivation of South African proteas was introduced into the Canary Islands in the 1980s. The first plantations were carried out on the island of Tenerife, to monitor the performance of several commercial species of the genera *Leucadendron*, *Leucospermum*, *Protea* and *Serruria*. At present, they are also planted on La Palma and Gran Canaria. These farms mainly cultivate different cultivars of the genus *Leucospermum*, among them 'High Gold' and 'Succession II'. The former with some tolerance to clay soils and the latter susceptible to failure in this type of soil.

In the Canary Islands there are large areas potentially suitable climatically for the cultivation of these plants, but not from the edaphological point of view if they have clay soils. The use of appropriate rootstocks can improve the performance of plants in clay soils (Moreno et al., 2001; Lanauskas et al., 2007). Within *Leucospermum*, L. 'Spider' is recommended as a rootstock for clay soils (Reinten & Manuel 1995), and we have seen that *L. patersonii* can also be used in clay soils.

On the other hand, rootstocks influence the mineral composition of leaves and shoots (Jiménez et al., 2007). This is particularly complex in proteas because there are notable differences in foliar nutrient content among genera, species, and cultivars of the same species (Claassens 1986; Montarone 2001, Hernández et al., 2008).

The information available on the nutrition of South African proteas is still rather incomplete (Rodríguez-Pérez, 2007). Important differences in the overall nutrient composition in flowering stems among genera, species, and cultivars of the same species have also been reported (Claassens 1986; Maier et al., 1995; Hernández, 2006).

The purpose of this study was to ascertain whether *L.* 'Succession II' could be successfully cultivated in a clay soil by grafting on a clay-tolerant rootstock, and additionally if grafting *L.* 'High Gold' plants on *L. patersonii* would significantly improve the growth and production of flowers, compared to plants growing on their own roots in that soil. The foliar nutrition, nutrient distribution in cut flowers, and nutrient removal by both cultivars were also studied. In this paper, the results in

MATERIALS AND METHODS

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The assays were carried out at the Higher Technical School of Agricultural Engineering (now the Agricultural Engineering Section of the Higher Polytechnic School) of the University of La Laguna, on a 600 m2 plot of clay soil (Alfisol Udalf). Planting was carried out on 29th March 2006 in simple lines, in separate ridges 1.50 m apart with the plants separated 1 m along the line. Grafted plants of *L.* 'Succession II' (*L. lineare* × *L. cordifolium*) and *L.* 'High Gold' (*L. cordifolium* × *L. patersonii*) on *L. patersonii* (a rootstock resistant to this type of soil) were used, along with non-grafted plants of the same cultivars. At the time of planting, all plants were 6 months old.

The experimental design was a randomized block with 4 repetitions. Each treatment consisted of three rows of five plants each. The data were taken from the three central plants of the middle row. In the assay, 120 plants per cultivar were employed, 240 in total. Treatments were: 'High Gold' planted directly (T1), 'High Gold' grafted (T2), 'Succession II' planted directly (T3), and 'Succession II' grafted (T4). Prior to planting, the irrigation system was installed, along with a black polypropylene weedmat covering the ridges. Once in place, the height and diameter of the plants were measured, as well as the thickness of the trunk (main stem) at ground level.

A drip irrigation system with drippers spaced 30 cm apart was used, with a flow rate of 4 L/h, such that a homogeneous moist strip was formed along the row when watering.

Fertilization was via irrigation water. The pH was then corrected to 6.0 with sulphuric acid. Following Hernández (2006), 18.5 g N, 2.25 g P, 16 g K, 22 g Ca, 14.5 g Mg were applied to each plant during the first year of cultivation. These quantities were doubled from the second year of cultivation. Mean temperatures ranged from 12 to 15 °C in winter, and from 17 ° to 20 °C in summer, with an average relative humidity of 80%.

Four foliar samplings were carried out during the vegetative cycle (8 months long) for three consecutive years. The first was in August 2006. The most recent fully developed leaves were sampled (Benton et al., 1991), which were usually the 4th or 5th leaf counting from the apex. A composite sample was taken from each replication of the four treatments. The samples were washed in distilled water and dried in an oven at 80ºC, after which they were ground to powder. One g of the powder was ashed in an oven at 480ºC then mineralized by dry ashing with 6 M hydrochloric acid (Chapman & Pratt, 1961). The levels of Na, Cu, Fe, Mn, and Zn cations were determined by ICP (Perkin Elmer).

Data were subjected to one-way variance analysis, using Tukey's multiple range tests at P = 0.05, after testing for normality of the distribution (Kolmogorov-Smirnov test) and homogeneity of variances (Levene's test) and regression analysis by SPSS statistical software (SPSS Inc., Chicago, IL, USA) for Windows version 15.0 (Microsoft Corp., Redmond, WA, USA).

TABLES

Tables

Table 1 Foliar content of Na and microelements in the plants of *Leucospermum* 'High Gold' and *L.* 'Succession II' in year 2006.

Sampling	*Treatme	g/kg	mg/kg	mg/kg	mg/kg	mg/kg
		Na	Fe	Mn	Cu	Zn
August	T1	12.0b	50	107	2	18b
	T2	9.3a	52	80	3	25ab
	T3	9.8ab	49	101	2	26ab
	T4	8.9a	55	105	3	31a
September	T1	10.7a	69	158	8	25
	T2	9.3ab	62	122	8	33
	T3	10.4ab	66	191	7	35
	T4	8.6b	62	146	7	38
November	T1	6.6	75a	220	3	19a
	T2	5.7.	74a	183	3	25ab
	T3	6.2	47b	218	2	18b
	T4	5.3	50b	196	2	28*
December	T1	6.4a	33	137	1b	11b
	T2	5.9ab	31	146	2a	17a
	T3	6.5a	28	154	1b	11b
	T4	5.0b	34	143	2a	19a

*T1 = 'High Gold' planted directly; T2 = grafted 'High Gold'; T3 = 'Succession II' planted directly; T4 = grafted 'Succession II'. Data in columns of the same month followed by different letters are significantly different at P = 0.05.

Table 2 Foliar content of Na and microelements in the plants of *Leucospermum* 'High Gold' and *L.* 'Succession II' in year 2007.

Sampling	*Treatme	g/kg	mg/kg	mg/kg	mg/kg	mg/kg
		Na	Fe	Mn	Cu	Zn
May	T1	7.4 a	76 a	192	1	11 c
	T2	5.0 b	67 ab	205	1	14 bc
	T3	7.8 a	42 c	177	2	16 b
	T4	5.0 b	51 bc	201	2	21 a
July	T1	5.8 a	49	220	12	15 b
	T2	4.1 c	54	214	11	18ab
	T3	5.1 b	55	208	11	20 a
	T4	3.9 c	52	177	10	22 a
September	T1	5.0 a	49	144	13	15 b
	T2	4.0 b	55	181	11	16 b
	T3	4.9 a	60	217	11	19ab
	T4	4.1 b	56	164	14	24 a
November	T1	4.3 b	77	303 b	1	1 b
	T2	3.7 b	93	606 a	1	4 b
	T3	5.3 a	64	496 ab	2	9 a
	T4	3.9 b	85	288 b	3	11 a

*T1 = 'High Gold' planted directly; T2 = grafted 'High Gold'; T3 = 'Succession II' planted directly; T4 = grafted 'Succession II'. Data in columns of the same month followed by different letters are significa

Table 3 Foliar content of Na and microelements in the plants of *Leucospermum* 'High Gold' and *L.* 'Succession II' in year 2008

Sampling	*Treatme	g /kg	mg/kg	mg/kg	mg/kg	mg/kg
		Na	Fe	Mn	Cu	Zn
May	T1	9.3	62 a	50	6	16
	T2	7.5	59 a	49	7	19
	T3	9.4	43 b	56	5	16
	T4	7.4	41 b	49	6	17
July	T1	9.1 a	55	62 b	7	13
	T2	8.2 ab	59	77 ab	6	9
	T3	8.9 a	59	90 a	8	11
	T4	7.3 b	48	77 ab	6	15
September	T1	8.5	76	81 b	11	14
	T2	8.8	49	97 ab	9	15
	T3	7.6	52	135ab	14	15
	T4	7.2	50	164 a	11	15
November	T1	8.1 a	69 a	197	11	23
	T2	8.4 a	70 a	188	11	25
	T3	7.9 a	45 b	219	10	25

*T1 = 'High Gold' planted directly; T2 = grafted 'High Gold'; T3 = 'Succession II' planted directly; T4 = grafted 'Succession II'. Data in columns of the same month followed by different letters are significantly different at P = 0.05.

RESULTS AND DISCUSSION

The concentrations of Na and microelements observed in 2006 (August, September, November and December), 2007 and 2008 (May, July, September and November) can be seen in Tables 1, 2 and 3, respectively.

Sodium

The values observed in 2006 seem high at first glance, although they really are not (Table 1). Although Nichols (1988) mentioned that concentrations of up to 2.0 g/kg appear to be normal, he considered that many proteas can tolerate higher levels. **Hawkins and Cramer (2011) reported an average concentration of 8.1 g/kg in *Leucospermum*.** In general, its concentrations were higher than those determined by Maier et al. (1995) and Haigh et al. (1997) in the genus *Protea*, and by Cecil et al. (1995), in *Leucadendron*. However, low Na levels in soils (León et al., 2013) contrast surprisingly with its high concentrations in the leaves of the different cultivars, suggesting that these plants have a special avidity for Na, as already observed in previous work (González et al., 2008; Hernández et al., 2008).

In 2007, in general, Na concentrations were somewhat lower than the previous year, but higher than in the genus *Protea* (Haigh et al., 1997, Maier et al., 1995), and *Leucadendron* (Cecil et al., 1995) (Table 2). The following year, 2008, the high Na levels continued (Table 3).

Microelements

In 2006, the minimum level of Fe in proteas, in genera,l indicated by Nichols (1988) (40 mg/kg) was higher than those obtained in this study (Table 1). Price (1986) and Maier et al. (1995) reported a range of 51–54 mg/kg, while Haigh et al. (1997), determined concentrations between 15 and 170 mg/kg in eleven species of protea.

In 2007, while the highest Fe values were lower than the average of 117 mg/kg indicated by Parvin (1986) for *L. cordifolium*, they exceeded the range of 57 to 65 mg/kg found in 'High Gold' by Hernández et al. (2008) and the 13.4-48.6 mg/kg reported by Alvarez et al. (2012) in 'Succession II' (Table 2). However, in 2008 they were quite similar to those (41 to 74 mg/kg) detected by Fernández-Falcón et al. (2008). (Table 3).

Manganese concentrations in 2006 (Table 1)were higher than those indicated by Nichols (1988), who examined protea leaves in general and determined concentrations between 50 and 300 mg/kg, while Maier et al., (1995) found values from 43 to 44 mg/kg.

The varying concentrations of Mn in 2007 widely encompassed the average of 309 mg/kg indicated by Parvin (1986) for *L. cordifolium*, but were very close to the range of 343-536 mg/kg found by Hernández el al. (2008) (Table 2). Alvarez et al. (2012) reported a range of 21-345 mg/kg in 'Succession II'. However, in 2008, the average indicated by Parvin (1986) for *L. cordifolium* was higher than that observed, although much more so were the upper limits of the range (260 to 736 g/kg) obtained by Fernández et al. (2008) (Table 3).

In 2006 and 2007 (Tables 1 and 2), the ranges observed in Cu resemble those obtained by Nichols (1988) and Haigh et al. (1997) in different *Protea* cultivars (2-8 mg/kg, and 2-10 mg/kg, respectively), although that found by Maier et al., (1995) was narrower (3.5-4.5 mg/kg.

Hawkins and Cramer (2011) reported an average concentration of 3.1 mg/kg in *Leucospermum*. In the third year 2008, the observed intervals were higher than the 3-6 mg/kg) found by Fernández et al., (2008) in several cultivars of *Leucospermum*, or generally above the average 6 mg/kg reported by Parvin (1986) in *L. cordifolium* (Table 3) .

Regarding Zn, the intervals observed in 2006, 2007 and 2008 (Tables 1, 2 and 3,n respectively) in both cultivars are higher than the 6-19 mg/kg referred to by Fernández Falcón et al., (2008) for some *Leucospermum* cultivars, with the exception of 'High Gold'.. **Hawkins and Cramer (2011) reported an average concentration of 13.3 mg/kg in *Leucospermum***

CONCLUSIONS

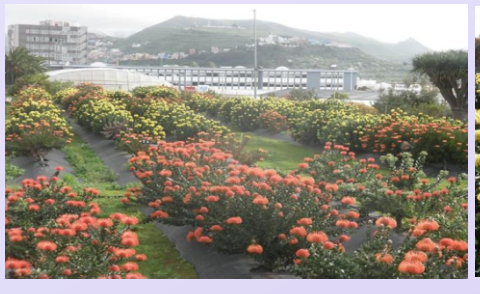
The foliar Na content of 'High Gold' was significantly higher than grafted 'Succession II' in three of the 2006 samples. In 2007, the highest Na concentrations were recorded in non-grafted 'High Gold'. The values stabilized between September and November. In 2008, the concentrations also remained stable over the months, except for grafted 'Succession II', which remained stable between May and September.

Foliar Fe did not show a defined pattern after comparing the different treatments during the three years studied. 'High Gold' was stable from August to September 2006, while for 'Succession II' this was from August to November 2006 and from May to September in 2007.

Like Fe, Mn content did not vary on a regular basis during this study. The levels of all four treatments remained stable between September and November 2006. The following year, 2007, stability was from May to September, and similarly in 2008 but from June onwards.

In general, foliar Cu concentrations were similar in all the samples during the three years, stabilizing in 2006 between November and December. In 2007, between July and September, and in 2008 between May and July, and between September and November.

Except in 2006, Zn levels remained similar between the different treatments in 2007 and 2008, as with Cu. In 2007, stabilization followed the same lines as Cu, between July and September. In 2008, Zn was stable from May to September in non-grafted 'High Gold' and grafted 'Succession II', there being no periodic stabilization in either of the other two treatments.



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