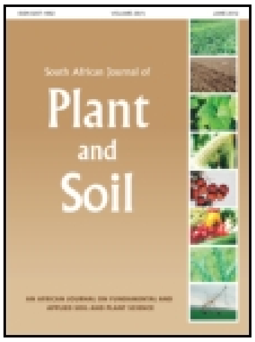

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Short Communication

Effect of potassium and potting-bag size on foliar biomass and related attributes and oil composition of rose geranium (*Pelargonium graveolens*)

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This study was conducted to evaluate the effect of four concentrations of potassium (K; 1.3, 3.3, 5.3 and 7.3 mmol L^{-1}) and two potting-bag sizes (5 and 10 L) on foliar biomass and related attributes and oil composition of rose geranium (*Pelargonium graveolens*). Plants were grown in a climate-controlled greenhouse at the University of the Free State and treatments were arranged in a split plot design. Potassium concentrations were allocated to the main plots and potting-bag size to the subplots replicated three times. Plant height, K tissue content, linalool, geraniol, geranyl formate and citronellol:geraniol ratio were affected by the K application. Plant height, number of branches, branch:height ratio, foliage fresh mass, K tissue content and oil yield were affected by the potting-bag size. Foliar fresh mass was significantly increased by the interaction between K concentration and potting-bag size. Growers may use a 5.3 mmol L^{-1} K concentration and a 5 L potting bag for optimum production of rose geranium under soil-less cultivation.

Keywords: C:G ratio, enzyme activation, oil quality, potassium, rose geranium

Rose geranium (*Pelargonium graveolens* L'Hér.) is native to South Africa and is produced commercially worldwide for use in perfumery, medicinal and aromatherapy industries (Weiss 1997).

Potassium (K) is the third-most important macromineral needed by plants. It is important for osmotic adjustment of sodium and calcium, protein synthesis and electrical neutralisation of anions (Xu et al. 2011). The objective of this study was to determine the effect of K concentration and potting-bag size on the yield and oil composition of rose geranium.

This study was conducted under natural light in a climate-controlled greenhouse at minimum and maximum temperatures of 24 and 26 °C at the Bloemfontein West Campus of the University of the Free State (29°10′ S, 26°17′ E) in summer. Potting bags were filled with soil-less sterile silica sand root medium (2 mm) (Sedibe and Allemann 2012). Four concentrations of K (1.30, 3.30, 5.30 and 7.30 mmol L^{-1}) and two potting-bag sizes (5 and 10 L) were laid out in a split plot design replicated three times. Potassium concentrations were allocated to the main plots and potting-bag size to the subplots. The electric conductivity and pH of the nutrient solutions were maintained at 1.63 mS cm^{-1} and 5.5, respectively, for all concentrations (Combrink 2005). Nutrient composition was prepared according to the levels described by Combrink (2005) and Sedibe and Allemann (2012). Nutrient solutions were recirculated daily during irrigation (1 h at 07:00, 11:00 and 15:00) and replaced with fresh solution after 14 d. A custom-built growing unit (450 cm × 800 cm × 215 cm) adapted from the designs of Sedibe and Allemann (2013) was used in the trial.

Plant height (cm) and number of branches was measured following the technique described by Pérez-Harguindeguy et al. (2013) and Damascos et al. (2008), respectively. Leaf area and chlorophyll content were determined using techniques described by Sedibe (2012) and Chen and Black (1992), respectively. Branch:height (B:H) ratio was calculated by dividing the number of branches per plant by plant height (cm) and expressed as branches per centimetre (Sedibe and Allemann 2012).

Leaf nitrogen content was determined using a Dumas combustion nitrogen analyser (FP-528, LECO Corporation, St Joseph, MI, USA) (Matejovic 1995). Potassium and phosphorus were measured using a high-resolution atomic absorption spectrometer (PerkinElmer, Shelton, CT, USA) as described by Sedibe (2012). Sulphur content was measured following the procedure of Sedibe (2012).

Rose geranium oil was extracted using a custom-built steam distillation unit (Sedibe 2012). Oil yield was determined by the procedures described by Swamy and Rao (2009). Only the main factors were considered for oil composition analysis due to financial constraints. Linalool, iso-menthone, citronellol, geraniol, citronelyll formate, geranyl formate and guaia-6,9-diene were determined for oil composition parameters. The data were analysed with SAS 9.2 statistical software (SAS Institute, Cary, NC, USA). Significant differences were compared using Tukey's least significant difference (LSD_T) at the 5% level of significance (Steel and Torrie 1980).

Plant height was the only growth parameter significantly ($P < 0.05$) affected by K application (Table 1). The tallest plants (49.3 cm) were produced at 5.3 mmol K L^{-1} but not significantly taller than plants produced at 1.3 (45.17 cm) and 3.3 mmol K L^{-1} (40.50 cm). The inconsistent plant height was attributed to the activation of enzymes that are responsible for plant growth (Xu et al. 2011).

Potting-bag size had a significant ($P < 0.01$) effect on plant height, number of branches, B:H ratio, fresh foliar mass and oil yield. All of these parameters were optimised when a 5 L potting bag was used. A significant interaction ($P < 0.05$) between 5.3 mmol K L^{-1} and 5 L potting-bag size affected the foliar fresh mass (Table 1). NeSmith and Duval (1998) reported that plants grown in potting bags have a root system that is exposed to moisture and tend to be short morphologically compared with field plants. The optimal potting-bag size selection should be selected along with and appropriate root medium type (Geply et al. 2011). Contrary to the present study, Watkinson and Wallace (2007) reported increased leaf area, foliar biomass and root biomass when larger potting-bags were used for little bluestem (*Schizachyrium scoparium* [Michx.] Nash) and lanceleaf coreopsis (*Coreopsis lanceolata* L.).

Potassium concentration and potting-bag size interaction had no significant effect on foliage tissue nitrogen, phosphorus and sulphur content (Table 2). However, plant tissue K content was affected by the interaction between K and potting-bag size at 7.3 mmol K L^{-1} concentration, where 10 L potting bag was used. An effect of K concentration on tissue K contents has been reported for cotton (*Gossypium hirsutum* L.) and rosemary (*Rosmarinus officinalis* L.), whereby high K application increased the K tissue content of cotton and rosemary (Gerardeaux et al. 2010; Puttanna et al. 2010).

As shown in Table 3, K concentration only affected the content of linalool ($P < 0.05$), geraniol ($P < 0.01$), geranyl-formate ($P < 0.01$) and C:G ratio ($P < 0.01$) at

Table 2: Nitrogen, phosphorus, potassium and sulphur composition of rose geranium foliage at four concentrations of potassium and two potting-bag size

Treatment	Plant mineral (%)			
	N	P	K	S
Potassium (mmol L^{-1})				
1.3	3.89	0.52	2.54	0.56
3.3	3.71	0.54	2.94	0.46
5.3	3.71	0.52	4.19	0.50
7.3	3.88	0.53	4.56	0.48
$LSD_{(0.05)}$	ns	ns	0.30**	ns
Potting bag (L)				
5	3.65	0.51	3.35	0.48
10	3.95	0.55	3.77	0.52
$LSD_{(0.05)}$	ns	ns	0.26**	ns
Potassium × potting bag				
1.3 × 5	4.05	0.48	2.23	0.48
3.3 × 5	3.59	0.52	3.07	0.46
5.3 × 5	3.41	0.50	3.82	0.48
7.3 × 5	3.48	0.53	4.25	0.46
1.3 × 10	3.72	0.55	2.83	0.63
3.3 × 10	3.83	0.55	2.80	0.45
5.3 × 10	4.00	0.53	4.55	0.51
7.3 × 10	4.26	0.53	4.86	0.48
$LSD_{(0.05)}$	ns	ns	0.52*	ns

* $P < 0.05$, ** $P < 0.01$, ns = non-significant

Table 1: Mean plant height, number of branches, branches: height (B:H) ratio, leaf area, chlorophyll content, foliar fresh mass, oil yield and oil content of rose geranium in response to four concentrations of potassium and two potting-bag sizes

Treatment	Parameter							
	Plant height (cm)	Number of branches (no. $plant^{-1}$)	B:H ratio (branches cm^{-1})	Leaf area (cm^2)	Chlorophyll (%)	Foliar fresh mass (g $plant^{-1}$)	Oil yield (g $plant^{-1}$)	Oil content (%)
Potassium (mmol L^{-1})								
1.3	45.17	34.78	0.74	29.13	27.68	333.05	0.74	0.23
3.3	40.50	32.97	0.81	28.85	26.71	261.40	0.87	0.32
5.3	49.30	36.33	0.70	34.28	27.75	419.55	0.61	0.22
7.3	37.39	27.11	0.67	30.59	26.69	261.55	0.79	0.49
$LSD_{(0.05)}$	9.30*	ns	ns	ns	ns	ns	ns	ns
Potting bag (L)								
5	49.22	44.30	0.89	31.61	27.16	463.75	1.10	0.30
10	36.96	21.89	0.57	29.82	27.26	174.03	0.41	0.33
$LSD_{(0.05)}$	4.98**	8.71**	0.15**	ns	ns	101.25**	0.31**	ns
Potassium × potting bag								
1.3 × 5	51.58	46.77	0.88	30.36	27.07	477.66	1.08	0.26
3.3 × 5	43.97	38.66	0.87	30.15	26.22	373.00	1.31	0.29
5.3 × 5	56.72	52.77	0.93	37.83	29.16	690.99	0.83	0.13
7.3 × 5	44.60	38.99	0.84	28.10	26.17	313.33	1.13	0.45
1.3 × 10	38.75	22.77	0.59	27.90	28.27	188.44	0.39	0.19
3.3 × 10	37.02	27.27	0.74	27.54	27.20	149.80	0.43	0.29
5.3 × 10	41.88	19.88	0.46	30.72	26.34	148.11	0.38	0.30
7.3 × 10	30.16	15.22	0.49	33.08	27.20	209.77	0.44	0.53
$LSD_{(0.05)}$	ns	ns	ns	ns	ns	202.51*	ns	ns

* $P < 0.05$, ** $P < 0.01$, ns = non-significant

Table 3: Effect of potassium (mmol L^{-1}) concentrations on oil composition of rose geranium

Potassium (mmol L^{-1})	Oil composition (%)									
	Linalool	Rose oxide (*cis*)	Rose oxide (*trans*)	Iso-menthone	Citronellol (C)	Geraniol (G)	Citronellyl formate	Geranyl formate	Guaia-6,9-diene	C:G ratio
1.3	1.25	0.09	0.00	1.00	34.98	9.03	21.01	5.02	9.43	3.89
3.3	0.50	0.15	0.04	1.24	35.19	6.22	21.62	3.53	10.00	5.69
5.3	0.84	0.13	0.03	2.69	31.32	8.06	20.96	4.95	10.31	3.90
7.3	0.55	0.19	0.08	1.77	33.70	6.29	22.13	3.99	10.18	5.38
$LSD_{(0.05)}$	0.49*	ns	ns	ns	ns	1.46**	ns	0.74**	ns	0.87**

* $P < 0.05$, ** $P < 0.01$, ns = non-significant

1.3 mmol K L^{-1}. These parameters were not different from the results obtained at 5.3 mmol K L^{-1}. Essential oil compositions were erratic and showed a high degree of inconsistency. Changes in the essential oil constituents were attributed to K owing to its effect on enzyme and metabolic activities during essential oil biosynthesis (Khalid 2013). Although the C:G ratio was significantly affected by K concentration, the ratios were higher than standards required by the perfumery industry.

In conclusion, growers may use 5.3 mmol K L^{-1} and a 5 L potting bag for optimum production of rose geranium under soil-less cultivation.

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