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# Effects of Salinity on Edible Marigold Flowers (*Tagetes patula* L.) †

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**Abstract:** Salinization is an increasing problem worldwide, limiting crop production. Soil salinity causes ion toxicity, osmotic stress, nutrient deficiency, and oxidative stress in plants, leading to the overproduction of reactive oxygen species (ROS). To counterbalance these effects, plants activate a complex detoxification system through the action of antioxidant pigments, carotenoids, phenolics, and flavonoids, and the accumulation of minerals, that play an important role in human health against several diseases. In this study, we investigated the impacts of salinity (0, 50, 100, and 300 mM NaCl) on the flowers of three *Tagetes patula* cultivars harvested after 14 days, recording mineral, total phenol and protein contents. Overall, all compounds increased with an increase in salinity levels, in comparison with control conditions. Results showed that edible marigold flowers are a promising crop with enriched nutritional contents and antioxidant activity that can be a new source of source of nutraceuticals. However, further tests are needed to evaluate the implications that salinity might have on the viability and yield of flowers.

**Keywords:** edible flowers; antioxidant; nutraceutical food; salinity; tolerance

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## 1. Introduction

Currently, there is an increasing consumer demand for functional and healthy foods [1]. In this context, the market niche for edible flowers is very promising; several species have been used in the human diet since ancient times [2]. Edible flowers add aesthetic value to food and drinks, introducing new colors and flavors in gourmet dishes, and providing new opportunities for gastronomic innovation [3]. In addition, many edible flowers contain several antioxidants, vitamins, and mineral compounds that provide a wide range of valuable nutraceuticals eventually beneficial to consumers' health [4]. Edible flowers offer a wide range of phytochemicals related to the prevention of several human diseases [4]. Thus, edible flowers are promising horticultural crops providing new solutions to farmers, helping to diversify agroecosystems and the sustainable use of natural resources. However, not all flowers are edible, since several plants have toxic substances and should not be included in the human diet [5]. Thus, it is important to understand the nutritional composition of flowers and the content of functional compounds that might be useful in the human diet.

Marigolds (*Tagetes* L.) are a good source of edible flowers. They have a growing demand in the food, medicinal, and floricultural industries [6]. Marigolds have high levels of antioxidant components including carotenoids, flavonoids, and phenolic acids [7] that play an important role in human health [8]. For instance, flower extracts of *T. erecta* have been reported to have a high neuroprotective potential against neurodegenerative disorders [9]. Short-term saline exposure for *T. patula* plants (10 days at 50and 100 mM NaCl) helps to increase their levels of antioxidants and other protective compounds [6]. This is because salinity causes oxidative stress in plants, leading to the overproduction of reactive oxygen species (ROS) [10]. To counterbalance these effects, plants activate a complex detoxification system through the action of antioxidant pigments, carotenoids, phenolics, and flavonoids, and the accumulation of minerals [11]. The use of saline water to grow, or the ability to grow under saline soils, is also a useful trait in the floriculture market, although studies on this topic remain scarce [6]. In this context, we tested the effects of salinity on the nutritional components of *Tagetes patula* flowers, grown with 0, 50, 100, and 300 mM NaCl. Specifically, we quantified the mineral composition and total proteins, fats, and phenolic compounds using three *Tagetes patula* cultivars to determine the potential beneficial effects of salinity on the production of these compounds.

## 2. Materials and Methods

### 2.1. Plant Material and Experimental Conditions

Three *Tagetes patula* cultivars (cv. Aurora Orange, Fireball, and Safari Scarlet) were grown in 2 L capacity potsin a controlled environmental chamber under a long-day photoperiod (16 h light), temperature of 23/19 °C (light/dark period), and relative humidity of 72–76%. Plants were watered every two days using Hoagland nutritive solution. One-month plants were exposed to the following treatments: 0, 50, 100, and 300 mM NaCl levels. Each treatment consisted of 10 biological replications, totaling 40 plants per cultivar. Two weeks after treatments, flowers were harvested for the determinations stated below.

### 2.2. Determination of Mineral Contents, Total Phenols, and Proteins

Mineral contents were determined by digesting flower samples (0.2–0.3 g) with hydrochloric acid (2 N HCl) (Merck, Darmstadt, Germany) [6]. K and Na were determined using flame photometry (Corning 410, Corning, Halstead, UK), while Mg, Ca, Cu, and Fe contents were determined using an atomic absorption spectrophotometer (Model 2280 Perkin Elmer, Norwalk, CT, USA). Data are expressed in g $kg^{-1}$ and mg $kg^{-1}$ of dry weight (DW) for macro- and micronutrients. The total phenol content (TPC) of flowers (0.5 g) was determined using the Folin–Ciocalteu method with 10 mL of methanol (50% $v/v$), measured at 755 nm. Results are expressed as equivalents of gallic acid (Scharlau, Barcelona, Spain) per gram of DW. The crude protein content of samples was estimated using the macro-Kjeldahl method (N $\times$ 6.25). The total fat was determined using a Soxhlet procedure.

### 2.3. Statistical Analysis

Mean values ($\pm$SE) were calculated from the 10 replicates per cultivar, using IBM SPSS v.22. To analyze the effects of salinity, we used multivariate ANOVA (at the 1% significance level) after checking the homogeneity of variance using Levene's Test for Equality of Variances. Significant differences between means were also followed by Tukey's test for post hoc comparisons (at the 5% significance level).

## 3. Results and Discussion

Exposure to salinity significantly increased the levels of N, K, Ca, and Mg in the flowers of *Tagetes patula* cultivars, although results depended on the level of salinity (Table 1). Mineral contents were usually enhanced with the increase in salinity levels, especially the levels of K (Table 1). Nevertheless, flowers grown with 300 mM NaCl usually showed lower values of minerals, even in comparison with control conditions, except for K values (Table 1). Overall, plants grown with 50 mM NaCl showed the highest values of mineral contents (Table 1). Positive effects of NaCl have also been found in *Zygophyllum xanthoxylum* plants, where cultivation with 50 mM NaCl resulted in optimal plant growth and reduced the negative impacts induced by different osmotic stresses [12]. Maximum growth also occurred in *Calligonum caput-medusae* seedlings, while higher salinity levels decreased growth, net photosynthetic rate, and stomatal conductance [13].

**Table 1.** Effects of salinity levels (0, 50, 100, and 300 mM NaCl) on the mineral contents (N, K, Ca, and Mg) of flowers from three *Tagetes patula* cultivars (cv. Aurora Orange, cv. Fireball, and cv. Safari Scarlet). Results are expressed as means ± SE (n = 10). Different superscripts in the same row indicate significant differences between salinity levels for the same species (ANOVA followed by a Tukey test at $p < 0.001$).

| Minerals | Cultivars | 0 | 50 | 100 | 300 |
|---|---|---|---|---|---|
| N | cv. Aurora Orange | 11.11 ± 1.22 [a] | 16.31 ± 1.22 [b] | 18.25 ± 1.12 [c] | 19.37 ± 1.56 [d] |
| | cv. Fireball | 10.13 ± 1.31 [a] | 16.44 ± 1.18 [b] | 18.24 ± 1.35 [c] | 19.20 ± 1.33 [d] |
| | cv. Safari Scarlet | 14.21 ± 1.65 [a] | 17.52 ± 1.11 [b] | 19.22 ± 1.56 [c] | 22.11 ± 1.56 [d] |
| K | cv. Aurora Orange | 11.09 ± 1.17 [a] | 12.22 ± 1.26 [b] | 13.25 ± 1.56 [c] | 12.15 ± 1.68 [b] |
| | cv. Fireball | 11.11 ± 1.21 [b] | 11.59 ± 1.12 [d] | 11.16 ± 1.65 [c] | 10.23 ± 2.55 [a] |
| | cv. Safari Scarlet | 11.01 ± 1.13 [c] | 11.55 ± 1.10 [d] | 10.20 ± 1.32 [b] | 10.11 ± 2.15 [a] |
| Ca | cv. Aurora Orange | 3.11 ± 1.12 [b] | 9.55 ± 1.57 [d] | 3.21 ± 1.99 [c] | 3.01 ± 2.95 [a] |
| | cv. Fireball | 3.15 ± 1.26 [c] | 9.50 ± 1.44 [d] | 3.10 ± 2.60 [b] | 3.00 ± 2.78 [a] |
| | cv. Safari Scarlet | 4.03 ± 1.19 [b] | 8.52 ± 1.35 [d] | 4.22 ± 2.24 [c] | 3.99 ± 2.67 [a] |
| Mg | cv. Aurora Orange | 0.18 ± 0.04 [b] | 1.55 ± 0.57 [d] | 0.21 ± 0.05 [c] | 0.11 ± 0.01 [a] |
| | cv. Fireball | 0.14 ± 0.05 [b] | 1.50 ± 0.57 [d] | 0.10 ± 0.08 [a] | 0.20 ± 0.02 [c] |
| | cv. Safari Scarlet | 0.28 ± 0.04 [c] | 1.52 ± 0.61 [d] | 0.22 ± 0.06 [b] | 0.19 ± 0.03 [a] |

The three cultivars also showed significant differences in the mineral contents (always $p < 0.001$); the lowest content was found in cv. Aurora Orange, and the highest in cv. Safari Scarlet. Similar values of N and K were reported in other *T. patula* flowers (cultivars not reported) grown for 10 days with 50 and 100 mM NaCl [6]. However, in that study, the levels of Ca and Mg decreased with salinity [6], while here, the response varied between cultivars (Table 1), but overall suggested a high tolerance to salinity. The vast majority of plants are intolerant to salt and unable to grow in saline soils [14]. Some plants cultivated with intermediate levels of salinity usually show high levels of antioxidant compounds, although reports are usually related to halophyte species such as *Salicornia ramosissima* [15] and *Crithmum maritimum* [16]. It is thusinteresting to find edible flowers that can grow under, at least, some saline levels, as found in this study.

*Tagetes patula* flowers are also a promising nutraceutical food as the levels of TPC and proteins were relatively high (Figure 1). TPC showed a significant increase in all cultivars as salinity levels also increased ($F_{3,14} = 121.265$; $p < 0.001$; Figure 1A). All flowers showed the highest levels of TPC at 300 mM NaCl (Figure 1A). Some differentiation in the levels of TPC was found between cultivars, with cv. Safari Scarlet triggering a higher level than the other cultivars, but only under control ($t = 3.013$; $p < 0.001$) and 50 mM NaCl ($t = 3.011$; $p < 0.001$) conditions.

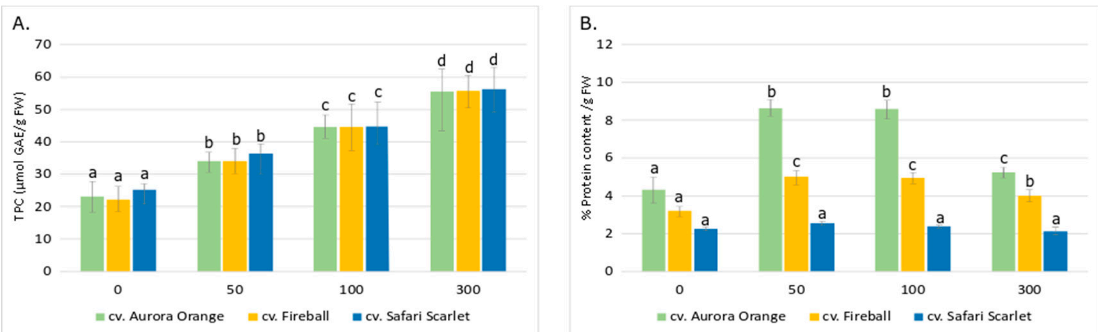


**Figure 1.** Effects of salinity levels (0, 50, 100, and 300 mM NaCl) on the total phenolic contents (**A**) and the total protein content (**B**) of flowers from three *Tagetes patula* cultivars (cv. Aurora Orange, cv. Fireball, and cv. Safari Scarlet). Results are expressed as means ± SE (n = 10). Different superscripts in the same row indicate significant differences between salinity levels for the same species (ANOVA followed by a Tukey test at $p < 0.001$).

Protein contents also varied significantly with salinity levels ($F_{3,14}$ = 123.887; $p < 0.001$). The highest values of proteins were found under 50 mM and 100 mM NaCl, while the lowest values were reported under 300 mM NaCl for all cultivars (Figure 1B), except for cv. Safari Scarlet, where no statistical differences were found between salinity levels ($F_{3,14}$ = 2.025; $p$ = 0.891).

Total fat contents remained low in all cultivars despite exposure to salinity (always $p > 0.05$), with an average content of 1.56 ± 0.87 in cv. Aurora Orange, 2.25 ± 0.99 in cv. Fireball, and 1.02 ± 0.83 in cv. Safari Scarlet. Thus, along with their bioactive potential, the edible flowers of *T. patula* also have a nutritional combination desirable from a health point of view, with good levels of proteins but low levels of fatty acids. The levels of proteins reported in this study are similar to the ones found in bananas [17], sunflowers [17], or pot marigolds, among other edible flowers [18]. The replacement of high-fat food with other options that are more beneficial to public health is crucial, and edible flowers such as the ones studied here are a good option in helping to feed the world.

## 4. Conclusions

Short exposure to salinity increased the levels of compounds useful for the human diet, therefore supporting the use of marigold flowers as a source of nutraceutical food. Considering that salinity increases the levels of antioxidants and minerals in *T. patula*, farmers can consider the use of saline water for short irrigation periods for marigolds. However, future studies should also address the impacts that salinity might have on plant growth and flower production.

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