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Response of Herbage Yield, Essential Oil Yield and Composition of South African Rose-Scented Geranium (*Pelargonium* sp.) to Conventional and Organic Nitrogen

Hintsa T. Araya, Puffy Soundy* and J. Martin Steyn
Department of Plant Production and Soil Science, University of Pretoria, Pretoria, 0002, Republic of South Africa

Clive Teubes
Clive Teubes CC, P.O. Box 4919, Randburg, 2125, Republic of South Africa

Robin A. Learmonth and Nare Mojela
Biosys Plant Extracts (Pty) Ltd, P.O. Box 72775, Lynnwood Ridge, 0040, Republic of South Africa

Abstract

A field experiment was conducted on rose-scented geranium in Pretoria, South Africa, to evaluate the response of plants to amount and source of N. Treatments consisted of two sources of N, comprising conventional or organic fertiliser sources at 100, 200 and 300 kg/ha N/year and a control (zero kg/ha N/year). The experiment was laid out in a randomized complete block design. The oil content of the plants (sub sample of 10 kg from each treatment) was determined by steam distillation and oil samples were analyzed by gas chromatography (GC). At the first harvest (summer/autumn), there was no significant effect of conventional N on fresh herbage and oil yield, probably due to leaching of N by rainfall. However, organic N at 100 kg/ha increased fresh herbage and oil yields by 57.5% and 47.9% over the control, respectively. In the second harvest (spring/summer), fresh herbage yield increased by 46.3% (conventional N) and 60.3% (organic N) at 100 kg/ha compared to the control. Compared to the control, 100 kg/ha conventional and organic N also increased essential oil yields by 93.6% and 129.4%, respectively. Increasing N levels of both sources increased citronellol percentage, in the first harvest. In the second harvest, organic N increased citronellol percentage, whereas conventional N had no effect. In both harvests, no effect of conventional N was observed on geraniol percentage compared to the control. Except for the 100 kg/ha level, the same was true for organic N. In the first harvest, application of conventional N beyond 200 kg/ha and all levels of organic N reduced guaia-6,9-diene percentage, while in the second harvest, it was not significantly influenced by either source or level of N. This study revealed that rose-scented geranium produced higher fresh herbage and essential oil yield when organic fertilizer was used as a source of N. Furthermore, N application influenced oil composition.

Key Word Index

Pelargonium sp., Geraniaceae, geranium, essential oil composition, geraniol, guaia-6,9-diene, citronellol, citronelly formate.

Introduction

Rose-scented geranium (*Pelargonium* sp.) belongs to the family Geraniaceae and it is a multi-harvest, high value, commercially important essential oil yielding aromatic plant. The essential oil isolated from the herbage of the plant is widely used in the fragrance and cosmetics industry and in scenting of soaps. The oil is isolated by steam distillation. China, Egypt, and Réunion Island are historically the leading rose geranium essential oil producing countries (2,5). Oil from each region has a unique chemical composition and, therefore, a unique position in the market. Réunion oil (Bourbon) has typically demanded the highest price. The chemical characteristics of Réunion oil are well understood. South Africa is now producing significant quantities of geranium oil. How the plant responds to agronomic practices such as source and amount of N, under South African conditions, has not previously been studied. Previous field experiments by this research group (unpublished data) showed that the plant usually grows well after establishment until first harvest, but re-growth can, under

*Address for correspondence

certain circumstances, be poor. Poor growth results in low herbage yield and, consequently, low total oil production per hectare. Poor growth is believed to be due to a combination of factors, including nutrient deficiencies. Other authors (3,5-7) have reported that faster growth of the crop can be attained by application of N before planting and after harvesting. Knowing the exact amount of N for each growing region and how the plant responds to source of N, is important for economically viable production of this crop. The market demand for organically certified rose geranium from South Africa is increasing, requiring that a better understanding of the organic fertilizer to provide the nutrient demand of the crop be developed.

The objective of this study was to investigate the response of rose-scented geranium, in terms of fresh herbage yield and essential oil yield and oil composition, to different amounts of conventional and organic N fertilizers.

Experimental

A field experiment was conducted at the University of Pretoria's Hatfield Experimental Farm, Pretoria, South Africa. The experimental site was situated at 25°45'S latitude, 28°16'E longitude and 1372 m above sea level. The soil at a depth of 0 to 30 cm was sandy clay loam in texture (22.7% clay) with a 6.3 pH (1:2.5, soil:water), 6.1 (g/kg) total carbon, 0.04% total N, 12 kg/ha P and 152 kg/ha exchangeable K.

Two sources of N, namely conventional (limestone ammonium nitrate or LAN, 28% N) and organic fertilizers (blend of four organic fertilizers) (Table I) at three levels (100, 200 and 300 kg/ha N/year) and a control (no N) were replicated four times in a randomized complete block design. Phosphorous (P) and potassium (K) fertilizers were applied at 90 and 60 kg/ha/year, respectively, in all the plots. For conventional N treatments, super phosphate and potassium chloride were used as sources of P and K, respectively. The yearly P and K were split into three applications, with one third applied before planting, followed by equal splits after each harvest. Similarly, the yearly N was applied in six equal splits at two monthly intervals and harrowed in manually. For organic N treatments, the yearly amount was applied in three splits, one portion before planting followed by equal splits after cutting back of the plants. Application of organic N treatments was designed to achieve comparable levels to conventional N and at the same time ensuring P and K levels of 90 and 60 kg/ha/year, respectively.

The experimental site had four blocks of 20 rows wide, with four rows per block assigned to each of the treatments. The four rows of each experimental plot were 5.6 m long, with a 1 m path between plots, which gave a total area of 22.5 m^2/plot.

Table I. Nitrogen (N), phosphorous (P) and potassium (K) content of the organic fertilizers used for the trial

N: P: K	N (g/kg)	P (g/kg)	K (g/kg)
7:2:2 (11)	70	20	20
2:3:2 (16)	46	69	46
3:1:5 (18)	60	20	100
4:1:1 (15)	100	25	25

From the four rows per treatment, the two center rows were used for measurement of fresh herbage and essential oil yield and oil composition analysis, while the two rows on either side were used as borders to reduce treatment overlap. Healthy and rooted cuttings (45 days old) of rose geranium were planted in the experimental plots on January 29, 2004, at a spacing of 0.625 m between plants and 1 m between rows, which gave a total of 16,000 plants/ha. Rainfall was supplemented with drip irrigation and prior to irrigation, soil water content was measured to a depth of 60 cm using a neutron probe (Neutron water meter, Model 503 DR, CPN Corporation, CA, USA) on a weekly basis.

At each harvest, fresh herbage yield, oil yield and oil composition were determined. The crop was harvested at four-monthly intervals. For the first harvest the growth period was from February to May (summer/autumn) and for the second harvest from September to December (spring/summer). Plants were cut to a height of 20-25 cm above ground level and herbage yield per hectare was computed. Oil content of the foliage (a sub sample of 10 kg from each treatment) was determined by steam distillation using a custom-made unit. The total essential oil yield per hectare was computed per treatment according to the oil content and harvested area. The oil samples were analyzed by gas chromatography (GC). For GC analysis, an Agilent GC (FID) model 6890N fitted with 30 m x 0.25 mm DB-5 fused silica capillary column and film thickness of 0.25 µm was used, with helium as carrier gas. The temperature programming was 50°-200°C, with ramp amount of 5°C/min and with detector and injector temperatures of 220°C. The compounds were identified by comparing their retention times and rentention indices (8) to standard values. After each harvest, soil samples were taken for N, P and K analysis and based on this, nutrients used by plants and lost via leaching and volatilization were replaced so that the re-growth was started with the same amount of nutrients as for the previous harvest. Standard cultivation and plant protection practices were followed to control weeds, insects and diseases during the experimental period. Statistical analysis and interpretations were based on comparison of treatment means as well as comparison between cumulative harvests. The collected data were subjected to analysis of variance (ANOVA) and analysis was carried out using the SAS package (10).

Results and Discussion

Herbage and essential oil yields: The statistically analyzed data showed that application of conventional N had no significant effect on fresh herbage and essential oil yields of rose-scented geranium compared to the control for the first harvest (summer/autumn) (Table II). However, application of organic N at 100 kg/ha increased fresh herbage and oil yields by 57.5% and 47.9% compared to the control, respectively. The lack of response of the plant to the applied conventional N could be due to leaching of N by heavy rainfall that occurred during this growing cycle (Figure 1).

In the second harvest, application of N from both sources (conventional and organic) increased fresh herbage as well as oil yield (Table II). The increases in fresh herbage yield over the control due to conventional and organic N at 100 kg/ha were 46.3% and 60.3%, respectively. The 100 kg/ha level of N also increased oil yield by 93.6% and 129.4% over the control for conventional and organic N, respectively.

Increasing N level beyond 100 kg/ha with both N sources (conventional or organic) did not contribute to further significant increases in the fresh herbage yields for either harvests or the cumulative yields over the two harvests (Table II). For oil yield, further N increments provided no advantage for the first harvest. For the second harvest, further positive responses to increased N levels above 100 kg/ha were observed, with a significantly higher oil yield at 300 kg/ha organic N.

Rajeswara Rao et al. (2) also reported an increase of 19.1% in fresh herbage yield and 24.1% in oil yield at 100 kg/ha N, but no response with higher N levels. However, Prakasa Rao et al. (3) reported an increment in fresh herbage and oil yield of geranium with each increment of applied N. Similarly, in India, application of 200 kg/ha N increased fresh herbage and oil yield over no N and 100 kg/ha N (6,7).

The average effect of all levels of organic N was compared to the average effect of all levels of conventional N. In all instances, organic N produced higher herbage and oil yields (Table II).

Interaction between nitrogen amount and source: For the second harvest, there was a significant ($p \leq 0.05$) interaction between amount and source of N for oil yield (Figure 2). This implies that oil yield responded differently to an increase in N levels for the two sources of N. As organic N increased, oil yield increased, while it did not alter significantly when conventional N increased. Application of 300 kg/ha in the form of organic N increased the oil yield by 180.7% compared to the control and by 22.4% compared to 100 kg/ha organic N (Table II; Figure 2).

Scheffer et al. (4) also reported that application of organic fertilizer (composed of cattle manure + straw) significantly increased the oil yield of *Achillea millefolium* L. The positive response of the plant to organic N could be due to the nature of organic fertilizers in improving soil structure, water holding capacity and soil microbial activity (1,9). Furthermore, the possibility of lower N loss through leaching and their slow nutrient releasing nature compared to conventional fertilizers may be the reason for increased herbage and oil yield.

Oil composition: There were significant differences in the composition of the oil with amount and source of N (Table

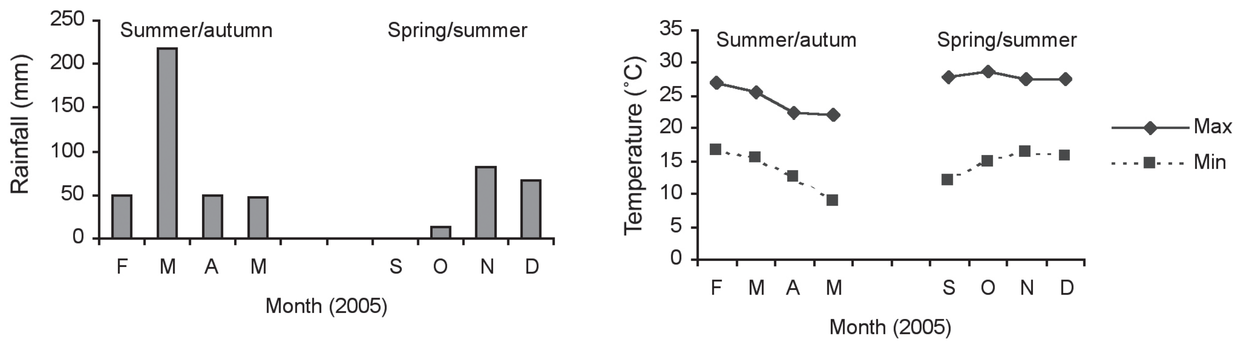

Figure 1. Rainfall (mm) and maximum and minimum temperatures (°C) during the experimental period, for the first (summer/autumn) and second harvests (spring/summer)

Table II. Influence of amount and source of N on fresh herbage (t/ha) and essential oil yield (kg/ha) of rose-scented geranium

Source of N	Treatments	Herbage yield (t/ha)			Oil yield (kg/ha)		
		Harvest			Harvest		
	N (kg/ha/year)	1	2	Total	1	2	Total
Control	0	14.83	20.91	35.74	7.27	13.59	20.86
Conventional	100	15.63	30.59	46.22	9.53	26.31	35.84
	200	17.00	32.54	49.54	7.99	27.01	35.00
	300	16.43	30.80	47.23	7.88	21.25	29.13
Organic	100	23.36	33.52	56.88	10.90	31.17	41.92
	200	23.78	35.23	59.01	11.89	32.76	44.65
	300	23.80	41.48	65.28	10.95	38.15	49.10
LSD (α =0.05)		6.08	7.96	9.72	2.45	6.82	7.22
Conventional (over all N levels)		16.35	31.31	47.66	8.47	24.86	33.33
Organic (over all N levels)		23.65	36.74	60.38	11.20	34.03	45.23
LSD (α = 0.05)		2.88	4.56	5.21	1.48	4.07	4.18

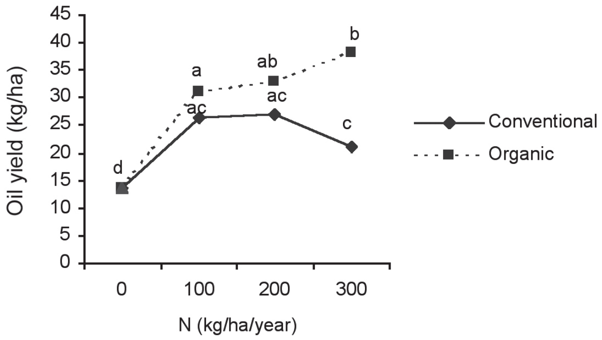

Figure 2. Interaction of amount and source of N on essential oil yield of rose-scented geranium

III). The citronellol percentage increased with an increase in levels of N for both sources, and was higher with organic than conventional N in the first harvest, for all levels of N. In the second harvest, application of conventional N and 100 kg/ha organic N had no significant effect compared to the control, while further application of organic N increased the citronellol percentage, with the highest at 300 kg/ha. Application of conventional N in both harvests had no significant effect on geraniol percentage compared to the control. Except for the 100 kg/ha level, organic N did not significantly influence the geraniol percentage either. Ram et al. (5) indicated that the citronellol content of geranium increased with increasing conventional N up to 160 kg/ha, while geraniol content was decreased.

In the first harvest, conventional N up to 200 kg/ha had no significant effect on guaia-6,9-diene percentage, compared to the control. Further application (300 kg/ha N) reduced the guaia-6,9-diene percentage. All levels of organic N also lowered the guaia-6,9-diene percentage, compared to the control. In the second harvest, the guaia-6,9-diene percentage was not significantly influenced by either source or level of N.

Results of this study revealed a general trend that increased application of N increased herbage and oil yield. This effect was more pronounced for organic N than conventional N in both harvests, including cumulative yields. This shows that rose-scented geranium has preference to the source of N (conventional or organic) in herbage and oil yield production. On the other hand, increased N showed a tendency to increase the citronellol levels, particularly in the autumn months and to decrease guaia-6,9-diene. This trend may, for certain commercial applications, negate the benefit of increased yield with increased N application.

Acknowledgments

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Table III. Change in concentration of major constituents of rose-scented geranium essential oil as influenced by amount and source of N in the first (summer/autumn) and second (spring/summer) harvests

Source of N	N (kg/ha)	Linalool	Iso-menthone	Citronellol	Geraniol	Citronelly formate	Geranyl formate	Guaia-6,9-diene
		First harvest (%)						
Control	0	0.27	4.04	25.40	6.98	16.12	5.71	9.64
Conventional	100	0.27	4.46	25.83	7.74	16.36	6.01	9.43
	200	0.30	3.17	26.78	7.62	17.13	6.29	8.82
	300	0.54	3.68	29.23	8.66	17.88	6.79	6.53
Organic	100	0.74	3.19	31.13	8.81	20.68	9.99	5.30
	200	0.59	2.42	36.66	5.36	23.62	8.13	4.52
	300	0.89	2.97	35.89	7.98	22.99	9.40	4.39
LSD (α = 0.05)		0.17	NS	1.67	1.75	1.75	1.75	1.75
		Second harvest (%)						
Control	0	0.55	1.75	30.02	10.68	19.54	6.18	6.51
Conventional	100	0.57	4.28	30.16	11.83	18.88	6.33	6.61
	200	0.49	3.55	29.50	12.53	18.52	6.59	6.23
	300	0.82	3.27	28.90	10.44	20.02	6.51	6.89
Organic	100	0.84	4.05	30.52	12.90	18.15	6.92	5.95
	200	0.66	0.25	31.89	11.25	19.99	6.88	6.57
	300	0.76	3.37	32.18	11.20	19.05	6.55	6.31
LSD (α = 0.05)		0.18	1.62	1.75	NS	NS	NS	NS

NS = non significant at $p \leq 0.05$

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