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Influence of soil water management on plant growth, essential oil yield and oil composition of rose-scented geranium (*Pelargonium* spp.)

by

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A	Plot area
ASW	Available soil water
cv.	Cultivar
D	Water deep percolation
DM	Dry mass
ET	Evapotranspiration
FAO	Food and Agricultural Organization of the United Nations (Rome, Italy)
FM	Fresh mass
GC	Gas chromatography
G:C ratio	Geraniol to citronellol ratio
G_s	Stomatal conductance
H_{LA}	Harvested land area
I	Irritation water applied
IW:CPE ratio	Irrigation water to cumulative pan evaporation ratio
ℓ	Litre
LAI	Leaf area index
LA (LA)	Leaf area
MAD	Maximum allowable depletion
n	Number of soil layers
P	Rainfall (precipitation)
PRD	Partial root zone drying
R	Water runoff
R_A	Neutron probe reading in air
R_S	Neutron probe reading in soil
R_t	Transpiration rate
RWC	Relative water content
R_z	Plant root zone
SANDA	South African National Department of Agriculture
SFE	Supper fluid extraction
S_1	Initial soil water content of a cropping season (regrowth period)
S_2	Final soil water content of a cropping season (regrowth period)

THRIP	Technology and Human Resources for Industry Programme (South Africa)
UIDEA	Uganda's Investment in Developing Export Agriculture (Uganda)
V_I	Volume of irrigation water
WUE	Water use efficiency
θ_d	Depleted water
θ_{FCi}	Volumetric soil water content at field capacity
θ_i	Measured volumetric soil water content
θ_{PWPi}	Volumetric soil water content at plant permanent wilting point
ψ_W	Water potential

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INFLUENCE OF SOIL WATER MANAGEMENT ON PLANT GROWTH, ESSENTIAL OIL YIELD AND OIL COMPOSITION OF ROSE-SCENTED GERANIUM (*PELARGONIUM* SPP.)

by

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ABSTRACT

Introducing effective irrigation management in arid and semi-arid regions, like most areas of South Africa, is an indispensable way of maximising crop yield and enhancing productivity of scarce freshwater resources. Holistic improvements in agricultural water management could be realised through integrating the knowledge of crop-specific water requirements. In order to develop effective irrigation schedules for rose-scented geranium (Pelargonium *capitatum* x *P. radens*), greenhouse and field experiments were conducted at the Hatfield Experimental Farm of the University of Pretoria, Pretoria, South Africa, from 28 October 2004 to 2006.

Results from 20, 40, 60 and 80% maximum allowable depletion (MAD) levels of the plant available soil water (ASW) indicated that plant roots extracted most of the soil water from the top 40 cm soil layer, independent of the treatment. Both essential oil yield and fresh herbage mass responded positively to high soil water content. Increasing the MAD level to 60% and higher resulted in a significant reduction in herbage mass and essential oil yields. An increase in the degree of water stress apparently increased the essential oil concentration (percentage oil on fresh herbage mass basis), but its contribution to total essential oil yield (kg/ha oil) was limited. There was no significant relationship between MAD level and essential oil composition. For water saving without a significant reduction in essential oil yield of rose-scented geranium, a MAD of 40% of ASW is proposed.

Response of rose-scented geranium to a one-month irrigation withholding period in the second or third month of regrowth cycles showed that herbage mass and oil yield were positively related. Herbage yield was significantly reduced when the water stress period was imposed during the third or fourth month of regrowth. A remarkable essential oil yield loss was observed only when the plants were stressed during the fourth month of regrowth. Essential oil content (% oil on fresh herbage mass basis) was higher in stressed plants, especially when stressed late, but oil yield dropped due to lower herbage mass. The relationship between essential oil composition and irrigation treatments was not consistent. Water-use efficiency was not significantly affected by withholding irrigation in the second or in the third month of regrowth. With a marginal oil yield loss, about 330 to 460 m^3 of water per hectare per regrowth cycle could be saved by withholding irrigation during the third month of regrowth. The overall results highlighted that in water-scarce regions withholding irrigation during either the second or the third month of regrowth in rose-scented geranium could save water that could be used by other sectors of society.

In greenhouse pot experiments, rose-scented geranium was grown under different irrigation frequencies, in two growth media. Irrigation was withheld on 50% of the plants (in each plot) for the week prior to harvesting. Herbage and essential oil yields were better in the sandy clay soil than in silica sand. Essential oil content (% oil on fresh herbage mass basis) apparently increased with a decrease in irrigation frequency. Both herbage and total essential oil yields positively responded to frequent irrigation. A one-week stress period prior to harvesting significantly increased essential oil content and total essential oil yield. Hence, the highest essential oil yield was obtained from a combination of high irrigation frequency and a one-week irrigation-withholding period. In the irrigation frequency treatments, citronellol and citronellyl formate contents tended to increase with an increase in the stress level, but the reverse was true for geraniol and geranyl formate.

Leaf physiological data were recorded during the terminal one-week water stress in the glasshouse pot trial. Upon rewatering, stomatal conductance (G_s) and transpiration rate (R_t) were significantly lower in the less often irrigated than in the more often irrigated treatments, while leaf water potential (ψ_w) and relative water content (RWC) were the same for all plants, indicating that water stress had an after-effect on G_s and R_t. At the end of the stress period, G_s, R_t,

ψ_w and RWC were lower in the plants from the more often irrigated than from the less often irrigated treatments. Irrespective of irrigation treatment, one type of non-glandular and two types (different in shape and size) of glandular trichomes were observed. In water stressed-conditions, stomata and trichome densities increased, while the total number of stomata and trichomes per leaf appeared to remain more or less the same. Water stress conditions resulted in stomatal closure.

Keywords: Citronellol; citronellyl formate; essential oil content; geraniol; geranyl formate; herbage yield; irrigation-withholding period; maximum allowable depletion level; relative water content; stomatal conductance; transpiration rate; trichomes; water potential; water stress; water use; water-use efficiency