Moldovan A *et al.* (2023)
Notulae Botanicae Horti Agrobotanici Cluj-Napoca
Volume 51, Issue 2, Article number 13173
DOI:10.15835/nbha51213173
Research Article

# The influence of fertilization on the morpho-decorative characteristics of geraniums (*Pelargonium zonale*)

Andreea MOLDOVAN[1], Antonia ODAGIU[2*], Ioana MOLDOVAN[1], Catalina DAN[1], Maria CANTOR[1*]

[1]*University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Horticulture and Business in Rural Development, 3-5 Mănăștur Way, 400372 Cluj-Napoca, Romania; andreea.moldovan@usamvcluj.ro; maria.cantor@usamvcluj.ro (*corresponding author); ioana.moldovan@usamvcluj.ro; catalina.dan@usamvcluj.ro*
[2]*University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Agriculture, 3-5 Mănăștur Way, 400372 Cluj-Napoca, Romania; antonia.odagiu@usamvcluj.ro (*corresponding author)*

## Abstract

Geraniums (pelargoniums or storksbills, officially named as *Pelargonium zonale* (L.) L'Hér. Ex Aiton) are appreciated worldwide due to their ornamental potential and versatility. The research was conducted to emphasize the evolution of morpho-decorative and qualitative traits of two geranium cultivars of high aesthetic value, namely 'Tango Salmon' (Montevideo) and 'Tango Dark Red', depending on two different fertilization, conventional-chemical fertilization, and unconventional scheme, with a homeopathic solution respectively. It is excessive repetitiveness and is not the case.) cultivar, unconventional fertilization scheme tested conducted to the best results regarding most morpho-decorative characters investigated (33.40 cm height, 21.10 leaves/plant, 34.75 flowers/inflorescence, 2.35% nitrogen, and 48.34 SPAD). For cultivar 'Tango Dark Red', the conventional fertilization conducted to the best results in terms of height (18.90 cm), stems/plant (5.90), leaves/plant (14.95), and flowers/inflorescence (37.55), while unconventional fertilization led to higher nitrogen accumulation (2.18%) and enhanced chlorophyll synthesis (47.08 SPAD). Between nitrogen and chlorophyll contents within geranium leaves, strong positive correlations were identified in 'Tango Salmon', and weak to moderate in 'Tango Dark Red' cultivar. Higher scores were attributed to aesthetic indicators for 'Tango Salomon' compared to 'Tango Dark Red'. The unconventional fertilization of geranium cultivars is an eco-friendly solution for enhancing their morpho-decorative characteristics.

***Keywords:*** aesthetic; correlation; nitrogen; pelargonium; predictor; score

## Introduction

The production of ornamental plants represents a horticultural sector in full development, which revel in appreciation within national and international profile markets. Its structure includes a wide range of products, from ornamental plants grown for leaves, to plants grown for flowers, both for cut flowers and potted, from nurseries, to greenhouse crops, etc. It is considered that the largest consumer market for ornamental plants is Europe, whereas the European countries with the largest commercial flow reported for this product category

*Received: 20 Apr 2023. Received in revised form: 10 Jun 2023. Accepted: 28 Jun 2023. Published online: 30 Jun 2023.*
From Volume 49, Issue 1, 2021, Notulae Botanicae Horti Agrobotanici Cluj-Napoca journal uses article numbers in place of the traditional method of continuous pagination through the volume. The journal will continue to appear quarterly, as before, with four annual numbers.

are Germany, Great Britain, France and Italy (Bonaguro *et al*., 2021). In contemporary society, flowers are a daily presence in human life, be it public or private moments and spaces (Toma and Petra, 2020).

Due to their ornamental qualities, geraniums represent a valuable commodity on the horticultural market. They are preferred as interior plants or balcony plants, with an ornamental impact for the exterior of buildings, and in addition to their decorative appearance and due to their good resistance to adverse environmental conditions, they are preferred as plants that are part of urban green areas (Norman *et al*., 2009; García-Sogo *et al*., 2012; Zawadzińska and Salachna, 2018; Schroeter-Zakrzewska *et al*., 2021).

The genus *Pelargonium* is one of the seven genera belonging to Geraniaceae family, namely *Geranium, Pelargonium, Erodium, Monsonia, Hypseocharis, Rhynchotheca* and *Sarcocaulon* (Marcussen and Meseguer, 2017). Most of the species belonging to the genus *Pelargonium* originate in the southern hemisphere, mainly in South Africa, with a weaker representation in Australia, East Africa and some islands, such as Saint Helena, Tristan de Cuhna (James, 2002; Blerot *et al.,* 2015;). The genus shows great variety, consisting of a considerable number of species, between 280 and 400, based on speciality literature (Marcussen and Meseguer, 2017; Hashemabadi *et al*., 2018; Aboksaria *et al*., 2018). *Pelargonium* flowers differ from those of other genera by having the upper two (posterior) petals differentiated from the lower three (anterior) petals. Also, the posterior sepal is modified in the way that it is fused with the pedicel differently from the others, forming the nectary tube. Among the subgenera of the genus *Pelargonium, Ciconium* is the most important in the ornamental plant market, mainly due to the species *Pelargonium zonale* (L.) L'Hér. Ex Aiton and *Pelargnonium inquinans* (L.) L'Hér. Ex Aiton (James, 2002; James, 2002; Blerot *et al*., 2015).

The different species of *Pelargonium* known have particular structures, from woody, to succulent or herbaceous. They can be annual or perennial plants, and some have tubers. All have petiolate, alternate, stalked leaves, that show a great variety in regard with size, colour, pubescence. *Pelargonium zonale* (L.) L'Hér Ex Aiton, syn. *Geranium zonale* L. and *P. hortorum* L.H. Bailey, also known as common geranium, is one of the most representative species of the genus (Cantor *et al*., 2021). This species of geraniums can be divided into several subspecies and depending on the basic constituent trait, they can even be dwarf or miniature. Also, geranium varieties belonging to *P. zonale* can be subdivided according to the colour of the leaves or the shape and colour of flowers (James, 2002).

In addition to the decorative role, geraniums represent an important horticultural product due to their potential in the cosmetic and pharmaceutical industries, through the volatile oil extracted from the flowers (Gauvin *et al*., 2004; Araya *et al*., 2006; Blerot *et al.,* 2015; Iancu *et al*., 2017), as well as its quality as antimicrobial agent (Andrade *et al.,* 2011; Hsouna *et al*., 2012), or a natural bio accumulator for heavy metals (Orroño and Lavado, 2009).

The concerns that have been registered globally regarding a clean production, by identifying "green", ecological solutions, for the agricultural sector in general, are also found in the horticultural sector of ornamental plants. According to the United Nations Environment Program (UNEP, 2006), clean production provides for the continuous application of a preventive environmental strategy integrated into productive processes, products and services, in order to increase overall efficiency and reduce risks, both for the anthropic consideration and for the environment. According to the mentioned document, clean production involves five main components that refer to: the conservation of raw materials, water and energy, the elimination of toxic and dangerous emissions and the reduction of waste (Bonaguro *et al.,* 2021).

The identification and/or improvement of the organic methods already put into practice, intended for the cultivation of ornamental plants, is now a continuous challenge for producers (Minuto *et al.,* 2005). In this context, one may note that a significant factor influencing the cost and the efficiency for growing flowers in pots, is the substrate. Peat is the main component of most substrates used for ornamental plants. The very high consumption of peat, to produce flowers in greenhouses, is a limiting factor and consequently, there is a growing interest in identifying a substitute for it, with similar properties, preferably from renewable sources (Bonaguro

*et al.,* 2021). In this respect, one may note that unconventional alternatives for peat replacing with compost in geranium greenhouse culture are currently proposed (Gong *et al*., 2018; Massa *et al*., 2018).

The application of homeopathic products, in accordance with the Homeopathic Pharmacopoeia guidelines established by Hahnemann in 1810 (Mukerji and Erns, 2022), contributed to introducing agro-ecological practices as an alternative to conventional agriculture (Andrade *et al.,* 2011). The homeopathic approach includes the disintegration of radiation and matter, without nuclear rupture, but through the mechanical action on smaller particles and the addition of inert substances with dynamic activity (Bonato, 2008). Agricultural homeopathy, also known as the application of homeopathy in agriculture and horticulture, presents an ecologically and economically sustainable approach that has the potential to decrease the reliance on chemicals in global farming practices. The homeopathy practices contribute to enhancing internal processes in plants, thereby optimizing their growth and development. Empirical evidence in various crops has scientifically validated the capability of homeopathic products to modify the physiological response of plants, increase foliage abundance, flowering, and enhance fruit yield (Mazón-Suástegui *et al.*, 2020). The use of the homeopathic method in plant production allows influencing the biological processes of plants, either to accelerate or to delay growth. Moreover, used as fertilizers directly promote increased production. In agriculture, homeopathic products are defined as remedies prepared from diseased tissue or disease products, but are not chemically characterized. They can be derived from products of animal, human or vegetable origin. They can be complex compounds, resulting from pathological secretions or excretions, infected tissues, or simple compounds, such as pure including corn. Additionally, other homeopathic treatments with Calcarea carbonica, Carbo vegetabilis, and Magnesia carbonica are recommended due to their potential to produce beneficial responses in plants (Mazón-Suástegui *et al.*, 2020). Thus, testing homeopathic products in ornamental plants production as growth promoters is a challenging opportunity.

Considering all these, the current research was conducted for testing conventional and unconventional fertilization strategies for obtaining improved morpho-decorative traits in two cultivars of geraniums, 'Tango Salmon' (Montevideo) and 'Tango Dark Red' respectively, considered as very decorative.

## Materials and Methods

*Experimental*

Experiments regarding the influence of fertilization upon morpho-decorative characteristics of *P. zonale* plants were carried out in the greenhouse of the Horticultural Research Institute of Transylvania (ICHAT), whereas the chemical analyses were carried out in the Environmental Quality Monitoring Laboratory of the Faculty of Agriculture, both within the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Experiments were organized in two successive years, 2019 and 2020 respectively, the plants being maintained in similar conditions, according to the same experimental scheme (green house temperature 18-21 °C, humidity 60-65%).

*Plant material*

The biological material was represented by two cultivars of *P. zonale* as follows: 'Tango Salmon' and 'Tango Dark Red', selected for the general appreciation of the decorative traits and their adaptability. The 'Tango Salmon' cultivar has an average height of 27 cm, slightly fragrant salmon-pink inflorescences at the ends of the stems, which appear for a long period, from late spring to early autumn (Figure 1). The palmate-round leaves are strong, remain green, with prominent brown stripes, throughout the year. The fruit is of no ornamental importance. The mature plant does not require special care. This plant grows very well in both full sun and partial shade conditions. It requires medium humidity conditions, but does not tolerate excess water. It is not picky about soil type or soil pH. It is extremely tolerant to urban pollution.

The cultivar 'Tango Dark Red' can grow to an average height of 20-30 cm, has dark red, slightly fragrant, large inflorescences (Figure 1). The flowering period lasts from late spring to early autumn. Its leaves are palmate-round, strong, and remain green with prominent brown stripes throughout the year. They are sensitive, mainly to the attack of *Botrytis cinarea* Pers. which produce the disease called 'grey rot' and *Puccinia pelagronii-zonalis* Doidge which causes the disease called 'leaf rust', especially when excessive nitrogen fertilization is applied.

**Figure 1.** 'Tango Salmon' (a) and 'Tango Dark Red' *Pelargonium* cultivars (b)

In each experimental year, the vegetal material was purchased (Syngenta Romania). After reception on 10 March each year, geranium cuttings with four fully grown leaves were placed in plastic pots with a capacity of 1.5 L each, and a diameter of 12 cm. Pindstrup peat was used as soil substrate.

*Fertilization*

Conventional fertilization was carried out with an approved product (15% N, 11% $P_2O_5$, 29% $K_2O$, 0.12% Fe, 0.06% Mn, 0.02% B, 0.015% Cu, 0.01% Mo, 0.015% Zn 15-11-29 + Trace Elements (TE)), being considered chemical fertilization. On the other hand, a mixture of homeopathic natural products known as Schuessler Salts was used for the unconventional foliar fertilization, as an alternative solution. The product was developed by Dr. Wilhelm Heinrich Schuessler, a German physician from the 19$^{th}$ century, who made a significant discovery regarding the health benefits of various mineral salts and developed a homeopathic approach to utilize these mineral salts, allowing for their assimilation by the body's cells. This approach is based on twelve fundamental remedies specifically formulated for biochemical treatments, namely: calcium fluoratum, calcium phosphate, iron phosphate, potassium chloride, potassium phosphate, potassium sulphate, magnesium phosphate, sodium chloride, sodium phosphate, sodium sulphate, silica, and calcium sulphate (Lennon and Rolfe, 2004). The salts were purchased from homeopathic pharmacies, as twelve separate liquid solutions. For applying the homeopathic treatment with Schuessler Salts, they were mixed in equal proportions previous each administration.

*Trial organization*

The research concerning the influence of the fertilization method (chemical and unconventional) on the morpho-decorative traits was organized as a bifactorial trial: factor 1, the geraniums' cultivar, with two graduations, 'Tango Salmon' and 'Tango Dark Red', while factor 2 was the fertilization method, with three graduations: unfertilized (control), conventional chemical fertilization, in a dose of 1-2 g/L weekly, by drip, and unconventional fertilization with the above mentioned mixture of homeopathic natural products (in a dose of 5 mL/L tap water). The foliar application was done weekly for all variants, for 12 weeks, from the moment of cuttings' plantation up to complete flowering (Figure 2).

After 12 weeks from cuttings plantation, when plants reached maturity, the following parameters were determined: plant height (cm), number of stems, number of leaves and number of flowers/inflorescences, the concentration of nitrogen (%) and chlorophyll (SPAD), which were determined from the leaf tissue of the plants. Total nitrogen was determined by the Kjeldahl method (Șara and Odagiu, 2005). The estimation of leaf chlorophyll concentration was performed using the non-destructive method with SPAD-502 device (Konica-Minolta, Tokyo, Japan); SPAD values were determined by measuring the ratio of light transmitted through the leaf at the UV wavelength 650 nm and the infrared wavelength 940 nm. All determinations were expressed as multi-year averages, for each variant.

In view of the aesthetic assessment, three parameters were considered, namely the vegetative growth, foliage compactness, and the general aspect. They were evaluated by assigning a score from 1 to 5, with the mention that the threshold value for commercialization was considered to be the one corresponding to the score of 3 (Brentari *et al.*, 2020) (Figure 2).

**Figure 2.** *P. zonale* plants analysed for aesthetic assessment

*Statistical analysis*

From the combination of the two factors (cultivar and fertilization treatments), six experimental variants were obtained, which were placed in randomized blocks, in three repetitions, with ten plants/repetition. The results were operated and expressed as means for the entire period of the investigation, in order to note the differences among the variants.

The IBM SPSS Statistics v.20 program for Windows was used to calculate the statistical parameters of interest corresponding to descriptive statistics (mean, standard error of the mean,), and the application of Least

Significant Differences analysis at 5% significance threshold (LSD5%). In order to determine the intensity of the interactions between the nitrogen content and chlorophyll determined from the leaf samples, the Pearson correlation coefficients and those of determination were calculated. The Pearson parametric test was chosen because the variability values (CV%) indicated the homogeneity of data and the representativeness of the means (Merce and Merce, 2009). The significance of differences was tested using Duncan test, using the XLSTAT program.

## Results and Discussion

For both geranium cultivars studied, the different fertilization schemes affected the morphological traits (Tables 1 and 2). The use of unconventional fertilization scheme led to the best results of the most important morphological traits, in regard with the decorative impact, analysed for 'Tango Salmon' cultivar: plants had 33.40 cm height and 34.75 flowers/inflorescence, respectively. The number of stems was close to conventional fertilization, both significantly above the control variant (7 and 7.07 compared with 5.7 stems/plant). Even more, the lack of fertilization (control scheme) depressed the development of the above-mentioned traits compared to both fertilization schemes, even if the variability within the investigated features was not consequential (Table 1). According to the obtained results for 'Tango Salmon' cultivar, one may note that differentiated fertilization led to significant differences in plant height and number of flowers within inflorescence. Concerning the number of stems and leaves, significant differences were reported only between control and both conventional and unconventional fertilized variants (Table 1).

**Table 1.** The development of distinct morphological traits of 'Tango Salmon' geranium variety, within different fertilization schemes

| Variant | Plant height (cm) | Number of stems | Number of leaves | Number of flowers/ inflorescences |
|---|---|---|---|---|
| Control | 25.24 ± 1.35 $^{a}$ | 5.70 ± 11.53 $^{a}$ | 16.50 ± 2.14 $^{a}$ | 26.80 ± 3.18 $^{a}$ |
| Conventional | 30.02 ± 1.18 $^{b}$ | 7.05 ± 0.94 $^{b}$ | 20.55 ± 1.79 $^{b}$ | 32.60 ± 2.55 $^{b}$ |
| Unconventional | 33.40 ± 1.38 $^{c}$ | 7.00 ± 0.97 $^{b}$ | 21.10 ± 1.79 $^{b}$ | 34.75 ± 2.83 $^{c}$ |
| Mean ± S.E. | 29.55 ± 0.021 | 6.58 ± 0.26 | 19.37 ± 0.021 | 31.38 ± 0.95 |
| F | 9.063* | 7.477* | 8.674* | 0.711$^{ns}$ |

Legend: The data are presented as mean values and standard error of the mean (mean ± S.E.). Different letters between means within different fertilization scheme denote significant differences (LSD test, $p<0.05$; F-Fisher coefficient).

Ribeiro *et al.* (2000) obtained similar results with those obtained in the present study for 'Tango Salmon' cultivar. When solid waste compost was administered for fertilizing potted geraniums, in concentration of 10%, they obtained 16.30 leaves/plant (compared to 16.50 reported in our study in control), while with a concentration of 20%, 23.80 leaves/plant were noted (compared to 21.10 reported in our study when unconventional fertilization was applied). The administration of 40% solid waste compost conducted to 4.30 stems/plant (compared to 5.70 reported in our study in control S1), and when administered a concentration of 10%, there were 7.80 stems/plant (compared to 7.05 reported in our study when conventional scheme was applied). Corresponding to 40% solid waste compost fertilization, they reported 24.6 flowers/inflorescence (compared to 26.80 reported in our study in control), and when administered 20%, 37.70 flowers/inflorescence were obtained (compared to 37.55 reported in our study when conventional fertilization was applied).

In 'Tango Dark Red' cultivar, the use of conventional fertilization scheme led to the best results for all morphological traits (18.90 cm height, 5.90 stems/plant, 14.95 leaves/plant, and 37.55 flowers/inflorescence), while the lack of fertilization (control scheme) determined the decrease of values to above-mentioned characters. Significant differences depending on fertilization, in regard with the number of flowers/inflorescences resulted when $LSD_{5\%}$ test was applied. For the plant height, the number of stems and

leaves, significant differences were reported only between control (unfertilized) and both conventional and unconventional fertilized variants (Table 2), while the number of flowers per inflorescence was superior and statistically assured for unconventional fertilization.

Gong *et al.* (2018) reported higher values for plant height compared to both geranium varieties analysed in the hereby study, framing the trait within 39.98-61.51 cm, when waste compost and vermicompost as peat substitutes were used as growing media. Álvarez-García *et al.* (2019) obtained as average plant height within 23.10-26.00 cm, when fish production waste water mixed with nutrient solutions in different concentrations were used as fertilizer, while Massa *et al.* (2019) obtained an average plant height within 24-31 cm using green compost for peat substitution. These height intervals emphasize lower means compared to those reported in the current investigation for 'Tango Salmon' (Montevideo), 25.24-33.40 cm, but superior compared to those obtained in 'Tango Dark Red' cultivar, 15.49-18.90 cm, respectively.

**Table 2.** The development of distinct morphological traits of 'Tango Dark Red' geranium variety, within different fertilization schemes

| Variant | Plant height (cm) | Number of stems | Number of leaves | Number of flowers/ inflorescences |
|---|---|---|---|---|
| Control | 15.49 ± 1.40 [a] | 4.55 ± 0.83 [a] | 11.80 ± 2.31 [a] | 28.85 ± 3.44 [a] |
| Conventional | 18.90 ± 1.66 [b] | 5.90 ± 1.12 [b] | 14.95 ± 2.56 [b] | 37.55 ± 3.62 [b] |
| Unconventional | 18.47 ± 1.36 [b] | 5.65 ± 1.04 [b] | 14.01 ± 2.63 [b] | 34.40 ± 2.91 [c] |
| Mean ± S.E. | 17.71 ± 0.021 | 5.37 ± 0.26 | 13.63 ± 0.021 | 33.60 ± 0.95 |
| F | 7.125* | 7.291* | 12.169** | 0.962[ns] |

Legend: The data are presented as mean values and standard error of the mean (mean ± S.E.). Different letters between means within different fertilization scheme denote significant differences (LSD test, $p<0.05$; F-Fisher coefficient).

Concerning the foliage, Álvarez-García *et al*. (2019) also reported averages framing within 24.80 – 30.80 leaves/plant, which emphasizes much higher values compared to those we reported in 'Tango Salmon' and 'Tango Dark Red' geranium cultivars. Schroeter-Zakrzewska *et al.* (2021) reported averages framing within 9.9 – 18.9 leaves/plant when they used compost from post-consumer wood for *P. zonale* cultivation.

Superior nitrogen valorisation and intensification of chlorophyll synthesis were reported analysing 'Tango Salmon' geranium cultivar cultivated under the proposed unconventional fertilization scheme, which is confirmed by the higher nitrogen mean (2.35%), accompanied by higher chlorophyll mean (48.34 SPAD) contents, compared to means corresponding to other experimental schemes. The same evolution was also observed in 'Tango Dark Red' cultivar, with highest nitrogen (2.18%), and chlorophyll (47.08 SPAD) mean contents corresponding to unconventional fertilization scheme (Table 3).

Analysing nitrogen and chlorophyll contents in both geranium cultivars, results that different fertilization strategies led to significant differences. Concerning chlorophyll content reported in 'Tango Salmon' and nitrogen content quantified in 'Tango Dark Red', significant differences were observed between control unfertilized on one hand, and both conventional and unconventional fertilized, on the other hand.

**Table 3.** Nitrogen (N) and chlorophyll content within the investigated geranium cultivars, when different fertilization schemes were used

| Variant | *P. zonale* cultivars | | | |
|---|---|---|---|---|
| | 'Tango Salmon' (Montevideo) | | 'Tango Dark Red' | |
| | N (% from dry matter) | Chlorophyll content (SPAD) | N (% from dry matter) | Chlorophyll content (SPAD) |
| Control | 1.02 ± 0.18 [a] | 35.24 ± 1.85 [a] | 0.93 ± 0.17 [a] | 34.28 ± 2.80 [a] |
| Conventional | 1.96 ± 0.14 [b] | 42.20 ± 1.09 [b] | 1.91 ± 0.17 [b] | 41.35 ± 1.29 [b] |
| Unconventional | 2.35 ± 0.15 [c] | 48.34 ± 0.79 [b] | 2.18 ± 0.27 [b] | 47.08 ± 1.38 [c] |
| Mean ± S.E. | 17.71 ± 0.021 | 5.37 ± 0.26 | 13.63 ± 0.021 | 33.60 ± 0.95 |
| F | 7.125* | 7.291* | 12.169** | 0.962[ns] |

Legend: The data are presented as mean values and standard error of the mean (mean ± S.E.). Different letters between means within different fertilization scheme denote significant differences (LSD test, $p<0.05$; F-Fisher coefficient).

Similar results were obtained by Conversa *et al.* (2015) in a study conducted on 'Pinnacle Dark Red' geranium cultivar. Using unconventional fertilization (with biochar), they obtained superior mean for nitrogen accumulation in leaves compared to the mean reported when conventional fertilization was applied (1.71% versus 1.63%). Massa *et al.* (2018), when conducted a trial with two different compost fertilization schemes, obtained a mean nitrogen bioaccumulation in foliar apparatus framing within 2.47% – 2.86%, which is slightly superior compared to the levels obtained in present research. Nevertheless, superior values concerning chlorophyll content (47.16 SPAD – 65.63 SPAD) compared to those reported in our research were emphasized by Brentari *et al.* (2020), in an experiment conducted on hydroponic culture of *P. zonale*.

It is well known that there is a linear relationship of different intensity between chlorophyll and nitrogen content in plant leaves, function of species, and/or culture management (Zanin and Sambo, 2006; Papasavvas *et al*., 2008; Bojović and Bojović, 2009; Güiza-Castillo *et al*., 2020). Studies in the field emphasize that the use of SPAD-meter may be considered as a useful approach for assessing nitrogen levels from plants' leaves (Balasubramanian *et al*., 1999; Duttarganvi *et al*., 2014; Saberioon *et al.*, 2014), which is the benefit of plant growth thereafter.

According to our study, strong simple and positive Pearson correlations were identified between nitrogen and chlorophyll contents of geranium leaves in 'Tango Salmon' cultivar, framing within R = 0.827 and R = 0.881, corresponding to control and conventionally fertilized variants (Figures 1A-1B) respectively. According to the values of the coefficient of determination, considering nitrogen independent variable, results that in the variant of control (unfertilized), 68.30% of variance in chlorophyll content is supposed to be predicted by nitrogen content in leaves, while 31.70% cannot be explained by the dependence described by the simple Pearson correlation. In conventionally fertilized variant, 77.60% of variance in chlorophyll content can be predicted by nitrogen content in leaves (Figures 3A-C). Wang *et al.* (2012b) reported coefficients of determinations of 0.861 and 0.950 in two geranium cultivars 'Horizon deep Red' and 'Horizon Tangerine' respectively, which were higher compared with those reported in the hereby research ($R^2$ = 0.683 – 0.776), while similar values were found by Wang *et al.* (2012a) in 'Rocky Mountain White' ($R^2$ = 0.629) and 'Rocky Mountain Dark Red' ($R^2$ = 0.672) cultivars.

Unlike the previous detailed geranium cultivar, in 'Tango Dark Red' moderate and weak simple positive Pearson correlations were identified between nitrogen and chlorophyll, which framed within R = 0.202 – 0.445, corresponding to unconventionally fertilized and control variants. Considering nitrogen independent variable, results that in control unfertilized 19.80% of variance in chlorophyll content was predicted by nitrogen content in leaves, while in unconventionally fertilized variant, only 4.10% of variance in chlorophyll content was predicted by nitrogen content in leaves (Figures 3D-1F). The correlations emphasized by the current research are weaker compared to those reported by Dunnet *et al.* (2015), who identified correlated

relationships between nitrogen and chlorophyll contents between 0.402-0.962, function of N fertilization rate in *Pelargonium* × *hortorum* L.H. Bailet planted in pots.

The aesthetic assessment emphasizes no significant differences (Duncan test, $p>0.05\%$) between scores corresponding to conventional and unconventional fertilization, whereas when compared to control (unfertilized), the differences were significant (Duncan test, $p<0.05\%$) for both geranium cultivars (Table 4).

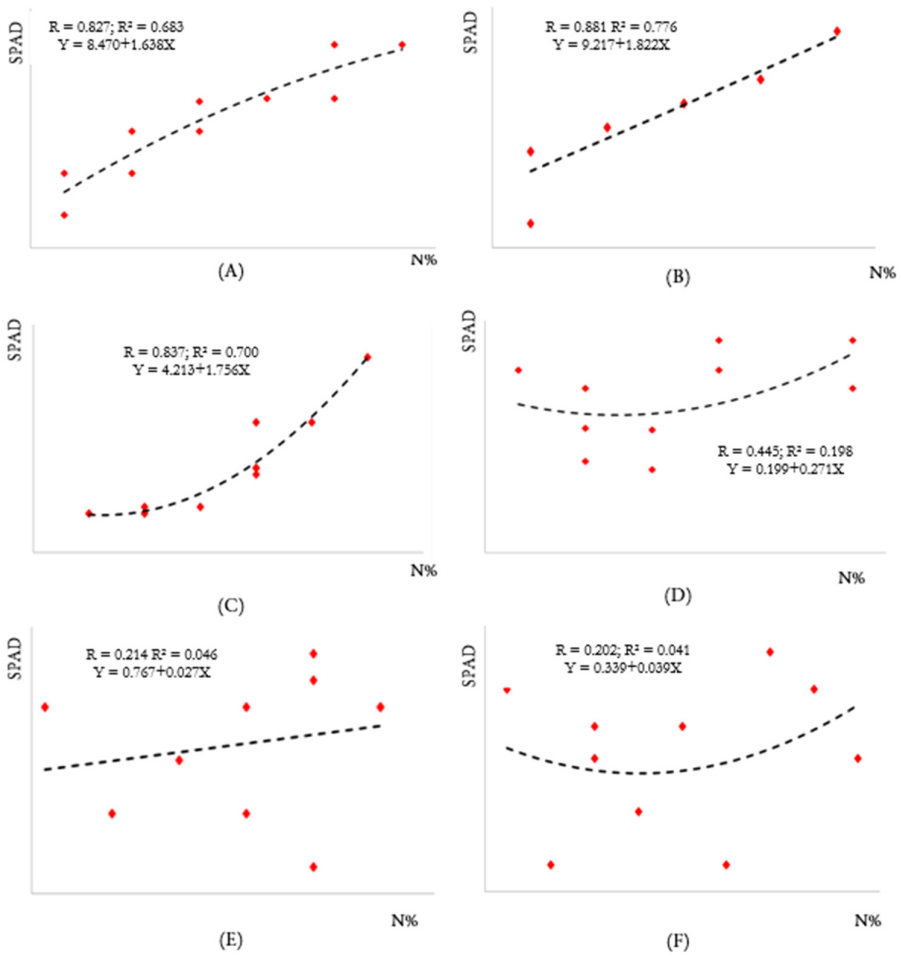


**Figure 3.** The correlations between nitrogen (%) and chlorophyll (SPAD units) contents in the leaves of geranium cultivars analysed when different fertilization schemes were used
(A) 'Tango Salmon' geranium cultivar, control; (B) 'Tango Salmon' geranium cultivar, conventional fertilization; (C) 'Tango Salmon' cultivar, unconventional fertilization; (D) 'Tango Dark Red' cultivar, control; (E) 'Tango Dark Red' cultivar, conventional fertilization; (F) 'Tango Dark Red' cultivar, unconventional fertilization

**Table 4.** Aesthetic assessment of *P. zonale* cultivars, when different fertilization schemes were used

| Treatment | *P. zonale* cultivar | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 'Tango Salmon' (Montevideo) | | | | 'Tango Dark Red' | | | |
| | AM | Vegetative growth | Foliage compactness | General aspect | AM | Vegetative growth | Foliage compactness | General aspect |
| Control | 3.3 [a] | 2.7 [a] | 3.6 [a] | 3.5 [a] | 3.1 [a] | 2.5 [a] | 3.5 [a] | 3.2 [a] |
| Conventional | 4.2 [b] | 4.1 [b] | 4.4 [b] | 4.2 [b] | 4.1 [b] | 3.9 [b] | 4.3 [b] | 4.1 [b] |
| Unconventional | 4.6 [b] | 4.3 [b] | 4.8 [b] | 4.7 [b] | 4.4 [b] | 4.2 [b] | 4.6 [b] | 4.5 [b] |

Legend: The data are presented as mean values and standard error of the mean (mean ± S.E.). Different letters between means within different fertilization scheme denote significant differences (LSD test, $p<0.05$; F-Fisher coefficient).

No significant differences (Duncan test, $p>0.05\%$) between aesthetic scores were attributed to the investigated geranium varieties cultivated according to different fertilization schemes (Figure 4).

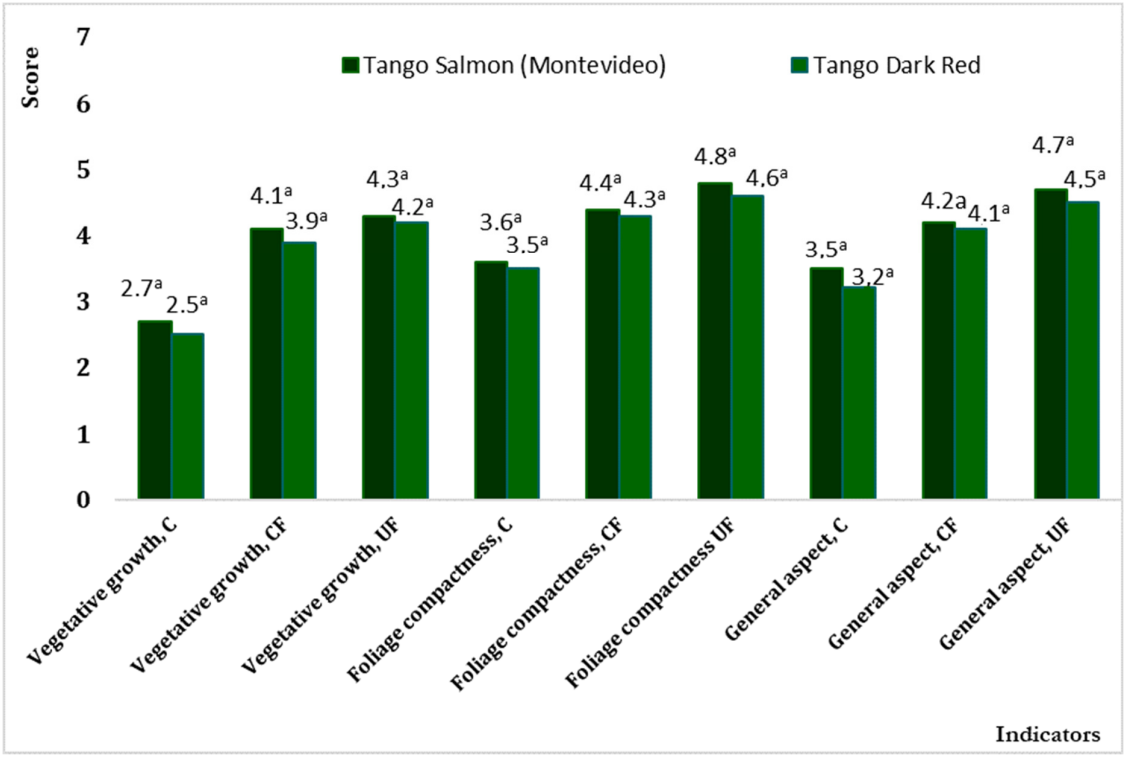


**Figure 4.** The comparative aesthetic assessment of geranium cultivars depending on different fertilization schemes; aesthetic scores were used (scale 0-7)
C-control; CF-conventional fertilization; UF- unconventional fertilization; the same letter between cultivars denotes not significant differences (Duncan test, $p>0.05$)

All aesthetic indicators valuable for commercialization, whatever fertilization scheme, received within the hereby investigation higher scores for 'Tango Salomon' compared to 'Tango Dark Red' geranium cultivar. In unfertilized plants of both geranium cultivars investigated, lower scores were reported, compared to those noted when fertilization schemes were applied. Nevertheless, the positive influence of both fertilization schemes on general aesthetic value of plants is worth considering. In the meantime, the results emphasize a more appropriate influence of the unconventional fertilization. Brentari *et al.* (2020) reported arithmetic means between the scores of the aesthetic indicators function of cultivation system, framing within 3.30-4.27,

when *P. zonale* plants were cultivated in three low-tech soil-less systems. Their interval of results was narrower compared to those reported in the current study in both analysed geranium varieties, 3.3-4.6 in 'Tango Salmon', and 3.1-4.4 in 'Tango Dark Red', respectively. If for geranium cultivars cultivated in current study higher maximum average score was reported, to 'Tango Dark Red' variety corresponds a lower arithmetic mean of 3.1 compared to that reported by Brentari *et al.* (2020), of 3.3, respectively. Thus, it can be said that ecological impact, cost correlation and the ease of supply or use of fertilization scheme can be taken into consideration for a sustainable cultivation of geraniums.

## Conclusions

The morpho-decorative characters of 'Tango Salomon' and 'Tango Dark Red' geranium varieties analysed differ significantly depending on the fertilization scheme applied. The unconventional fertilization approach conducted to better results concerning nitrogen assimilation, chlorophyll synthesis, and aesthetic traits in both geranium cultivars. The plants' height, number of stems/plants, leaves/plant, and flowers/inflorescence were all advantaged when using the unconventional fertilization scheme in 'Tango Salomon' geranium variety, while in 'Tango Dark Red' variety when conventional scheme was applied. 'Tango Salomon' variety was defined by better performances in terms of the majority of investigated traits, except the number of flowers/inflorescences. Better nitrogen valorisation and chlorophyll yield, strongly correlated, characterized 'Tango Salomon' geranium cultivar. The results emphasized in the hereby study is in accordance with those resulted from other research performed on different geranium varieties. According to the research, the use of unconventional solutions for fertilizing geranium has noticeable performances and represents a good option for replacing the conventional approach.

## Authors' Contributions

Conceptualization: AM and MC; Data curation: IM; Formal analysis: AO; Funding acquisition: AM; Investigation: AM and IM; Methodology: MC and AO; Project administration: AM; Resources: AM and IM; Software: AO; Supervision: MC and CD; Validation: MC; Visualization: AM and AO; Writing - original draft: AM; Writing - review and editing: AO and CD. All authors read and approved the final manuscript.

**Ethical approval** (for researches involving animals or humans)

Not applicable.

## Acknowledgements

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

## Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

## References


Aboksaria HA, Hashemabadib D, Kaviani B (2018). Application of bio-fertilizer for *Pelargonium peltatum* growth in new organic substrates, Journal of Plant Nutrition 41(2):137-149. *https://doi.org/10.1080/01904167.2017.1381733*

Álvarez-García M, Urrestarazu M, Guil-Guerrero JL, Jiménez-Becker S (2019). Effect of fertigation using fish production wastewater on *Pelargonium* × *zonale* growth and nutrient content. Agricultural Water management 223:105726. *https://doi.org/10.1016/j.agwat.2019.105726*

Andrade MA, Cardos MG, Batista LR, Freire JM, Nelson DL (2011). Antimicrobial activity and chemical composition of essential oil of *Pelargonium odoratissimum*. Revista Brasileira de Farmacognosia 21:47-52. *https://doi.org/10.1590/S0102-695X2011005000009*

Araya HT, Soundy P, Steyn JM, Teubes C, Learmonth RA, Mojela N (2006). Response of herbage yield, essential oil yield and composition of South African rose-scented geranium (*Pelargonium* sp.) to conventional and organic nitrogen. Journal of Essential Oil Research 18:111-115. *https://doi.org/10.1080/10412905.2006.12067130*

Balasubramanian V, Morales AC, Cruz RT, Abdulrachman S (1999). On farm adaptation of knowledge intensive nitrogen management technologies for rice system. Nutrient Cycling in Agroecosystems 53:59-69. *https://doi.org/10.1023/A;1009744605920*

Blerot B, Demarne F, Baudino S, Prunier C, Toulemonde B, Caissard JC (2015). Botany, agronomy and biotechnology of *Pelargonium* used for essential oil production. Phytochemistry Reviews. *https://doi.org/10.1007/s11101-015-9441-1*

Bojović B, Marković A (2009). Correlation between nitrogen and chlorophyll content in wheat (*Triticum aestivum* L.). Kragujevac Journal of Science 31:69-74.

Bonaguro Je, Coletto L, Sambo P, Nicoletto C, Zanin G (2021). Environmental analysis of sustainable production practices applied to cyclamen and zonal geranium. Horticulturae 7:8. *https://doi.org/10.3390/horticulturae7010008*

Brentari L, Michelon L, Gianquinto G, Orsini F, Zamboni F, Porro D (2020). Comparative study of three low-tech soilless systems for the cultivation of geranium (*Pelargonium zonale*): A commercial quality assessment. Agronomy 10:1430. *https://doi.org/10.3390/agronomy10091430*

Cantor M, Buta E, Buru T (2021). Cultura plantelor ornamentale în climat controlat [Cultivation of ornamental plants in controlled climate]. AcademicPres, Cluj-Napoca.

Conversa G, Bonasia A, Lazzizera C, Elia A (2015). Influence of biochair, mycorrhizal inoculation, and fertilizer rate on growth and flowering of pelargonium (*Pelargonium zonale* L.) plants. Frontiers in Plant Science 6:429. *https://doi.org/10.3389/fpls.2015.00429*

Domokos E, Janka B, Bálint J, Molnar K, Fazakas C, Farkas LJ, Domokos J, Albert C, Mara G, Balog A (2000). Arbuscular mycorrhizal fungus *Rhizophagus irregularis* influences *Artemisia annua* plant parameters and artemisinin content under different soil types and cultivation methods. Microorganisms 8:899. *https://doi.org/10.3390/microorganisms8060899*

Dunn BL, Shrestha A, Goad C (2015). Determining nitrogen fertility status using optical sensors in geranium with controlled release fertilizer. Journal of Applied Horticulture 17(1):7-11.

Duttarganvi S, Channabasavanna AS, Rao S, Halepyati AS (2014). Effect of LLC and SPAD based nitrogen management on growth and yield of lowland rice (*Oryza sativa* L.). Bioscan 9:663-665.

García-Sogo B, Pineda B, Roque E, Antón T, Atarés A, Borja M, Beltrán Jp, Moreno V, Cañas La (2012). Production of engineered long-life and male sterile *Pelargonium* plants. BMC Plant Biology 12:156. *https://doi.org/10.1186/1471-2229-12-156*

Gauvin A, Lecompte H, Smadja J (2004). Comparative investigations of the essential oils of two scented geranium (*Pelargonium* sp.) cultivars grown on Reunion Island. Flavour and Fragance Journal 19(5):455-460. *https://doi.org/10.1002/ffj.1354*

Gong X, Li S, Sun X, Wang L, Cai L, Zhang J, Wei L (2018). Green waste compost and vermicompost as peat substitutes in growing media for geranium (*Pelargonium zonale* L.) and calendula (*Calendula officinalis* L.). Scientia Horticulture 236:186-191. *https://doi.org/10.1016/j.scienta.2018.03.051*

Güiza-Castillo LL, Pinzón-Sandoval EH, Serrano-Cely PA, Cely-Reyes GE, Serrano-Agudelo PC (2020). Estimation and correlation of chlorophyll and nitrogen contents in *Psidium guajava* L. with destructive and non-destructive methods. Revista Colombiana de Ciencias Hortícolas 14(1):26-31. *https://doi.org/10.17584/rcch.2020v14i1.11341*

Hsouna AB, Hamdi N (2012). Phytochemical composition and antimicrobial activities of the essential oils and organic extracts from *Pelargonium graveolens* growing in Tunisia. Lipids Health and Disease 11:167. *https://doi.org/10.1186/1476-511X-11-167*

Iancu C, Cioanca O, Hancianu M, Mircea C (2017). Dried extracts and essential oils of some *Pelargonium* species: chemical and biological assessment. Indian Journal of Pharmaceutical Education and Research 3:421-4. *https://doi.org/10.5530/ijper.51.3s.60*

James J (2002). Cultivation and sales of *Pelargonium* plants for ornamental use in the UK and worldwide. In: Lis-Balchin (Ed). *Geranium* and *Pelargonium*, Medicinal and aromatic plants - industrial profiles. *https://doi.org/10.1201/9780203216538*

Lennon N, Rolfe L (2004). Homeopathic Cell Salt Remedies: Healing with Nature's 12 Mineral Compounds. Garden City Park, NY, Square One Publishers.

Marcussen and Meseguer (2017). Species-level phylogeny, fruit evolution and diversification history of *Geranium* (Geraniaceae). Molecular Phylogenetics and Evolution 110:134-149.

Massa D, Malorgio F, Lazzereschi S, Carmassi G, Prisa D (2018). Evaluation of two green composts for peat substitution in geranium (*Pelargonium zonale* L.) cultivation: Effect on plant growth, quality, nutrition, and photosynthesis. Scientia Horticulturae 228:213-221. *https://doi.org/10.1016/j.scientia.2017.10.025*

Manuel MSJ, Michel OSC, Milagro GB, Araceli AQM, Fernando AP, Daulemys BS, ... Boris BM (2019). Agricultural Homoeopathy: A New Insight into Organics. In: Multifunctionality and Impacts of Organic and Conventional Agriculture. Moudrý J, Ferreira Mendes K, Bernas J, da Silva Teixeira R, de Sousa RN (Eds). IntechOpen. *https://doi.org/10.5772/intechopen.84482*

Merce E, Merce C (2009). Statistică – paradigme consacrate și paradigme întregitoare [Statistics – consecreted paradigms and fulfilling paradigms]. AcademicPres, Cluj-Napoca.

Minuto A, Grasso V, Gullino Ml, Garibaldi A (2005). A chemical, non-chemical and biological control of *Phytophthora cryptogea* on soilless-grown Gerbera. Acta Hortiulturae 698:153-158. *https://doi.org/10.17660/ActaHortic.2005.698.20*

Mukerji N, Ernst E (2022). Why homeopathy is pseudoscience. Synthese 200:394. *https://doi.org/10.1007/s11229-022-03882-w*

Norman Dj, Huang Q, Yuen Jm, Mangravita-Novo A, Byrne D (2009). Susceptibility of geranium cultivars to *Ralstonia solanacearum*. HortScience 44:1504-1508. *http://dx.doi.org/10.21273/HORTSCI.44.5.1504*

Orroño D, Lavado RS (2009). Heavy metal accumulation in *Pelargonium hortorum*. Effects on growth and development. Phyton 78:75-82.

Papasavvasa A, Triantafyllidisb V, Zervoudakisa G, Kapotisa G, Samarasc Y, Salahasa G (2008). Correlation of SPAD-502-meter readings with physiological parameters and leaf nitrate content in *Beta vulgaris*. Journal of Environmental Protection and Ecology 9(2):351-356.

Ribeiro HM, Vasconcelos E, dos Santos JQ (2000). Fertilisation of potted geranium with a municipal solid waste compost. Bioressource Technology 73:247-249. *https://doi.org/10.1016/S0960-8524(99)00168-6*

Saberioon MM, Amin MSM, Gholizadeh A, Ezrin MH (2014). A review of optical methods for assessing nitrogen contents during rice growth. Applied Engineering in Agriculture 30(4):657-669. *https://doi.org/10.13031/aea.30.10478*

Schroeter-Zakrzewska A, Wolna-Maruwka A, Kleiber T, Wróblewska H, Głuchowska K (2021). Influence of compost from post-consumer wood on development, nutrition state of plants, microbiological and biochemical parameters of substrates in zonal pelargonium (*Pelargonium zonale*). Agronomy 11:994. *https://doi.org/10.3390/agronomy11050994*

Șara A, Odagiu A (2005). Controlul calității nutrețurilor [Forage Quality Control]. AcademicPres, Cluj-Napoca.

Toma F, Petra S (2020). Floricultură și compoziții florale [Floriculture and Floral Compositions]. Total Publishing București.

Zawadzińska A, Salachna P (2018). Ivy pelargonium response to media containing sewage sludge and potato pulp. Plant Soil and Environment 64:180-185. *https://doi.org/10/2018-PSE*

Wang Y, Dunn BL, Arnall DB (2012a). Assessing nitrogen status in potted geranium through discriminant analysis of ground-based spectral reflectance data. HortScience 47(3):343-348. *https:///doi.org/10.21273/HORTSCI.47.3.343*

Wang Y, Dunn BL, Arnall DB, Mao P (2012b). Use of an Active canopy sensor and SPAD chlorophyll meter to quantify geranium nitrogen status. HortScience 47(1):45-50. *https:///doi.org/10.21273/HORTSCI.47.1.45*

Zanin G, Sambo P (2006). Using SPAD-meter in nitrogen fertilization of *Rosa chinensis* Jacq. var. *mutabilis*. HortScience 41:969-970. *https://doi.org/10.21273/HORTSCI.41.4.969D*