Influence of clay soil on two *Leucospermum* cultivars planted directly or grafted on clay-soil resistant rootstock. Study of plant growth and cut flowers production.

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INTRODUCTION

Most species of South African proteas are found in the Cape region. The mountainsides are covered by a sclerophyllous vegetation (fynbos) of which the proteas are part, growing from sea level up to 1300 m altitude, although some species can be found up to 2300 m high or more.

In cultivation, these plants adapt to a wide range of soils, from sandy to loamy clay. In the case of the latter, the percentage of silt+clay should not exceed 70%, with the percentage of clay not exceeding 30% (Malan, 1995)

The soils should preferably be light, acidic, with low nutrient content. Claassens (1981) indicated that clay soils should be avoided, because they tend to become waterlogged due to their low permeability.

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. Within *Leucospermun*, *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.

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 terms of growth and flower yield are presented.

*Leucopermum´*Succession II'in bloom (2008)

*Leucopermum´*HighGold` in bloom (2009)

Data collection: weight and length of floral stems and diameter of the flowers

Picking the flowers (2008)

MATHERIAL AND METHODS

Assay Description

The assays were carried out at the Higher Technical School of Agricultural Engineering 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.

Growth and production study

No flowers were collected during the first year of the trial. In the second week of December the plants were measured (height, plant diameter, trunk thickness at ground level), and then pruned, leaving 3-4 bearers to form the structure of the plant. In the following years, these parameters were measured at the end of vegetative growth, which occurred in the months of November-December, depending on the cultivar.

Flower collection in the 2nd year began on 9th November, 2007 in the case of L. 'Succession II' and on 9th January 2008 in the case of 'High Gold', the former ending on 18th and the second on 26th March 2008. In the third year, collection began on 22nd October 2008 in the case of L. 'Succession II' and on 27th February, 2009 for 'High Gold', ending on 18 March and 4 April, respectively. Since there was considerable plant mortality at the end of the experiment in the T3 treatment ('Succession II' without grafting), insufficient data were obtained to include them in the statistical analysis.

The flowers were collected when they showed the first row of fully extended stamens, leaving a 10-15 cm long bearer on the plant. The cut flowers evaluated came from the three central plants from the middle line of each treatment. Once cut they were weighed and floral stem length and flowerhead diameter were measured. Commercial flowers were classified according to their length in 10 cm intervals, from 30 cm to a maximum 80 cm. Once the harvest was finished, the plants were pruned between 2nd-7th April, in both the 2nd and 3rd years of cultivation, leaving 6-12 bearers.

During the experimental period, preventive phytosanitary control was carried out by combined application of insecticides and fungicides (to avoid possible resistance). Given the weakening of the plants due to clay soil and presence of Fusarium, some of them died. To mitigate the effects of the pathogenic fungus, they were treated with Trichoderma harzianum (Trianum). The presence of nematodes was also detected throughout the experiment, so Oxamyl was applied every six months. To eliminate weeds, two pre-emergence herbicides were used after planting: Oxadiazón (Ronstar) and Oxifluorfen (Goal).

Throughout the crop cycle, temperature and relative humidity were monitored. The recording of these parameters was carried out with a thermohygrograph.

The parameters evaluated were the following:

- Plant height.
- Trunk thickness
- Plant diameter.
- Diameter of commercial flowers collected.
- Total flower production.
- Commercial production of flowers.

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) by SPSS statistical software (SPSS Inc., Chicago, IL, USA) for Windows version 15.0 (Microsoft Corp., Redmond, WA, USA).

RESULTS AND DISCUSSION

Growth

Plant height

In the first year of cultivation, the grafted plants of 'Succession II' showed the highest growth in height (average 28.98 cm), followed by the same cultivar without grafting (23.95 cm) and non-grafted 'High Gold' (23.35 cm). There were significant differences only between grafted 'Succession II' and grafted 'High Gold'). In 2007, the growth in height of grafted 'Succession II' was significantly higher than non-grafted. However, in 'High Gold' the opposite happened, the non-grafted plants grew significantly higher than the grafted ones. In the following year 2008, there were no significant differences between grafted and non-grafted plants of 'High Gold'. The height of 'Succession II' could not be compared, due to the death of many of the non-grafted plants, as stated before.

Trunk thickness

In 2006, the growth of the trunk (main stem) thickness at ground level followed an inverse pattern compared to height, varying from 1.05 cm in 'Succession II' plants without grafting to 1.48 cm in High Gold' plants without grafting, although the statistical analysis showed no significant differences between the different treatments (P> 0.05). In 2007, there were significant differences in 'Succession II' between grafted and non-grafted plants, while not in the case of 'High Gold'. This behaviour of 'High Gold' was maintained in 2008.

Plant diameter

In 2006, the grafts of 'Succession II' cultivar reached a maximum diameter of 79.38 cm, followed by non-grafted 'High Gold' (74.82 cm). Growth in diameter of grafted 'Succession II' was significantly greater than non-grafted, however there were no significant differences between grafted and non-grafted 'High Gold' in this parameter. This finding was maintained in the following year of cultivation. In 2008 there were no differences between the different treatments.

Flower production

Table 1 shows the production of non-commercial and commercial flowers in the 2007-2008 campaign, the latter category grouped by the length of the floral stem. The production of commercial flowers varied from 8.1 to 16.9 flowers/plant in non-grafted and grafted 'Succession II', respectively, there being significant differences between them. In 'High Gold', non-grafted plants produced an average of 15.5 flowers each, compared to 14.8 from grafted plants.

The analysis of variance between the ranges classified commercial flowers according to their length, and only showed significant differences between treatments in the ranges 50-60 and 60-70 cm. In the range 50-60 cm, 'High Gold' without grafting produced a significantly higher number of flowers than grafted. However, in 'Succession II', the grafted ones showed more. In the 60-70 cm range, there were only significant differences between the grafted and non-grafted plants of the 'High Gold' cultivar.

The same Table 1 shows the production yield in the following campaign, 2008-2009, The analysis of variance between the intervals did not show significant differences between treatments in the intervals 40-50 and 50-60. In the first (40-50 cm), 'High Gold' without grafting produced a higher number of flowers than grafted, although there were no significant differences between them. Grafted 'Succession II' produced 9.6 flowers/plant, slightly less than grafted 'High Gold'. In the second interval (50-60 cm), the same trend continued, since there were no significant differences between grafted and non-grafted 'High Gold'.

Coetzee (1995) documented equal yields of 6 and 15 flowers per plant for 'High Gold' and 'Succession II' in the second and third years of development, respectively. Fernández-Falcón et al., (2008) reported a production of 9.82 flowers/m2 by 'High Gold' growing in mature plantations on the island of La Palma. Malan (2012) reported that 'High Gold' yielded 8 and 20 flowers per plant for the same two yearly stages while 'Succession II' gave 18 and 35 flowers.

The values obtained in our study (Table 1) provide superior yields in all cases, both in grafted and non-grafted plants, except those reported by Malan (2012) for 'Succession II'. Grafted plants showed significant positive differences in both 'Succession II' treatments, while 'High Gold' yields were similar in the first harvest, but significantly superior for non-grafted plants in the second harvest. This confirms the above-mentioned comments regarding stem growth, that grafting of 'Succession II' plants is economically beneficial, whereas it is not necessary for 'High Gold'.

Flower diameter

In the 2007-2008 campaign, the diameter of the collected commercial flowers ranged from 9.51 cm in 'High Gold' and 9.89 cm in 'Succession II', both grafted. There were no significant differences between grafted and non-grafted High Gold', or between grafted and non-grafted 'Succession II'. 'High Gold' followed the same pattern in the following campaign, 2008-2009 (Table 6).

The graft did not influence the diameter of flowers within the same cultivar. The fact that grafted 'Succession II' showed significantly higher values in the second harvest than those measured in grafted and non-grafted 'High Gold' may be due to the characteristics of the former cultivar, which became clearer as the plants developed. Malan (2012) reports diameters of 10 cm and 12 cm for 'High Gold' and 'Succession II', respectively.

TABLES

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Table 1. Flower production of *Leucospermum* 'High Gold' and *L.* 'Succession II' in 2007-08 and 2008-09 campaigns. The values in brackets correspond to this last campaign.

Treatments*	Commercial flowers/ stem length interval (cm)					Commercial flowers/plant	Commercial flowers/m²
	30-40	40-50	50-60	60-70	>70		
T1	2.3 (9.5b)	4.0 (19.6a)	6.2a (10.6a)	2.8a (1.2)	0.2 (0)	15.5a (41.2a)	11.2a (28.7a)
T2	2.5 (8.8b)	8.1 (12.5ab)	2.1bc (7.1ab)	1.6bc (0.9)	0.4 (0.3)	14.8a (29.4b)	10.5a (20.3b)
T3	3.2 (-)	4.6 (-)	0.3c (-)	0b (-)	0 (-)	8.1b (-)	5.6b (-)
T4	2.4 (16.1a)	7.9 (9.6b)	5.1ab (3.3b)	1.4ab (0.9)	0.2 (0)	16.9a (29.8b)	11.9a (21.0b)

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

Table 2 . Flower diameter of *Leucospermum* 'High Gold' and *L.* 'Succession II' in 2007-08 and 2008-09 campaigns.

Treatment*	Flower diameter (cm) 2007-08	2008-09
T1	9.57.ab	9.81b
T2	9.51b	9.76b
T3	9.80ab	—
T4	9.89a	10.19a

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

CONCLUSIONS

Grafting of 'High Gold' plants on *L. patersonii* did not improve either growth or flower production, so it is not considered necessary in clay soil.

However, grafting 'Succession II' on a L. patersonii rootstock allowed it to develop properly in clay soil and provided good flower production compared to non-grafted plants, many of which died in their third year.

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