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RESPONSE OF ZINNIA PLANTS TO FOLIAR APPLICATION OF SALICYLIC ACID

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Abstract

Zinnia elegans Jacq. is one of the most popular annual flowering plants, highly appreciated due to the great diversity of flower sizes, shapes and colours, as well as abundant blooming throughout the summer. It is widely used in gardens, and as a cut flower in bouquets and floral arrangements, but can also be grown in containers and pots, for patios and balconies decoration. This study was conducted to evaluate the effect of exogenous salicylic acid (SA) applied in different concentrations (0, 75, 100 and 200 ppm), on the vegetative growth and flowering of this plant. The results showed that foliar application of salicylic acid had a positive effect on the main analysed morphological characteristics. The maximum values of plant height, number of branches per plant, leaf length and width, number of flowers and flower diameter were obtained in plants sprayed with 200 ppm SA, compared to control plants. The salicylic acid induced early flowering, the lowest number of days required to opening of the first flower was recorded at 100 ppm concentration.

Key words: *Zinnia, salicylic acid, foliar application.*

INTRODUCTION

Zinnia elegans Jacq. (Compositae family) is an important annual garden plant, native to Mexico, with upright, vigorous, branching and hairy stem, that can reach 15-100 cm in height, depending on the type and cultivar. The leaves are simple, entire, opposite, sessile, ovate to lanceolate, up to 10-12 cm long, covered with short hairs and rough to the touch. There are numerous beautiful varieties, with a wide range of shapes, sizes and colours of flowers. The solitary inflorescences form at the end of each branch and can be single, semi-double or double, in different shades of white, pink, red, yellow, orange, green, purple, even bicoloured or with interesting stripes and speckles. The attractive small inflorescences of the dwarf cultivars, that have 3-6 cm in diameter, or the spectacular extra-large inflorescences of 10-15 cm diameter, attract the beneficial insects as bees and butterflies. Zinnias bloom continuously throughout the summer until autumn or to the first frosts. It prefers sandy, loamy, moderate moisture soils, well-drained, rich in organic matter and mineral elements. Zinnias grow best and flower abundantly in sunny places, protected from the wind, and they are heat and drought-tolerant plants, but very sensitive to low temperatures.

It very easily propagated by seeds sown outdoors, directly in the ground after the last spring frost has passed or indoors from February until April.

Zinnia is one of the most appreciated and cultivated annual plants for the long period of flowering and the abundance of flowers in various, intense and bright colours, that bring visual interest in parks, gardens and urban green spaces, for the fast growth and the low maintenance requirements. The dwarf and compact varieties are used in flower beds, borders, mass plantings, but can also be planted in window boxes, as well as in pots and containers for decorating patios, terraces and balconies. The tall varieties are very attractive in mixed borders, groups on lawns or along a walkway, and as cut flowers in bouquets and flower arrangements.

Salicylic acid (SA) is an important phytohormone, present naturally in very low concentrations in plant tissues, which has an essential role in the regulation of various physiological and biochemical processes such as membrane permeability, uptake and transport of ions, antioxidant enzymes activities, stomatal closure, inhibition of ethylene biosynthesis, thermogenesis, photosynthetic rate, increasing of chlorophyll and carotenoid pigments content, etc. (Hayat & Ahmad, 2007).

Numerous studies worldwide had as objective to determine the responses of plants to adverse environmental conditions and the role of salicylic acid in reducing or mitigating the negative effects of different biotic and abiotic stress factors, which reduce the growth and development of the plants, and also limit the crop productivity.

The application of exogenous salicylic acid has been shown to be beneficial for plants both in optimal and stress environments (Khan et al., 2015), and can provide protection of plants by improving the tolerance to various types of abiotic stresses (Koo et al., 2020), such as drought (Zarghami et al., 2014; Yao et al., 2016; Zargarian et al., 2016; Abaspour Esfaden et al., 2019; Abbas et al., 2019; Akhtar et al., 2022), low temperatures (cold and chilling stress) (Promyou et al., 2012; Huang et al., 2016), heat (Cao & Li, 2014; Shen et al., 2016), salinity (Kamali et al., 2012; Zheng et al., 2018; Abd El Gayed, 2020), heavy-metal contaminants (El-Tayeb et al., 2006; Sharma et al., 2020), ultraviolet radiation (Liu et al., 2022; Zheng et al., 2022), nutritional deficiency (Guo et al., 2019), and inducing the plant resistance to different diseases (Durner et al., 1997; Kumar, 2014). The positive effects of salicylic acid foliar application on some ornamental plants grown both under normal and different stress conditions have been reported in many studies. It was found that SA improved the germination of *Zinnia elegans* (Huang et al., 2015) and *Limonium bicolor* seeds (Liu et al., 2019), promoted the rooting of poinsettia and azalea cuttings (Sardoei et al., 2014; Hou et al., 2020), enhanced various vegetative and flowering parameters like the plant height, the number of branches per plant, the leaf area and number of leaves, the number and diameter of flowers in *Antirrhinum majus* (Akram et al., 2022), *Calendula officinalis* (Bayat et al., 2012), *Ixora coccinea* (Gad et al., 2016), *Cyclamen persicum* (Farjadi-Shakib et al., 2012), *Saintpaulia ionantha* (Jabbarzadeh et al., 2009), *Gladiolus grandiflora* (Pal et al., 2015), *Tagetes* sp. (Poudel & Subedi, 2020), *Impatiens walleriana* (Safari et al., 2022), as well as the productivity of ornamental and horticultural plants (Larqué-Saavedra & Martin-Méx, 2007; Hayat et al., 2010), and induced early flowering in *Sinningia speciosa* (Martín-Mex et al., 2015). SA also delayed flower senescence and extended the vase life of rose cut flowers (Zamani et al., 2011), carnation (Roodbaraky et al., 2012), zinnia (Iqbal et al., 2012), chrysanthemum (Mashhadian et al., 2012), lisianthus (Bahrami et al., 2013), gerbera (Mehdikhah et al., 2016), gladiolus (Saeed et al., 2016), tuberose (Ezz et al., 2018), sunflower (Othman & Esmail, 2020), alstroemeria (Langroudi et al., 2020).

The objective of this study was to evaluate the efficiency of salicylic acid foliar application on growth and flowering characteristics of the *Zinnia elegans* plants.

MATERIALS AND METHODS

The study was conducted in the Floriculture Research Area, Faculty of Horticulture, University of Craiova, Romania, to evaluate the influence of salicylic acid applied by foliar spraying, in improving the growth of plants and flower quality. The zinnia seeds were purchased from Agrosel seed company and were sown in March 2019, under greenhouse conditions, in plastic trays, filled with a permeable sowing substrate, containing sphagnum white peat (ProfiMix, Agro CS). The healthy and uniform size seedlings were transplanted at the four-leaf stage, in a growing substrate composed of a peat and perlite mixture (1:1), in 10 cm diameter plastic pots. In May, the vigorous seedlings were planted in open field, at a distance of 30 cm between rows and 20 cm between plants along the row. After 15 days from the planting in soil, foliar treatments with salicylic acid (SA) were applied in three concentrations (75, 100 and 200 ppm), while the control plants were sprayed at the same time with tap water, early in the morning, using a manual sprayer.

The foliar applications with SA were repeated two times, at an interval of one week, during the vegetative stage of plants. The experimental observations on vegetative and flowering parameters included the plant height (cm), number of branches per plant, length and width of the leaves (cm), number of flowers and flower diameter (cm), as well as the number of days from sowing to flowering.

The experiment was arranged in randomized complete block design with three replications. The statistical analysis of recorded data was performed by one-way analysis of variance (ANOVA) for each parameter studied, and the differences between the means of the treatments were compared using Duncan's multiple range test (DMRT) at the 5% probability level.

RESULTS AND DISCUSSIONS

Vegetative growth parameters

The variability of growth parameters of zinnia plants in response to salicylic acid foliar application is shown in table 1. In terms of the average plant height, the higher values than the control plants (41.66 cm) were obtained in all variants, but the highest value was recorded by the plants sprayed with 200 ppm SA (53.50 cm), where the height increased significantly in comparison with the other concentrations applied, and these results are in agreement with those reported by Zeb et al. (2017).

The efficacy of exogenous SA on plant growth and development, depends on many factors as the concentration used, the species and plant developmental stage, timing and methods of application (soaking the seeds before sowing, irrigating or foliar spraying), number of applications, the endogenous level of salicylic acid in plant, etc. (Horváth et al., 2007; Li et al., 2022). Elbohy et al. (2018) reported a significant increase of plant height, number of flowers and flower diameter in zinnia plants grown in open field and sprayed with 300 ppm SA. In another study, Al-Abbasi et al. (2015) observed similar growth promoting responses at lower concentrations of SA (50 mg L^{-1}). Basit et al. (2018) evaluated the effect of exogenous application of different doses of SA on marigold (*Tagetes* sp.) in greenhouse conditions, and concluded that for better growth and flower production, the plants should be sprayed before flowering stage with 120 mg/L SA solution.

Regarding the average number of branches per plant, the statistical analysis of the data indicated a positive significant influence of exogenous SA application, at all treatments compared to the control plants. The maximum number of branches (5.46) was noticed at 200 ppm SA application, which was found statistically similar to 100 ppm concentration (4.78), while the minimum value of this vegetative parameter was recorded in the untreated plants. The leaf sizes generally increased, but salicylic acid spraying in different concentration had no statistically significant effect on the length and width of the leaves.

In many studies, it has been suggested that the beneficial effect of SA on plant growth, could be related to its action in stimulating chlorophyll synthesis, the improvement of photosynthetic rate and stomatal conductance, as well as in the activity of some important enzymes. SA interacts with other plant hormones, such as auxins, gibberellins, cytokinines and ethylene, to regulate plant growth by modulating cell division and tissue expansion in roots and stems (Arif et al., 2020).

Table 1. The effect of foliar application of salicylic acid on the vegetative growth of *Zinnia elegans* plants

Salicylic acid concentration (ppm)	Plant height (cm)	Number of branches/ plant	Leaf length (cm)	Leaf width (cm)
0	41.66 b	2.63 d	9.75 a	4.11 a
75	42.83 b	3.81 c	10.29 a	4.53 a
100	45.16 b	4.78 ab	10.63 a	4.86 a
200	53.50 a	5.46 a	11.12 a	5.25 a

Means with same letter(s) in a column are statistically non-significant at the 5% significance level according to Duncan's multiple range test.

Flowering parameters

Data presented in table 2 show that foliar application of salicylic acid caused a significant increase in number of flowers per plant. The plants treated with salicylic acid in 200 ppm concentration had the highest number of flowers (6.41), while at the plants sprayed only with tape water was recorded the lowest number of flowers (3.25). Similar results have been reported in *Gazania rigens* L. (El-Shanhorey & Hassan, 2021), *Lilium* cv. Tresor (Pahare & Beura, 2022), *Calendula officinalis* L. (Pacheco et al., 2013). There were no significant differences between treatments concerning the diameter of flowers. The foliar spraying of salicylic acid determined significant decreases in number of days to flowering. The comparison of average values revealed that the treated plants had an earlier flowering. The minimum value for number of days from sowing to flowering was recorded at the treatment with SA in 100 ppm concentration (60.84), followed by the variant where 200 ppm SA was applied (62.51). The flowering was delayed in control plants, where no salicylic acid was applied and the highest number of days to opening of the first flower (66.45 days) was recorded.

Flowering is an important parameter that is directly related to yield and productivity of plants (Hayat et al., 2010).

The exogenous application of salicylic acid stimulates flower bud formation and induces early flowering in different ornamental plant species, because accelerates biosynthesis of secondary metabolites and acts as a regulator of flowering time in non-stressed plants (Martínez et al., 2004). Alwan et al. (2018) showed that the soaking of *Iris hollandica* bulbs in the distilled water prior to planting led to delay in the time of flowering (113.80 days), in comparison to those were soaked in 200 mg L^{-1} salicylic acid, where the flowering occurred much earlier, after only 100 days. Martín-Mex et al. (2010) found that salicylic acid at 1 µM induced early flowering with six days, and also increased the number of flowers in *Petunia hybrida.*

Table 2. The effect of salicylic acid on flowering of *Zinnia elegans* plants

Salicylic acid concentration (ppm)	Number of flowers	Flower diameter (cm)	Number of days to flowering (day)
0	3.25 c	6.61 a	66.45 d
75	4.37 bc	6.94 a	64.72 c
100	4.62 b	7.22 a	60.84 a
200	6.41 a	7.53 a	62.51 b

Means with same letter(s) in a column are statistically non-significant at the 5% significance level according to Duncan's multiple range test.

CONCLUSIONS

The foliar application of salicylic acid in the vegetative growth stage had a positive effect on zinnia plants and induced the enhancement of the growth and flowering parameters. The results showed that spraying with 200 ppm SA significantly increased the plant height, the number of branches per plant and the number of flowers compared to the control plants, while salicylic acid applied in concentration of 100 ppm reduced the number of days to flowering and determined an earlier flowering of the plants.

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