Yield and Mineral Response of Rose geranium (*Pelargonium graveolens*) to Phosphorus and Two Irrigation Methods

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Abstract: This study was undertaken to determine the effect of phosphorus and irrigation methods on yield and mineral composition of rose geranium. Four phosphorus concentrations (0.1, 0.8, 1.50 and 2.20 mmol L^{-1}) and two irrigation methods (drip and ebb-and-flood) were tested in a split plot experiment. Phosphorus treatments were allocated to the main plots, and irrigation systems to sub-plots. Irrigation took place four times per day (08:00, 11:30, 14:00 and 18:00) for 30 minutes. Plants were harvested five months after planting and dry mass, height, number of branches, fresh mass, chlorophyll content, leaf area, oil yield and mineral composition of foliage determined. Phosphorus concentration did not have a significant (P<0.05) effect occurred on any of the parameters measured, Irrigation method had a significant ($P<0.05$) effect on dry mass, height, fresh mass and oil yield. Foliar Ca, P and K were affected significantly (P<0.05) by changes in the phosphorus concentration in the nutrient solution. Dry mass, height, number of branches, fresh mass, chlorophyll content, leaf area, oil yield were not affected significantly (P<0.05) by the interaction between phosphorus and irrigation methods. Drip irrigation was the best irrigation system for the production of rose geranium. Changes in the P concentration did not affect growth or yield parameters.

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1. Introduction

Rose geranium *(Pelargonium graveolens* L.) belongs to the *Geraneacea* family and is an important essential oil plant used in the chemical, pharmaceutical, food and flavouring industries. Large quantities of rose geranium oil are exported to international industries for flavour and fragrance, cosmetics and personal health care, aromatherapy as well as food manufacturers (DAFF, 2009). Currently, the crop is grown in an open field conditions that are not always suitable for the successful production of high value oil crops. Exposure of these crops to extreme conditions alters the quality of oil and also lowers oil yield, while plants grown under unprotected conditions may take a protracted period to become established (Rao et al., 1996). To avoid the effects of adverse conditions, growers in South Africa are considering growing rose geraniums under protection, i.e. in greenhouses, tunnels or shade structure.

Greenhouse cultivation is highly intensive production method where plants are grown in pots and irrigated with balanced nutrient solutions Plants are grown in pots containing root medium. The root system development, amount of water required, and nutrients retained in the rooting zone are determined by both container volume and the rooting medium characteristics (Dole and Cole, 1994). The correct choice of irrigation method for a specific plant species is instrumental in determining the optimal use of nutrients by plants in the system (Sedibe et al., 2006).

Declining availability of good quality irrigation water has been a prime concern in cultivated crops (Sinclair et al., 1984). This affects hydroponic systems, which depend on water with a fairly low salt load in order to make a quality nutrient solution. This is particularly important when using ready-mixed fertilisers, where the added salts, together with the salts already in the water can lead to possible sodification problems in the rooting medium. In order to reduce this problem it would be necessary to select an irrigation system that provides a better water distribution through the medium, and provides for drainage if required (Sedibe et al., 2006). Growing plants using re-circulating water is an attractive option given the water and nutrient saving potential. Further savings are obtained by application of soilless culture techniques (Papadopoulos, 1991). Ebb-and-flood system is an effective sub-irrigation and nutrient delivery within a closed system (Sedibe et al., 2006; Fischer et al., 1990).

In an ebb-and flood system salts that are not absorbed by plants tend to accumulate in the upper part of the substrate, where most of the roots are present. In contrast, when drip irrigation is used, salts tend to accumulate throughout the substrate used and this might require flushing or replacement of the substrate at some stage, leading to increased costs and disruption of the production cycle. The main objective of this study was to determine the effect of phosphorus and irrigation method on yield and mineral composition of rose geranium.

2. Material and Methods

The trial was conducted on the west campus facility of the University of the Free State in Bloemfontein (29°06' S and 26°18' E), at an altitude of 1 351 m above mean sea level. Bloemfontein is located in the central region of South Africa.

Rose geranium plants were grown from cuttings in an air-conditioned glasshouse maintained at 25±1°C under natural daylight conditions. The seedlings were planted into 5 L polyethylene pots filled with 2 mm silica sand when they were approximately 10 cm tall. These pots were transferred to the irrigation systems used in this trial.

Table 1. Fertilizer formulation used to induce phosphorus (**1** = 0.1, **2** = 0.8, **3** = 1.5 and **4 =** 2.2 mmol L^{-1}) concentrations used to irrigate rose geranium plant (

Fertilizer	**Application (g 1000 L^{-1} of water)**			
	1	**2**	**3**	**4**
KNO_3	412	355	298	241
K_2SO_4	139	123	110	92
KH_2PO_4	14	109	204	299
NH_4NO_3	36	36	36	36
$5Ca(NO_3)_2.NH_4NO_310H_2O$	653	653	653	653
$MgSO_4.7H_2O$	252	252	252	252

Four nutrient solutions were mixed using potassium nitrate, potassium sulphate, mono potassium sulphate, ammonium nitrate, calcium nitrate and magnesium sulphate to provide final phosphorus concentrations of 0.1, 0.8, 1.5 and 2.2 mmol L^{-1} respectively (Table 1). The pH of the nutrient solutions was set to 5.5, and the Electrical Conductivity of each solution was adjusted to 1.57 mS cm^{-1} as described by Sedibe and Allemann (2012). The anion and cation concentrations of each of these macro nutrient solutions are given in Table 2. Micronutrients were applied to each solution as described by Combrink (1998) and Combrink and Kempen (2011).

The hydroponic unit consists of two tanks (450 x 800 x 215 mm) supplied from a single 100 L capacity nutrient solution reservoir (Figure 1). A pump with a 700 L h^{-1} flow rate is installed in the reservoir and supplies the nutrient solution through a 20 mm amiad filter via 20 mm HD polyethylene pipe to both tanks. One tank is set up as an ebb-and-flood system with a flood level of 80 mm, while the other is equipped with six 4 L h^{-1} button drippers. The flood level is reached approximately 12 minutes after the pump switches on, and it takes around 15 minutes for the nutrient solution to drain. Drain pipes from the two tanks return the excess nutrient solution to the reservoir so that it can be re-used.

Table 2. Macro nutrient compositions of the nutrient solutions containing different phosphorus concentrations (mmol L^{-1})used to irrigate rose geranium plants (P, $H_2PO_4^-$; S, SO_4^{2-})

P	**Ions (mmol L^{-1})**						
	NH_4	**K**	**Ca**	**Mg**	**NO_3**	**P**	**S**
0.1	1	6	7	3	11.0	0.1	3.8
0.8	1	6	7	3	10.5	0.8	3.6
1.5	1	6	7	3	10.0	1.5	3.4
2.2	1	6	7	3	9.5	2.2	3.3

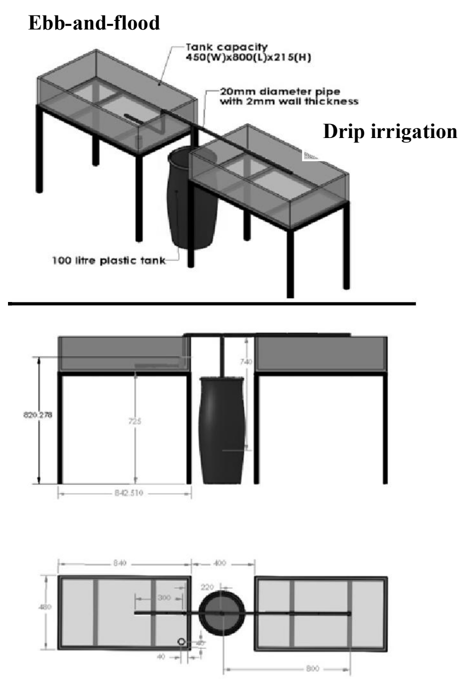

Figure. 1 A Schematic illustration of the ebb and flood and drip irrigation (Hydroponics) methods (The hydroponic unit consist of a pump (flow rate: 700 L hr^{-1}), pipe (HD PE 20mm tubing), Flood level: (80mm), 6 drippers (flow rate: 4 L hr^{-1} button) and Flood level is reached in approximately 12 minutes. The flood levels have a draining duration of approximately 15 minutes. The pump is installed in each water reservoir tank (100 L), and is having an outlet going through a 20mm amiad filter. The tube splits into two directions one to the flood container; the other branch into drip container that have six, 4 L hr^{-1} button drippers. All open ended pipes are blocked off with 15 mm plugs. All the overflow and draining pipes route back to the tank for recirculation of the nutrient solution)

The trial was conducted in an evaporatively cooled polycarbonate structure, and a randomised complete block experimental design with a spilt plot layout was used. Nutrient solutions were allocated to main plots, and irrigation system to sub-plots. Pots containing geranium plants were randomly allocated to either the ebb-and-flood or drip irrigation systems. Each experimental unit consisted of six pots, each containing a single plant used as a replicate

Irrigation took place at 08:00, 11:30, 14:00 and 18:00 daily using a 30 min irrigation pulse each time. Nutrient solution was discarded and fresh solution was prepared every two weeks in order to prevent over concentration of salts in the solution. Five months after commencing the trial plants were harvested and the following parameters determined: plant height (measured to the highest naturally occurring point) and number of branches per plant. The chlorophyll content of nine randomly selected young leaves from the top one-third of the plant was determined using a CCM-200 hand held chlorophyll content meter (Opti-Science, USA). Plants were then cut 10 cm above ground level and the fresh mass determined. Approximately 2 kg of fresh material was retained for oil extraction and the rest dried at a temperature of 68°C for a period of 72 hours and dry mass determined.

Dry material was milled to a diameter of 0.25 mm using a micro hammer mill (Culatti, Zurich) after determining the dry mass and used for chemical analysis (Jones et al., 1991). The magnesium, calcium, phosphorus, potassium and sulphur content of the leaves was determined using an Inductively Coupled Plasma Optical Emission Spectrometer (Optima 4300 DV, ICP-OES, PerkinElmer Inc., USA). All methods used were described by Zasoski and Burau (1977). The nitrogen content of the material was determined using the Dumas combustion method in a Leco FP-528 combustion nitrogen analyzer (LecoCorp, St. Joseph, MI, USA) as described by Matejovic (1995) and Etheridge et al. (1998).

Oil extraction from the fresh material sample took place using steam distillation for a period of 60 minutes as described by Sedibe and Allemann (2012) to determine oil yield. This oil was then analysed using a Aligent gas chromatograph (Model 6890) fitted with a 30 m x 0.25 mm DB-5 fused silica capillary column with a film thickness of 0.25 µm, using the procedure described by Adams, 2004).

Analysis of variance was conducted on the data using SAS version 9.3 (SAS Institute, 2004). Parameters showing significant difference ($P<0.05$) were then subjected to further analysis using Tukey's HSD test to separate treatment means (Steel and Torrie, 1980).

3. Results and Discussion

Foliar dry mass, foliar fresh mass, height, number of branches, leaf area and oil yield were not affected significantly by the P levels and by the interaction between P concentration and irrigation methods (Table 3; Figure 2). Reduction in height decreased branching and lower leaf area effected oil yield. Results obtained on this study is in agreement with the results obtained on Pelargonium graveolens, *Tanacetum parthenium*, *Ocimum basilicum* and *Agathosma betulina* by Sedibe and Allemann (2012); Ramezani et al. (2009) and Saharkhiz and Omidbaigi (2008). These increases noted on feverfew (*Tanacetum parthenium* L.) and rose geranium were presumable affected by the pH of the nutrient solutions. The increased mass is ascribed to the role of P in cell division, root growth, reproductive growth and vegetative of plants (Sedibe and Allemann, 2012; FSSA, 2007).

Mass, height, number of branches were increased significantly ($P<0.01$) where drip irrigation methods was used over ebb-and-flood and this resulted in high oil yield. Poor performance of ebb-and-flood is associated with poor aeration and high temperature of the substrates (Sedibe et al., 2005). Drip method ensures high water use efficiency. It is also high in localized application and flexibility in irrigation scheduling and chemical applications. Drip ensures that applied plant nutrients become available to a large fraction of the rooting system as is the case with sandy soil (Clothier, 1984; Bucks and Nakayama, 1980).

Chlorophyll contents were affected significantly ($P<0.05$) by phosphorus. The effect of P on chlorophyll was optimized at 2.20 mml L^{-1} P concentrations. However irrigation and the interaction between P and irrigation methods had no effect on chlorophyll contents (Table 3). Chlorophyll content is mainly used as an alternative measure for N status of most plant species (Fontes and de Araujo, 2006).

As it can be seen in Table 4, foliar calcium was affected significantly by phosphorus and irrigation methods at $P<0.05$ and $P<0.01$, respectively. The effect of P on foliar Ca content was erratic and inconsistent. Calcium concentrations of rose geranium grown on drip and ebb-and-flood irrigation methods were 1.83 and 1.68%, respectively. The variation in environmental condition within the greenhouse during experimentation period could have stimulated or suppressed transpiration, so causing differences in foliar Ca concentration. Calcium concentration obtained with the drip method was well within the limits for a healthy plant growth (1.72-2.06%). Foliar P content was affected significantly by the interaction between P and irrigation methods (Figure 1; Table 4). This interaction occurred at P at 0.8 and 1.5 mmol L^{-1} where drip was used as an irrigation method. An abrupt decline in K content of the plant tissue showed a decrease as the P concentration increased from 0.1 to 1.5 mmol L^{-1} (Table 3).

Table 3. Plant parameters of rose geranium as affected by phosphorus concentration (mmol L^{-1}) and irrigation system (FD, foliar dry mass; H, height; B, number of branches; FM, foliar fresh mass; CH, chlorophyll content; LA, leaf area; OL, oil yield (g $Plant^{-1}$)

	FD	H	B	FM	CH	LA	OL
P							
0.10	49	44	16	357	23	20	0.51
1.80	51	44	20	424	18	31	0.62
1.50	54	46	19	397	18	32	0.68
2.20	69	50	19	377	24	32	0.55
P	***ns***	***ns***	***ns***	***ns***	*	***ns***	***ns***
LS	***ns***	***ns***	***ns***	***ns***	***7.03***	***ns***	***ns***
I							
D	79	47	21	587	22	27	0.83
EF	35	37	16	192	22	30	0.34
P	**	**	***ns***	*	***ns***	***ns***	**
LS	***14***	***6.79***	***ns***	***56.78***	***ns***	***ns***	***0.16***
PxI	ns	ns	ns	ns	ns	ns	ns

ns= not significant at P<0.05, *F-ratio probability of P<0.05, **F-ratio probability of P<0.01, $LSD_{T(0.05)}$=least significant difference (I, irrigation methods; D, drip irrigation; EF, Ebb and Flood; P, Pvalue; LS, $LSD_{T(0.05)}$; PxI, phosphorus and irrigation interaction)

Table 4. Mineral composition of rose geranium as affected by phosphorus concentration (mmol l^{-1}) and irrigation system

	Mg (%)	Ca (%)	P (%)	K (%)
P				
0.10	0.37	1.79	0.42	4.44
0.80	0.39	1.88	0.44	3.98
1.50	0.38	1.71	0.47	3.07
2.20	0.37	1.64	0.45	3.08
P	***ns***	*	***ns***	*
LS	***ns***	***0.25***	***ns***	***0.64***
I				
D	0.39	1.83	0.47	3.73
EF	0.34	1.68	0.43	3.47
P	***ns***	**	***ns***	***ns***
LS	***ns***	***0.09***	***ns***	***ns***
PxI	ns	ns	*	ns

ns= not significant at P<0.05, *F-ratio probability of P<0.05, **F-ratio probability of P<0.01, $LSD_{T(0.05)}$=least significant difference (I, irrigation methods; D, drip irrigation; EF, Ebb and Flood; P, Pvalue; LS, $LSD_{T(0.05)}$; PxI, phosphorus and irrigation interaction)

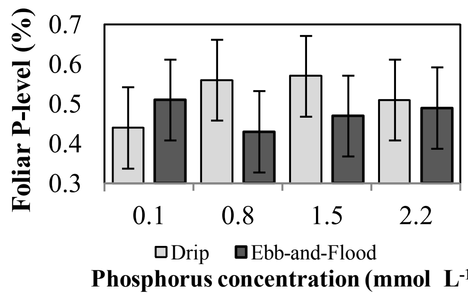

Figure 2. Interaction between phosphorus and irrigation methods (LSD=0.102) affects foliar phosphorus contents of rose geranium

Conclusions

Phosphorus applied at a low pH level in the nutrient solution did not have any impact on yield parameters, only reducing foliar Ca and K concentration, although it did increase the chlorophyll content. Using Drip irrigation resulted in a substantial increase in plant mass, height, chlorophyll content and oil yield, showing that this is probably the irrigation system of choice for hydroponically grown rose geranium.

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References

1. Adams RP. Identification of essential oil components by gas chromotography/quadrupole mass spectroscopy. Academic Press, Inc., New York, United States of America. 2004; p. 130-9.
2. Bucks DA, Nakayama FS. Injection of fertilizers and other chemicals for drip irrigation. In Agric.-Turf. Irrigation Association, Houston, Texas. 1980: pp. 166-80.
3. Clothier BE. Solute travel times during trickle irrigation. Water Resource Research 1984; 20: 1848-852.
4. Combrink NJJ, Kempen E. Nutrient solution management. Combrink Family trust, Cape Town, South Africa. 2011: pp. 30-9.

5. Combrink NJJ. Tomato fruit quality and yield as affected by NaCl in nutrient solutions. Journal of South African Society of Horticultural Science 1998; 8: 57-9.
6. DAFF (Agriculture, Forestry and Fisheries). Essential oil crops; production guidelines for rose geranium. Agriculture, Forestry and Fisheries, Department of Agriculture, Directorate: plant production, Agricultural Information Services, Pretoria, South Africa. 2009: pp. 117-1.
7. Dole JM, Cole JC. Growth of poinsenttias, nutrient leaching, and water-use efficiency respond to irrigation methods. Horticultural Science 1994; 29: 858-4.
8. Fischer D, Guacamole GA, Janes H. A system of intensive tomato production using ebb-and-flood. Professional Horticulture 1990; 4: 99-6.
9. Fontes PCR, de Araujo C. Use of chlorophyll meter and visual aspect for nitrogen management in tomato fertigation. Journal of Applied Horticulture 2006; 8: 8-1.
10. Jones JB, Wolf B, Mills HA. Plant analysis handbook. A practical sampling, preparation, analysis, and interpreting guide. Micro-Macro Publishing, Georgia, United States of America. 1991: pp. 55-9.
11. Mmolawa K, Or D. Root zone solute dynamics under drip irrigation: A review. Plant and Soil 2000; 222: 163-0.
12. Papadopoulos AP. Growing greenhouse tomatoes in soilless media. Agriculture Canada Publication. 1991; 18: 79-1.
13. Rao RBR, Kaul PN, Mallavarapu GR, Ramesh S. Effect of seasonal climatic changes on biomass yield and terpenoid composition of rose scented geranium (Pelargonium sp.). Biochemical Systems Ecology 1996; 24: 627-5.
14. SAS (Statistical Analysis Software). SAS STAT1 User's guide. SAS Institute, Inc. Cary, NC, United States of America. 2004: pp. 166-0
15. Sedibe MM, Allemann J. Yield and quality response of rose geranium (Pelargonium graveolens L) to sulphur and phosphorus application. South African Journal of Plant and Soil 2012; 29: 151-6.
16. Sedibe MM, Combrink NJJ, Reinten EY. Evaluation of soilless production systems for small scale production of two Amaranthus Species and Swiss chard, Beta vulgaris. South African Journal of Plant and Soil 2006; 23: 209-10.
17. Sedibe MM, Combrink NJJ, Reinten EY. Leaf yield of Amaranthus hypochondriatus L. (Imbuya), affected by irrigation systems and water quality. South African Journal of Plant and Soil 2005; 22: 171-4.
18. Steel RGD, Torrie JH. Principles and procedures of statistics: a biometrical approach (2nd edn). Kogakusha: McGraw-Hill. 1980; p. 107-10.
19. Zasoski RJ. Burau RG. A rapid nitric-perchloric acid digestion method for multi-element tissue analysis. Communication in Soil Science and Plant Analysis 1977; 8: 425-6.

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