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NUTRIENT DISTRIBUTION IN FLOWERING STEMS, NUTRIENT REMOVAL AND FERTILIZATION OF THREE PROTEACEAE CULTIVARS

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Abstract

Several parameters of flowering stems of two cultivars of protea *Leucospermum cordifolium* (Knight) Fourc ('Succession II' and 'Tango') and one of protea *Protea* L. (*Protea susannae x magnifica* 'Susara') were studied in different commercial plantations. These included length and weight measures, nutrient concentrations of detached parts (flower heads, leaves and stems), and removal of nutrients of harvested flowers. A base for fertilization was also calculated. Harvested flowers of 'Susara' removed more P, K and Cu than 'Succession II' and 'Tango', and more Ca and Fe than 'Tango'. 'Succession II' showed the highest Zn removal. The P and Cu removal by the crop of 'Susara' were significantly higher than those of both *Leucospermum* cultivars, while K, Ca, and Fe outputs of 'Susara' exceeded only those of 'Tango'. The nutrient top removals amounted to 4.55 g m^{-2} of N, 0.48 g m^{-2} of P, and 5.26 g m^{-2} of K. Data as a base to supply fertilizer to each cultivar are given, with N:P:K ratios of 1:0.08:0.87 for 'Succession II', 1:0.08:0.83 for 'Tango' and 1:0.10:1.27 for 'Susara'.

Keywords: *Leucospermum*, Succession II, Susara, Tango

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Introduction

Leucospermum and *Protea* are genera of the Proteaceae family that have obtained an increasing importance in the market of cut flowers worldwide, where they are known as proteas. Most of the species are native to Africa and Australia, which are also the main producers together with USA (Malan, 2012).

It is difficult to get a clear idea of the distribution of nutrients within the flowering stems in many proteas (genera *Leucadendron*, *Leucospermum* and *Protea*), because the chosen tissues are different depending on the authors. Cresswell (1991) took stems, young leaves and old leaves of *Leucadendron* cv. Harvest, and *Protea neriifolia* cv's Satin mink and Pink Ice, where he distinguished among optimum, high and toxic levels of phosphorous. Maier *et al.* (1995) analysed the nutrient contents of stems and leaves, axillary buds and flowers separately. The nitrogen and potassium contents of stems and leaves significantly exceeded those of the other fractions of the flowering stem, and the flowers showed the lowest calcium and magnesium concentrations. González *et al.* (2008) divided commercial flowers of five *Leucospermum* cultivars into flower head, half-distal and half-proximal stems, and half-proximal and half-distal leaves. Nutrient levels within every organ presented significant variations among cultivars. The nutrients related with the length of the stems also varied. Fernández-Falcón *et al.* (2008) observed that nutrient percentages in flower heads, leaves and stem of the flowering stem varied within the cultivar of *Leucospermum*.

These studies may help to determine nutrient removal of the crop by taking into account the nutrient content of the plant part that is generally harvested (Mengel and Kirkby, 2001). In the case of protea for cut flower there is very limited information in the literature that includes wastage by pruning and fallen foliage, which could represent up to 54 % of the total nutrients removed by a protea plant (León, 2011).

Claassens (1986) reported removal of 5.3 kg ha^{-1} N by flowering stems of *Protea neriifolia*, and 7.5 kg ha^{-1} N by *Leucospermum cordifolium*. He also did assays with *L. cordifolium* in sand hydroponic cultures, and obtained higher nutrient removals 30.0 kg ha^{-1} N, as well as increased values of P, K, Ca, and Mg. He concluded that protea crop removes low quantities of nutrients, and that fertilization with N could increase the productions in very acid and sandy soils. However, in a controlled fertilization experiment, Hawkins *et al.* (2007) reported that *Leucospermun* 'Succession' and *Leucadendron* 'Safari Sunset' acquired more N amounts than were supplied, but increasing N fertilization decreased their growth. They also found than 'Safari Sunset' removed 18 g N per plant, and 'Succession' 5.,5 g N per plant. Maier *et al.* (1995) detected N removal by *Protea* cv. Pink Ice of 26-43 kg ha^{-1}. Fernández-Falcón *et al.* (2008) reported higher amounts of N removed by the crops of *L. patersonii* and four *L. cordifolium* cultivars that reached nearly 150 kg ha^{-1} in some instances. In a compilation of works made in South Australia, Reid (2003) showed annual N exportations of *Protea* 'Pink Ice' and *Leucadendron* 'Silvan Red' which were 27.2 and 15.3 g $plant^{-1}$, respectively.

The study of nutrient removal of leaves and flowering stem of *Leucadendron* 'Silvan Red' and 'Safari Sunset' lead Cecil *et al.* (1995) to recommend annual applications of N and Ca at 20-30 g/plant, and Mg and K at 10-15 g/plant, that would meet the nutrient needs of both cultivars. Reid (2003) suggested that, to calculate the fertilizer needs based on the nutrient extractions of the crop, inefficiency of fertilizer by leaching should be taken into account, and proposed to apply at least double quantities of nutrients than the removed ones.

All these data show that nutrient removal and fertilization needs are different depending on genus, species and cultivars. The present paper aims to broaden the knowledge of nutrient distribution within the flowering stem of protea genera *Leucospermum* and *Protea*, and their nutrient removal. Besides, a base for fertilization was also calculated.

Materials and Methods

Two cultivars of *Leucospermum cordifolium* (Knight) Fourc ('Succession II' and 'Tango'), and one of *Protea* L. (*Protea susannae x magnifica* 'Susara') were studied in commercial plantations located in eight municipalities of La Palma (Canary Islands, Spain), distributed around the island, to obtain the general averages of the parameters listed below. The cultivars were selected by their very high commercial importance. Soils were Inceptisols Andepts and Ultisol Udults.

Flowering stems of commercial quality (30 cm or more of length, straight and without defects in the cases of 'Succession' and 'Tango' and equal to or longer than 45 cm for 'Susara') were taken in the field from each of the mentioned cultivars, during the harvest season (January to April) of the years 2009 and 2010. Samples of each farm consisted of three replications per cultivar, with three flowering stems per replication.

Lengths of the flowering stems were measured before cutting them into different parts: flower head, leaves, and stem. Fresh weight and dry weight of each plant part were determined, as well as their nutrient concentrations. Dry weights were measured after drying each plant part in an oven at 80ºC, and weighting them till no difference in weight was detected between two weightings.

For chemical analysis purposes, 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 and then mineralized by dry ashing with 6 M hydrochloric acid (Chapman and Pratt, 1961). The P, K, Ca, Mg, Cu, Fe, Mn and Zn concentrations were determined by ICP Perkin-Elmer. Nitrogen was determined by the Kjeldahl method (Cottenie, 1980).

The nutrient content of the flowering stem for each cultivar was obtained from the concentrations of nutrients of the flowering stems and dry mass weight. The nutrient removal of each cultivar was calculated from the nutrient content of the whole flower and the flower yields by square meter that amounted to 30 flowers in 'Succession', 25 in 'Tango' and 10 in 'Susara'.

Production data were collected from the Association of Protea Growers of La Palma Island. Data were subjected to one-way variance analysis, using Tuckey b test at p = 0.05, by SPSS 15.0 statistical software. Correlation and regression analysis were also performed, but no important relationship among nutrients and/or other studied parameters was found. Soil chemical analysis has been reported elsewhere (Álvarez *et al*. 2012).

Results and Discussion

Nutrient concentration in the different plant parts of the flowering stems of the different cultivar

Flower: Succession II cultivar showed the highest concentrations of N, Mg, Na, and Zn (Table 1), though not significantly higher than 'Tango' for Mg. The Na concentration of 'Susara' flowers was significantly lower than 'Succession' and 'Tango'. The other nutrients presented similar concentrations among the cultivars.

Table 1. Nutrient concentration of different plant parts for a protea cultivar on a dry mass base for 2009 and 2010

Cultivar	Plant part	g kg^{-1}						mg kg^{-1}			
		N	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn
Succession	Head	8.16a	0.64	7.04	2.44b	1.58	6.17	35	83b	5	19
	Leaf	10.56a	0.56	4.52	9.16a	2.01	6.26	60	315a	4	21
	Stem	5.31b	0.59	8.69	3.72b	1.45	3.27	46	104b	5	14
Tango	Head	6.08b	0.59	5.87a	1.94b	1.42b	5.22a	32b	86b	8	12
	Leaf	10.31a	0.52	4.28b	9.12a	2.11a	5.68a	61a	553a	7	15
	Stem	5.72b	0.39	6.19a	3.15b	1.51b	3.38b	37b	112b	7	11
Susara	Head	5.35	0.50	6.36	2.40	0.91b	1.23a	34	83b	11	10b
	Leaf	6.08	0.43	3.75	8.03	1.43a	1.21a	38	199a	7	11b
	Stem	4.92	0.63	7.34	2.70	0.62c	0.66b	36	200a	11	20a

Different letters following the data within each column of each cultivar denote significant differences at p = 0.05 level.

Maier *et al.* (1995) found in *Protea* 'Pink Ice' lower concentrations of N, K, Ca, Mg, Na, Cu, Mn and Zn than those detected in this study, although the level of Na equalled that of 'Susara', and the concentration of Zn was higher than those of 'Susara' and 'Tango'. Phosphorus presented similar levels than the cultivars of this assay, while Fe exceeded them.

González *et al.* (2008) determined in five *Leucospermum* cultivars N and Zn concentrations close to those of this study. The same happened with Fe but only in two of the five cultivars. On the other hand, they observed P, Ca, Mg, Na, and Mn higher levels, where Mg became two to three times higher. Potassium and Cu concentrations in this study exceeded the ones detected by these authors, though K levels were lower than in some cultivars.

There were differences of some nutrient concentrations between cultivars of *Leucospermum*, as well as between those of *Leucospermum* and *Protea*, confirming what the literature mentioned on this subject (Parvin 1986; Cecil *et al.,* 1995; Montarone *et al.,* 2003). Na presented very high concentrations, specially in the cultivar 'Succession II', a fact that Alvarez *et al.* (2012) had pointed out for proteas.

Leaf: The leaves of 'Susara' cultivar exhibited significantly lower N, Mg, Na, Fe, Mn and Zn compared to the other cultivars (Table 1), though Mn concentration resembled that of 'Succession II', and Zn that of 'Tango'.

The concentrations of N, P, K, Ca, Mg and Na obtained by González *et al.* (2008) in several *Leucospermum* cultivars exceeded those detected in this study. Iron followed the same trend, but its values in one of the cultivars matched the ones of 'Succession II' and 'Tango'. On the contrary, Mn levels of this study surpassed the concentrations found by these authors in three cultivars, while the levels of Zn and Cu were similar.

The great accumulation of Na observed in the flower head of 'Succession II' appears also in the leaves, though in the case of the leaves 'Tango' presents similar Na levels. They remained significantly lower in 'Susara'. Moreover, the two genera presented notable differences in the concentration of some nutrients.

Stems: The stems of both 'Succession II' and 'Tango' had higher levels of Mg and Na compared to 'Susara' (Table 1). On the contrary, 'Succession II' stems showed the lowest concentration of Cu, while 'Susara' presented the highest one, and that of 'Tango' was intermediate.

Nitrogen, K, Mg, Na, Cu and Mn concentrations fell below those reported by Maier *et al.* (1995) in *Protea* 'Pink Ice', though Mg level in 'Susara' was similar, and greater than that of Na. Phosphorus and Zn values resembled those of this study, while Ca and Fe exceeded them.

On the other hand, González *et al.* (2008), in several *Leucospermum* cultivars, obtained N, P, K, Ca, Mg, Na, Fe and Zn concentrations higher than those of this study, with the exception of K in 'Succession II', that was alike. Copper levels did not differ, while Mn behaved without a clear trend.

As in the previous two organs, the concentration of Na in the stems of both cultivars of *Leucospermum* exceeded by far that of the cultivar of *Protea*, while differences of the concentrations of some nutrients between the genera turned up once more.

Fernández-Falcón *et al.* (2008) found the highest N, Ca, Mg, Na and Mn contents in the leaves of five *Leucospermum* cultivars, and the lowest P, K and Cu in the stems, and Fe in the flower. Zinc was similar in the three organs. Nevertheless, they found different behaviours of the nutrient contents in some of the cultivars, as has happened in this study. For example, N was similar in the three studied flower organs of 'Susara', the flower head of 'Succession' had more than the stem, and 'Tango' showed similar values in the stem and the flower head.

Total nutrient concentration of flowering stem on a fresh mass base

Both Leucospermum cultivars presented similar concentration of N, Mg and Na in the entire flowering stems (Table 2), though they significantly exceeded those of the Protea cultivar Susara. No differences were detected in the concentrations of the rest of the nutrients. Their behaviour was closely related to those observed in the detached organs.

Flowering stem length, fresh and dry mass of the different cultivars

Table 3 shows the lengths of flowering stems, as well as the fresh and dry weights of the entire flowering stems and the different studied parts (heads, stems and leaves).

Table 2. Total nutrient concentrations of the flowering stem of different protea cultivars on dry mass base for 2009 and 2010

Cultivars	g kg^{-1}						mg kg^{-1}			
	N	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn
Succession	8.30 a	0.59	6.75	5.10	1.68 a	5.23 a	47	168	5	18
Tango	7.46 a	0.67	5.44	4.74	1.68 a	4.76 a	44	264	7	12
Susara	4.51 b	0.52	5.82	4.38	0.99 b	1.03 b	36	161	10	14

Different letters following the data within each column denote significant differences at p = 0.05 level.

Table 3. Flowering stem length, fresh and dry mass of different parts of different protea cultivars for 2009 and 2010

Cultivars	Length (cm)	g							
		FFM*	LFM	SFM	FSFM	FDM	LDM	SDM	FSDM
Succession	56.8 b	30.4 b	22.8 b	23.8 b	76.8 b	5.4 b	7.3 b	7.0 b	19.8 b
Tango	57.0 b	32.2 b	24.5 b	22.3 b	79.7 b	6.3 b	7.7 b	6.8 b	20.5 b
Susara	72.6 a	95.3 a	80.8 a	62.4 a	238.5 a	32.2 a	33.1 a	24.4 a	89.6 a

* FFM = flower fresh mass; LFM = leaf fresh mass; SFM = stem fresh mass; FSFM = flowering stem fresh mass; FDM = flower dry mass; LDM = leaf dry mass; SDM = stem dry mass; FSDM = flowering stem dry mass
Different letters following the data within each column denote significant differences at p = 0.05 level.

Cultivar 'Susara' presented significantly higher data of all these parameters than the other two cultivars, while 'Succession II' and 'Tango' did not exhibited appreciable differences between them. The observed findings could be expected because 'Succession II' and 'Tango' come from the same genus (*Leucospermum*), and 'Susara' from *Protea* genus that produces longer and heavier flowers.

Total nutrient content of flowering stem on a dry mass base: *Leucospermum* cultivars 'Succession II' and 'Tango' had similar nutrient contents of the entire flowering stems (Table 4), but 'Susara' *Protea* cultivar significantly exceeded them. This could be due to the greater size of the *Protea* 'Susara' cut flowers, as remarked previously.

Table 4. Total nutrient content of the whole flowering stem of different protea cultivars on a dry mass base for 2009 and 2010.

Cultivars	g flowering stem^{-1}						mg flowering stem^{-1}			
	N	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn
Succession	0.15 b	0.012 b	0.13 b	0.10 b	0.033 b	0.11	0.9 b	3.6 b	0.10 b	0.34 b
Tango	0.14 b	0.011 b	0.12 b	0.10 b	0.033 b	0.10	0.9 b	4.8 b	0.15 b	0.24 b
Susara	0.41 a	0.048 a	0.53 a	0.39 a	0.088 a	0.09	3.2 a	14.6 a	0.80a	1.28 a

Different letters following the data within each column denote significant differences at p = 0.05 level.

Fernández-Falcón *et al.* (2008) observed higher N, P, K, Ca, Mg, Fe and Mn contents compared to this study. Nevertheless, two of the five cultivars investigated by these authors presented lower Mn contents than those of 'Susara'. The levels of Cu and Zn detected by these researchers rose above the values found in 'Succession II' and 'Tango', but they were lower than in 'Susara'.

Nutrient removal of the flowering stems per m². Table 5 shows the nutrient removal of each cultivar. Nitrogen, Mg and Mn showed similar outputs in the three cultivars. 'Tango' presented the lowest outputs of K, Ca and Zn, while the other two cultivars had analogous values. On the other hand, 'Susara' flowers removed more P and Cu than the other two cultivars, and more Fe than 'Tango'.

Table 5. Nutrient removal per protea cultivar according to number of flowering stems m^{-2} for 2009 and 2010

Cultivars	g m^{-2}					mg m^{-2}			
	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
Succession	4.55	0.35 b	3.96 b	3.12 a	1.00	27.8 ab	106.2	3.33 b	10.08 a
Tango	3.51	0.27 b	2.90 b	2.55 b	0.91	22.7 b	120.6	3.71 b	6.09 b
Susara	4.13	0.48 a	5.26 a	3.90 a	0.88	31.7 a	146.0	8.23 a	12.77 b

Different letters following the data within each column denote significant differences at p = 0.05 level.

The nutrient removal far exceeded the N, P, K, Ca and Mg outputs reported by Claassens (1986) for *P. neriifolia* and *L. cordifolium* grown in the field, though they approached those of N and P when these plants were grown in hydroponics. The outputs of N and P by *Protea* 'Pink Ice' observed by Maier *et al.* (1995) and Reid (2003) were more similar, and even some values of P and Ca surpassed the removals detected in this study. The removal of Zn and Fe exceeded that found by Reid (2003) for 'Pink Ice', while the opposite happened with Mg. Fernández-Falcón *et al.* (2008) reported different amounts of nutrients removed by crops of *Leucospermum*. They found nutrient removals higher, lower or similar to those observed in this study, depending upon the cultivar.

Though the nutrient content per cut flower of 'Susara' exceeded those of the other cultivars, as stated before, its yields were clearly lower. As a consequence, similar nutrient outputs among the cultivars resulted in some cases and 'Susara' even presented a lower Zn value than 'Succession II'.

Protea nutrient removal reported in the literature is based on the removal by the harvested flowers, but they do not include the nutrients removed by the crop wastes, so that they do not illustrate completely the real removals. León (2011) had observed that the plant mass of 'Succession II' wastes (pruning and pinching out) represented an average of 54 % of the total plant mass-produced throughout the crop cycle. In the present study, total nutrient removal could be calculated taking into account this percentage and extrapolating it to 'Tango' and 'Susara'. Such nutrient removal (flowering stems + crop wastes) would be 9.9 g m^{-2} N, 0.76 g m^{-2} P and 8.6 g m^{-2} K by 'Succession II', 7.6 g m^{-2} N, 0.59 g m^{-2} P and 6.3 g m^{-2} K by 'Tango', and 9.0 g m^{-2} N, 1.01 g m^{-2} P and 11.4 g m^{-2} K by 'Susara'. These data are appropriate as a base to supply NPK fertilizers to avoid depletion of these nutrients in the soil. The N:P:K ratios should be 1:0.08:0.87 for 'Succession II', 1:0.08:0.83 for 'Tango' and 1:0.10:1,27 for 'Susara'. The remarks of Reid (2003) on the loss of effectiveness of fertilizers by leaching may be also taken into account.

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