Determination of mineral element content of *Pelargonium roseum* plant by ICP-MS

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Abstract

Microelement content of different vegetative parts of *Pelargonium roseum* was evaluated by inductively coupled plasma – mass spectrometry (ICP-MS) technique. The analytical method allowed the determination of 20 elements (Li, Be, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Se, Rb, Sr, Ag, Cd, In, Ba, Ti, Pb, Bi). Samples from different vegetative parts (roots, lignified stems, green stalks, leafs, blooms) were analyzed and compared with soil samples. The vegetative part of the plant contained significant quantities of manganese, zinc and especially iron. The results can be very useful for the determination of the recommended doses of plant products for use in medicinal plant products considering its nutritional content and pharmacological functions.

Keywords: *Pelargonium roseum*, Microelemental analysis, ICP-MS, Dietary supplements

Introduction

*Pelargonium roseum* is a species of aromatic hairy herbaceous shrub indigenous to Southern Africa belonging to the Geraniaceae family, which was introduced and nowadays is highly cultivated in the Mediterranean part of Europe, Northern Africa and Central America. Sometimes this herb is also called *Pelargonium graveolens*, but despite the double name, it is the same herb - *Rose geranium*. It is called *Rose Geranium*, because this plant has both the characteristics in itself - Rose, because of the scent when it blooms and Geranium, because it is from the same genus as the common Geraniums (*Geraniaceae*) (Lis-Balchin et al., 1996).

*Pelargonium roseum* has a woody, straight stem with branches; its leaves are usually alternate, palmate lobed or pinnate, often on long stalks, and sometimes with light or dark pattern; covered with short, rough hairs, which give the plant a strong, pleasant rose-like scent. The erect stems bear five-petaled flowers in umbel-like clusters; the flower has a single symmetry plane (zygomorphic), which distinguishes it from the Geranium flower, which has radial symmetry (actinomorphic). It is an annual plant, but when dwarfed and domesticated it becomes perennial. Roots grow up to 60 cm in soil, fresh leaves grow in the whole year if the temperatures are not too low and its flowers
blooms actively between June and October (Fig. 1) (Lan-
cu et al., 2013).

It is cultivated mainly by the perfume industry and for
aromatherapy and there are subspecies with various other
scents. Calming and grounding, Pelargonium roseum es-
ternal oil helps to reduce feelings of stress and worry; it’s
balancing effect on the body and mind makes this oil an
excellent choice to uplift the mood and promote feelings
of well being (Dorman and Deans, 2000; Moyo and van
Staden, 2014).

Essential oil of Pelargonium roseum is used in herbal
medicine for its astringent and chemostatic effect, also
it regulates the bloodstream, stimulates the adrenal glands
and lymphatic system which in combination with its di-
uretic properties makes this essential oil excellent in the
fight against cellulite and fluid retention in the body (Cavar
and Maksimovic, 2012; Dzamic et al., 2014).

The antiseptic, antimicrobial and antifungal properties
of Pelargonium roseum essential oil were also assessed
and evaluated, with encouraging results, when compared
with the effects of different largely used antimicrobial sub-
stances (Baratta et al., 1998; Dorman and Deans, 2000).

An interesting study evaluated the potential of Pelar-
gonium roseum, to uptake and accumulate heavy metals
like nickel (Ni), cadmium (Cd) or lead (Pb); the metal con-
tent in the extracts from the entire biomass of the plant was
estimated using a flame atomic absorption spectrophotom-
eter; the results of the study indicated the efficacy of this
plant for decontamination of multiple metal-polluted sites
in phytoremediation industry (Mahdieh et al., 2013).

However there are no studies regarding the mineral el-
ement content of different parts of the plant. The aim of the
present study was to analyze traces of elements in different
parts of the plant (roots, stalks, leaves and flowers), with
the purpose of demonstrating the potential for a possible
use of this plant in nutritional supplements.

Material and methods

Plant material cultivation and harvesting

Cultivation of Pelargonium roseum species was carried
out in the herb garden of the University of Medicine and
Pharmacy from Tîrgu Mureș, Romania, on a total area
of 200 m². The harvest of the aerial parts was performed
in 3 stages; in July we harvested the ramifications of stalks
with 3-5 leaves, in August the ramifications of well-devel-
oped stalks and the third harvest was made at the end of the
vegetation period, in September. The roots were harvest-
ed at the beginning of October. Throughout the cultivation
period no herbicides or chemical fertilizers were used, be-
cause we wanted to preserve unspoiled the qualities of the
essential oils obtained subsequently.

From the harvested stalks and leaves, a part was dried
in order to prepare infusions and for physical and chemi-
cal determinations, and another was subject to distillation
in order to obtain essential oil.

Samples from roots, lignified stems, green stalks, leaves
and blooms were analyzed and the results were compared
with the ones obtained from soil samples. The soil samples
were taken from the cultivation zone.

Fig. 1. Pelargonium roseum.
Reagents

The mineral content of the plant was determined using an ICP-MS method. The technique can be used primarily for the positive ions detection. The elements whose concentration was studied were: lithium (Li), beryllium (Be), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), gallium (Ga), selenium (Se), rubidium (Rb), strontium (Sr), silver (Ag), cadmium (Cd), indium (In), barium (Ba), thallium (Tl), lead (Pb) and bismuth (Bi).

All reagents used for the microwave-assisted digestions: hydrochloric acid (HCl 36% (v/v)), nitric acid (HNO₃ 69% (v/v)) and hydrogen peroxide (H₂O₂ 33% (v/v)) (Merck, Darmstadt, Germany), were of analytical grade. High-purity water (18MΩcm) obtained with a NANOpur water purification system (Barnstead D4745, Thermolyne, USA) was used for standard preparation and sample dilution. Before use, all lab utensils were thoroughly acid cleaned and then rinsed with ultrapure water. All Teflon digestion vessels were previously cleaned in a bath with 10% (v/v) nitric solution for 24h, and then were rinsed with nanopure water, to avoid cross-contamination.

Sample preparation

The green mass subject to ICP determinations was processed by wet digestion method. The dried samples were grounded with a Mixer Grinder, and all the samples were originally stored in closed plastics bags until analysis. Samples of plant material were weighed (0.3 - 0.4 g / sample), introduced in teflon vessels and treated with nitric acid (4 mL), hydrochloric acid (0.25 mL) and hydrogen peroxide (1 mL). The vessels were then covered and left standing 24 hours under a hood, for the full decomposition of the plant material. After that the vessels were introduced in a microwave digestion apparatus for 30 minutes, where mineralization was performed in conditions of high pressure and temperature. The vessels were cooled for one hour and opened in order to evacuate the nitrogen oxides. The solutions obtained through this process were transferred in calibrated tubes and filled with nanopure water to 15 mL. A further dilution (1:10) was made in order to obtain the final samples analyzed by ICP-MS.

ICP-MS analysis

Analysis of the samples was carried out using an ICP-MS Ultramass 700 Varian system, with glass concentric nebulizer and quadropel detection. Argon (purity higher than 99.995%) (Siad SRL, Cluj-Napoca, Romania) was used as plasma and carrier gas.

A multi-elemental ICP standard solution XXI Certi Pur (Merck, Darmstadt, Germany), containing all the analyzed elements was used for calibration. The external calibration solutions including known concentrations of each target analyte, were prepared by diluting the stock multi-element standard solution in nanopure water containing 1% nitric acid. A blank solution consisting in nanopure water containing 1% nitric acid was used for the calibration curve. The nonspectral matrix effects associated to the ICP-MS measurements were resolved by the addition of internal standards to all of the used solutions (blank, calibration and sample). The standard solution was prepared by diluting single elemental stock solutions with nanopure water containing 1% nitric acid and up to 50 μg/L rhodium, terbium, yttrium and scandium. The calibration coefficients for all calibration curves were at least 0.999.

The isotopes used in this study were the following: Li-7, Be-9, Cr-52, Mn-55, Fe-57, Co-65, Zn-66, Ga-71, Se-78, Rb-85, Sr-88, Ag-107, Cd-111, In-115, Ba-137, Tl-205, Bi-209. The isotopes were chosen after careful evaluation of all possible isotopes, their abundances, potential interferences (meaningful in the analysis of plants) and the appropriate corrections were introduced.

The samples used for the trace element determination were prepared as follows: 1 mL solution obtained by wet digestion was filled with 8.70 mL of nanopure water and 0.1 mL internal standard (rhodium 4 μg/l and 0.2 mL isopropanol), thus obtaining a sample of 10 mL. This sample solution was introduced in the apparatus using a peristaltic pump, and brought in the form of aerosol by an argon plasma nebulizer.

Results and Discussion

The results of the microelemental analysis of the vegetative parts of the Pelargonium roseum plant are presented in Table 1.

The amounts of Li, Be, Cr, Co, Ga, Se, Ag, Cd, In, Tl, Bi were quantified in μg/kg while the amounts of Mn, Fe, Ni, Cu, Zn, Rh, Sr, Ba, Pb were quantified in mg/kg.

It is remarkable that the values obtained in the case of Fe analysis are significant; in green stalks Fe concentration was found to be 1.21 g/kg, whereas in leaves it was 0.66 g/kg (Fig. 2).

The Fe content is strongly influenced by pH and the redox potential of the environment, so that an alkaline soil favors Fe precipitation while an acidic soil determines its solubilization (Merian et al., 2008). The soil on which we cultivated Pelargonium roseum was a clayey soil with a pH of 7.63 and a Fe composition of 36.84 g/kg. The roots of the plant can be considered as Fe accumulator (11175 mg/kg) (Fig. 2).
Carmen Gâlea, Gabriel Hancu, Attila Csiszer, Csengele Monika Jeszenszky, Enikő Barabás

50 years, therefore vegetative parts of *Pelargonium roseum* can be a valuable source of Fe.

Amounts comparable with those found in the soil were found for Sr; as the roots contained a quantity of Sr (74.1 mg/kg), which exceeded the quantity found in the soil (54.82 mg/kg) (Fig. 3).

Previous studies show a correlation between the ratio of Sr and Ca from plants, both elements being taken up from soil in similar proportions. Although Ca was not determined from the vegetative parts of the plant, being present over the concentration range on which the determination was made; traces of Ca have been found at a morphological examination of the plant when calcium oxalate crystals were revealed (especially in roots). To date there are no eloquent studies regarding the essentiality of Sr for plants, animals or people (Merian et al., 2008).

Mn plays an essential part in plant metabolism, its function being correlated with redox processes when changes its valence from Mn$^{2+}$ to Mn$^{4+}$. It plays an important role in the photosynthesis process, both as oxygen generator and participating in the electronic transport associated to this process (Merian et al., 2008).

The active role, which Mn plays in photosynthesis, explains its presence in high quantities in leaves (53.3 mg/kg); while the smaller quantities were identified in the stems (29.7 mg/kg), where the presence of chlorophyll is low-

Table 1. Microelement content of the vegetative parts of *Pelargonium roseum*

<table>
<thead>
<tr>
<th>Vegetative parts</th>
<th>Li</th>
<th>Be</th>
<th>Cr</th>
<th>Co</th>
<th>Ga</th>
<th>Se</th>
<th>Ag</th>
<th>Cd</th>
<th>In</th>
<th>Tl</th>
<th>Bi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roots</td>
<td>1073</td>
<td>59</td>
<td>5472</td>
<td>650</td>
<td>270</td>
<td>490</td>
<td>22</td>
<td>640</td>
<td>39</td>
<td>29</td>
<td>3</td>
</tr>
<tr>
<td>Lignified stems</td>
<td>59</td>
<td>36</td>
<td>744</td>
<td>221</td>
<td>31</td>
<td>-</td>
<td>17</td>
<td>199</td>
<td>2</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Green stalks</td>
<td>80</td>
<td>50</td>
<td>940</td>
<td>119</td>
<td>45</td>
<td>424</td>
<td>10</td>
<td>164</td>
<td>8</td>
<td>9</td>
<td>150</td>
</tr>
<tr>
<td>Leafs</td>
<td>267</td>
<td>25</td>
<td>1584</td>
<td>1232</td>
<td>79</td>
<td>-</td>
<td>98</td>
<td>8</td>
<td>23</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>Blooms</td>
<td>227</td>
<td>161</td>
<td>1974</td>
<td>493</td>
<td>96</td>
<td>4161</td>
<td>-</td>
<td>20</td>
<td>12</td>
<td>40</td>
<td>45</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vegetative parts</th>
<th>Mn</th>
<th>Fe</th>
<th>Ni</th>
<th>Cu</th>
<th>Zn</th>
<th>Rb</th>
<th>Sr</th>
<th>Ba</th>
<th>Pb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roots</td>
<td>40.8</td>
<td>1175.6</td>
<td>3.5</td>
<td>19.7</td>
<td>62.5</td>
<td>5.4</td>
<td>74.1</td>
<td>24.8</td>
<td>156.5</td>
</tr>
<tr>
<td>Lignified stems</td>
<td>29.7</td>
<td>314.7</td>
<td>1.1</td>
<td>6.2</td>
<td>74.6</td>
<td>2.5</td>
<td>30.8</td>
<td>11.7</td>
<td>1</td>
</tr>
<tr>
<td>Green stalks</td>
<td>39.4</td>
<td>1213.9</td>
<td>1.2</td>
<td>4.5</td>
<td>54.9</td>
<td>6</td>
<td>54.8</td>
<td>11.2</td>
<td>0.8</td>
</tr>
<tr>
<td>Leafs</td>
<td>53.3</td>
<td>606</td>
<td>2.1</td>
<td>4.8</td>
<td>31.5</td>
<td>3.2</td>
<td>40.2</td>
<td>16.1</td>
<td>5.5</td>
</tr>
<tr>
<td>Blooms</td>
<td>45.7</td>
<td>967.2</td>
<td>2.2</td>
<td>8.3</td>
<td>42.2</td>
<td>4.8</td>
<td>36.3</td>
<td>28.5</td>
<td>3</td>
</tr>
</tbody>
</table>

Fig. 2. Fe concentration in different vegetative parts of *Pelargonium roseum*. 

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Determination of mineral element content of *Pelargonium roseum* plant by ICP-MS

er (Fig. 4).

Mn plays an important role in human metabolism as constituent and activator of different enzymatic systems. The Mn daily need of the human body is between 2-5 mg/day, therefore vegetative parts of *Pelargonium roseum* can be a source of Mn.

Relatively high concentrations of Zn were found in the vegetative parts of the plant, the highest concentrations were found in stems (74.6 mg/kg) and roots (62.5 mg/kg) in comparison with the soil content (170 mg/kg) (Fig. 5).

Zn is considered an essential element for living organisms, entering in the composition of more than 300 enzyme and proteins, which take part in all major metabolic processes. The Zn daily needs of a human body is 4.6 mg/day for men and 3.8 mg/day for women, therefore *Pelargonium roseum* can be useful in completing the daily needs of Zn.

High quantities of Se were found in the blooms (4161 μg/kg) in comparison with soil (490 μg/kg) (Fig. 6). The Se content from soil is not direct proportional with its biodisponibility towards plants (Merian et al., 2008). Se is involved in various enzymatic mechanisms, having also a protective role against toxins and carcinogens from the environment. The Se daily needs of a human body is around 20 μg/day; excepting its blooms *Pelargonium roseum* contains relatively small amounts of Se; but it should be noted that Se biodisponibility in the case of

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Fig. 3. Sr concentration in different vegetative parts of *Pelargonium roseum*.

Fig. 4. Mn concentration in different vegetative parts of *Pelargonium roseum*.
plants is much higher to that of the nutritional supplements, which recommends medicinal plants usage in order to supplement the shortage of this element (Merian et al., 2008).

The content of Li, Rb, Be, Ba, Cr, Co, Ni, Cu, Cd, Pb, In, Tl in the vegetative parts of the plant were much lower than their content in the soil.

All concentrations were within the recommended daily allowance (RDA) limits. RDA, the average daily dietary intake level, is expected to be sufficient to meet the nutrient requirements of all healthy individuals (World Health Organization, 1991; World Health Organization, 1998).

Human dietary micronutrients are required by humans in very small amounts, including at least 14 trace elements (As, B, Cr, Cu, F, I, Fe, Mn, Mo, Ni, Se, Si, V, Zn). The recommended daily intake of the micronutrient trace elements is of the order of: mg per day for B, Cu, F, Fe, Mn, Zn and μg per day for As, Cr, I, Mo, Ni, Se, Si, V.

These results, therefore, would suggest that consumption of *Pelargonium roseum* powder can provide users with some of the essential minerals that the human body requires for optimum function.

**Conclusions**

The knowledge of the elemental composition of plants is important for a variety of scientific areas – plant physiology, agriculture, environmental monitoring, medicine or

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**Fig. 5.** Zn concentration in different vegetative parts of *Pelargonium roseum*.

**Fig. 6.** Se concentration in different vegetative parts of *Pelargonium roseum*.
pharmacy; as plants usually uptake nutrients and also toxic substances from soil, water and air.

Considering the results of our ICP-MS analysis *Pelargonium roseum* can be useful source of Mn, Zn and especially Fe. The ICP technique was well suited for the multi-elemental analysis of vegetable samples in order to ascertain the nutritional role of medicinal plants and the daily dietary intake.

Taking in consideration the high content of Fe of certain vegetative parts of *Pelargonium roseum*, and the fact that people’s need of Fe is not entirely satisfied through nourishment, *Pelargonium roseum* might be used in order to supplement Fe input.

Another advantage can be the fact that *Pelargonium roseum* is a plant rich in Fe and with reduced tannin content; consequently the biodisponibility of Fe is not impeded. All these aspects are arguments for a possible use of a capsule which contains powder obtained from this plant as a nutritional supplement in case of iron deficiency.

It must, however, be stated that, because plants may absorb elements from the soil and environment, some of which may be toxic to humans, plant nutrition, climate, and soil conditions and locations could also determine the elemental contents.

Our results are a contribution to a better valorization of this medicinal plant. However further studies will be worthwhile to be performed to confirm the safety of these potential products as dietary supplements, to characterize active principles, and assess toxicity by laboratory assays.

References


Flavour Frag. J. 13, 235-244.


Резиме

Определување на содржина на минерали во Pelargonium roseum со примена на ICP-MS

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Ключни зборови: Pelargonium roseum, анализа на микроелементи, ICP-MS, додатоци во исхрана

Содржината на микроелементите во различни вегетативни органи на Pelargonium roseum е испитувана со метод на индуктивно спрегната плазма - масена спектрометрија (ICP-MS). Аналитичкиот метод овозможи определување на 20 елементи (Li, Be, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Se, Rb, Sr, Ag, Cd, In, Ba, Tl, Pb, Bi). Примероците од различни вегетативни органи (корени, линџифицирани стебла, зелени стебленца, листови, пупки) се анализирани и споредени со примероци на почва. Вегетативните органи на растението содржат значителни количини на манган, зинк и особено железо. Добиените резултати можат да бидат мошне корисни за определување на препорачана доза на делови од растението (растителни органи) за употреба во медицински растителни производи со оглед на неговата нутритивна вредност и фармакошките функции.