Journal of Pure and Applied Agriculture (2022) 7(2): 1-11
ISSN (Print) 2617-8672, ISSN (Online) 2617-8680
http://jpaa.aiou.edu.pk/

Foliar application of salicylic acid and its impact on pre and post-harvest attributes of *Antirrhinum majus* L.

Ahsan Akram[1*], Muhammad Adeel Asghar[1], Adnan Younis[1], Ahmed Faiz Akbar[1], Muhammad Talha[1], Amjad Farooq[2], Gulzar Akhtar[3], Muhammad Shafiqe [4] and Muhammad Zaighum Mushtaq[5]

[1]Institute of Horticultural Sciences, University of Agriculture, Faisalabad-38040, Pakistan
[2]Department of Environmental Sciences, COMSATS University Islamabad-Vehari Campus, 6110- Pakistan
[3]Department of Horticulture, Muhammad Nawaz Shareef University of Agriculture, Multan, Pakistan
[4]University of Agriculture, Faisalabad, Sub Campus Burewala, Burewala, Pakistan
[5]Biochemistry Section, Post-Harvest Research Centre, Ayyub Agricultural Research Institute, Faisalabad, Pakistan

*****Corresponding author: Ahsan Akram (ahsan.akram@uaf.edu.pk)

Abstract

Antirrhinum (*Antirrhinum majus* L.) is a popular specialty cut flower worldwide, has high demand and prospective due to its incredible color and species. It is a very stipulating flower on various occasions. A study was accompanied to assess the influence of salicylic acid (SA) on the growth, development, and post-harvest life of antirrhinum. The study was planned according to Randomized Complete Block Design has three replications and four levels of salicylic acid viz. 100 mg L^{-1}, 300 mg L^{-1}, 600 mg L^{-1}, 900 mg L^{-1} and control treatment were used. The data regarding pre-and post-harvest attributes plant height (cm), plant fresh weight (g), and dry weight (g), number of leaves, leaf area (cm^2), flower stalk length (cm), flower diameter (mm), leaf total chlorophyll content (SPAD value), membrane stability index (%), solution uptake (ml), flower opening percentage and vase life (days) was recorded according to the standard technique. The collected data were evaluated statistically by using the Statistix 8.1 software. The current investigation results indicated that using 600 mg L^{-1}salicylic acid concentration significantly enhance the plant height (91.33 cm), plant fresh weight (43.67 g), flower quality (9.17), and salicylic acid at 900 mg L^{-1} concentration enhance the number of leaves (59.33), flower stalk length (6.17 cm), the total number of florets (35.17), while by using 100 mg L^{-1} salicylic acid concentration increase in flower opening percentage (57.02 %), leaf relative water content (90.95 %), membrane stability index (108.16 %), solution uptake (40.44 ml) and vase life were (8.75 days). It is concluded that a higher dose of salicylic acid enhances the biomass production but decreases the postharvest life of Antirrhinum cut flowers. The use of lower concentration of salicylic acid enhances the post-harvest life of cut flowers.

Keywords: Antirrhinum, Longevity, Plant Growth Regulator, Salicylic acid, Vase life, Vegetative growth

To cite this article: Akram, A., Asghar, M. A., Younis, A., Akbar, A. F., Talha, M., Farooq, A., Akhtar, G., Shafiqe, M., & Mushtaq, M. Z. (2022). Foliar application of salicylic acid and its impact on pre and post-harvest attributes of *Antirrhinum majus* L. *Journal of Pure and Applied Agriculture, 7*(2), 1-11.

Introduction

Antirrhinum majus L. commonly known as snapdragon, after a reassessment of its former classical family, Scrophulariaceae, now belongs to the Plantaginaceae family. This herbaceous, winter annual plant belongs to the genus snapdragon of the dragon flowers, which gets its name from the petals' supposed resemblance to a dragon's face when pinched laterally opens and closes its mouth like a dragon. Antirrhinum is native to rocky regions of Europe, The United States, and North America (Dorling, 2008). Its irregularly shaped blooms appear in racemes at the end of the stem and come in a variety of hues (Ahmad & Dole, 2014). Buds open from bottom to top on the upright flower stalks, creating stunning color for a lengthy period. Snapdragons thrive in cooler temperatures, and most cultivars may even withstand a light frost (Celikel et al., 2010). Snapdragons can reach a height of 0.5 to 1 m and in extreme cases 2 m. The spirally organized leaves are roughly lanceolate, one to seven-centimeter-long, and 2-2.5 centimeter wide. The leaflets aren't there. Each flower is 3.5-4.5-centimeter-long, and has two jaws that close the corolla cylinder; uninhabited plants have rosy to purple blooms with yellow jaws. There are 8-30 small stalked flowers in a cluster in most cases.

Salicylic acid (SA) is also recognized as a phenolic molecule having an aromatic ring with a hydroxyl group. Salicylic acid is found in nature at low concentrations and plays a role in a variety of mechanisms in plants, including food intake, stomatal closure, ethylene inhibition, transpiration, protein, and chlorophyll production are all factors to consider. In pathogenic attacks, local or organized disease response is also used as a signaling element (Khan et al., 2003). In plants, SA functions similarly to auxin and cytokinin. It helps to improve the metabolic rate of cells, delay senescence, prolong bloom life, and induce flowering (Metwally et al., 2003). Exogenous administration of SA significantly minimizes the negative possessions of water shortage on the plant, and cell membranes and increased the ABA concentration in leaves, possibly contributing to plants' enhanced tolerance to water inadequacy (Bandurska and Stroinski, 2005). Salicylic acid has a significant impact on the function and structure of plants. It improves resistance to a variety of unfavorable substances from the surrounding environment, reinforcing the pattern of growth and development (Mateo et al., 2006). SA is a well-known phenol that may inhibit ACC oxidase, a direct precursor of ethylene, and decrease ROS by boosting enzyme antioxidant activity (Heidarnezhadian et al., 2017).

Cut spikes treated with SA had a higher total soluble sugar content. It may be suggested that because SA suppresses the activity of ACC synthase and the production of ethylene, it delays the breakdown of carbohydrates by slowing down respiration and increases vase life by retaining more sugar (Hemati et al., 2021). Salicylic acid extends the shelf life of a variety of horticulture crops by maintaining the integrity of the cell membrane, enhancing solution absorption, controlling stomata transpiration, and amplifying the activities of many antioxidant enzymes (Radwan et al., 2019; Abdelaal et al., 2020).

Exogenous spray of SA and GA_3 were applied on the *Ixora coccinea* L. to check the plant's growth and flowering. Application on plants with 400 parts per million enhanced the fresh and dry weight of roots and shoots, and the number of flowers. Plants sprayed with SA at 300 or 400 parts per million had the thickest fresh roots and the largest chlorophyll-a content in leaves, with no significant variations between them. Ixora flowering qualities were also improved by SA. Salicylic acid at 400 parts per million and GA_3 at 400 parts per million both had the highest number of flowers and florets per plant and floral weight values. Leaf area and dry weight of roots were both greatly increased by salicylic acid application, showing a strong association (Gad et al., 2016). Current investigation was planned to have an insight view of the objectives to check exogenous efficacy of salicylic acid to elucidate the effect of different SA concentrations on pre and post-harvest indices and evaluation of bloom quality, longevity, and freshness of *Antirrhinum majus* L.

Materials and Methods

The experiment was conducted at the Research Area of Institute of Horticultural Sciences, University of Agriculture, Faisalabad, during 2020-2021 to assess the consequences of pre-harvest SA application on *Antirrhinum majus* growth, yield, and vase life. Seeds of *Antirrhinum majus* cv. 'Apple blossom' was purchased from Pan American seed company and the nursery was raised in green-house using coco-coir, press mud, and sandy loam soil (1: 1: 1; v/v) as substrate. When they reached the 3-4 true leaf phase, the seedlings were transplanted into prepared soil beds. Before transplanting, the soil was prepared and NPK fertilizer (20:20:20) was applied at a rate of 100 kg per acre. The experiment was designed using a three-replicate Randomized Complete Block Design. Plants were spaced at 24 cm between plants as well as rows. Salicylic acid first dissolves in 90% ethanol and then in water at normal room temperature. The first foliar application of salicylic acid was done 20 days after transplanting, while the other two are within 15 days intervals. Different cultural practices like hoeing, weeding, insecticide spray, fertilization, and watering for all treatments were the same during the entire period of study. After randomization, all treatments were assigned with the following treatment combinations for foliar application of salicylic acid.

T_0 = control
T_1 = 100 mg L^{-1}
T_2 = 300 mg L^{-1}
T_3 = 600 mg L^{-1}
T_4 = 900 mg L^{-1}

Physiological parameters

Data concerning morpho-physiological, floral, and post-harvest attributes were noted. For data collection, five healthy and disease-free plants were randomly selected from each experimental unit having vigorous growth, tagged and collection of data was done for the following parameters:

Plant height (cm)

The plant height (cm) was measured with a measuring rod in centimeters, from top to bottom of the plant. The total number of leaves in each plant was counted up at the harvest stage from five carefully selected plants and the average was calculated. Leaf area (cm^2) was taken by measuring the maximum length and breadth of leaves from the middle of the leaf. Leaf area was measured in cm^2 according to Carleton and Foote (1965).

Leaf area = Length of leaf x Maximum breadth × 0.68
Where 0.68 = Constant factor

Leaf total chlorophyll content (mgg^{-1})

For leaf total chlorophyll content (mgg^{-1}) (SPAD Value) three healthy and mature leaves were carefully selected from individual plants and chlorophyll contents of leaves were recorded from three sites of a leaf (from the tip, middle, and base of leaves) with a digital leaf chlorophyll meter (Leaf+, FT green, LLC, USA) and the average was computed. For production time (days) the total days taken for commencement of flowering was noted in each treatment by calculating the days from transplanting date to earliest floret opening, which was the time to harvest stem. Stem diameter (mm) (the flowering portion of the stem) from the middle of the stem was recorded with a digital caliper and the average was calculated. For plant fresh weight (g) at full bloom, five flowers were harvested from each block and taken to the laboratory immediately, weighed on an electric weighing scale to get fresh weight, and the average was calculated. For plant dry weight (g) after getting fresh weight, flower stems were cut into pieces and were filled in paper bags, labeled accordingly, and put in a drying oven (Memmert-110, Schawabach) at a persistent temperature of 70 ºC for 72 hours. Flowers were taken out and weighed on an electric weighing balance after drying to a consistent weight, and an average was calculated. The dry mass of the flowers was then measured in grams, and an average was calculated. For flower spike length (cm) length of the spike was recorded at harvest from five stems of individual replicate using measuring scale and average was computed. Flower quality refers to the development of the bud, flower form and size, leaf quality, and flower color. The quality of the flowers was visually graded at a 1 to 9 scale, with 1 being the best and 9 being the worst.

1 = Poor quality
5 = Medium quality
9 = Best quality

After the endorsement of three different judges, the flower quality was scored, and an average was calculated (Cooper and Spokas, 1991; Dest and Guillard, 1987). The flower diameter (mm) of the lowermost open florets was measured in millimeters with a digital caliper from five stems (two florets per stem) from randomly selected plants and the average was computed. The number of florets per stem was counted from randomly selected five plants in each replicate at harvest and the average was calculated. The number of open and closed flower buds was counted at the end of vase life and percentage fined by using the formula:

Flower opening percentage = Number of open florets/ total florets × 100

Leaf relative water content (%)

For leaf relative water content % (LRWC) the weight of samples was taken right once to determine their fresh weight (FW) and then floated for four hours in sanitized water before being weighed over another time to determine their turgid weight (TW). The leaf samples were dried out in an oven at 70°C for 24 hours before being weighed. Using the formula, the LRWC was determined (Gonzalez and Gonzalez-vilar, 2001).

LRWC= (FW-DW)/ (TW-DW) x 100

Membrane stability index (%)

For membrane stability index (%age) on the last day of the vase's existence, it was measured. Five fresh-looking florets/flowers will be chosen at random from each replication and grind with silica powder for this purpose. The rubbed petals will be carefully washed with distilled water before being transported to test tubes having 15 mL distilled water. The test tubes were shaken in an orbital shaker for 10 minutes, and the EC_1 value was recorded. After another 100 minutes on the orbital shaker, the EC_2 was recorded (Ahmad, 2009), and the ion leakage was estimated using the equation below.

Ion leakage (%) = $EC_2/EC_1 \times 100$

Solution uptake (ml)

For Solution Uptake (ml) the water absorption was computed by deducting three control bottles' average water evaporation volume with no cut flowers from the quantity of water lost in bottles with flowers over the length of the experiment.

Vase life (days)

For Vase life (days) flowering stems were re-cut at uniform stem length and placed in distilled water until termination. Five individual stems were used in each treatment. Stems were placed in a vase life evaluation chamber at a temperature of 20±2˚C and relative humidity of 60±3 percent, with a daily light period of 12 hours given by white fluorescent tubes. When stems showed signs of drooping, fading, withering, or petal abscission, vase life was deemed to be over.

Statistical analysis

The collected data were analyzed statistically using ANOVA techniques, using Statistix 8.1 analytical software. The comparison of treatment means was done using the Least Significant Difference (LSD) test at probability level 0.05 (Steel et al., 1997).

Results

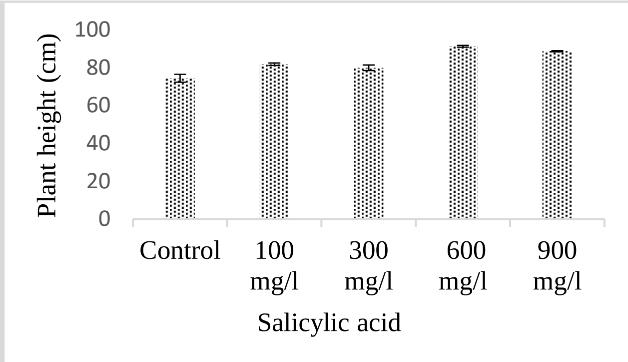
Foliar application of salicylic acid improved growth and postharvest longevity of *Antirrhinum majus* L. (Table 1 & 2)

Plant height (cm)

Plant height is an important criterion for determining the growth standard. Our study showed that the plant height was statistically analyzed and the comparison of mean shows the substantial superiority of T_3 (600 mg L^{-1}) 91.33 cm, while 74.45 cm in T_0 treatment showed minimum plant height (Fig. 1).

Number of leaves

The data regarding the number of leaves shown in (Fig. 2) was statistically analyzed and the comparison of mean showed that the substantial superiority of T_4 (900 mg L^{-1}) 59.33, followed by T_3 (600 mg L^{-1}) 57.00, while 50.50 in T_0 (control) which is the smallest and is ranked last.



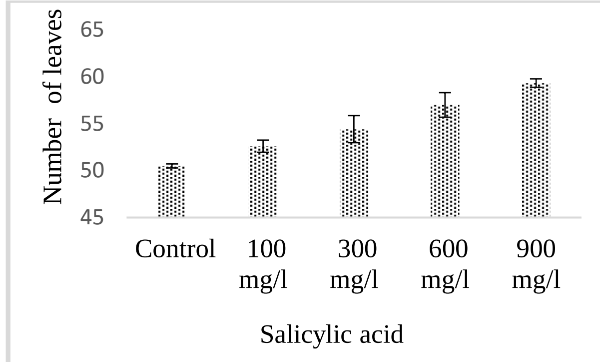


Fig. 1 Effect of foliar application of salicylic acid on plant height (cm) of *Antirrhinum majus* L. **Fig. 2** Effect of foliar application of salicylic acid on number of leaves per plant of *Antirrhinum majus* L.

Leaf area (cm^2)

Data pertaining to the maximum leaf area of snapdragon was observed in T_4 (900 mg L^{-1}) 20.12 cm^2, followed by T_3 (600 mg L^{-1}) and 11.74 cm^2 in T_0 (control) which was the lowest value on other treatments (Fig. 3). This experiment observed the leaf area was increased by increasing the salicylic acid concentration. Salicylic acid, a plant growth regulator, protects photosynthetic organelles from environmental threats while also increasing leaf area by increasing carbohydrates levels in plants.

Chlorophyll content (SPAD value)

As far as Chlorophyll content data was concerned, results showed that the maximum chlorophyll content in T_4 (900 mg L^{-1}) 68.70 and the minimum chlorophyll content in T_0 (control) 49.42 as compared to other treatments (Fig. 4). This experiment observed that the foliar application of salicylic acid has positive effects on morpho-physiological and molecular responses on snapdragon.

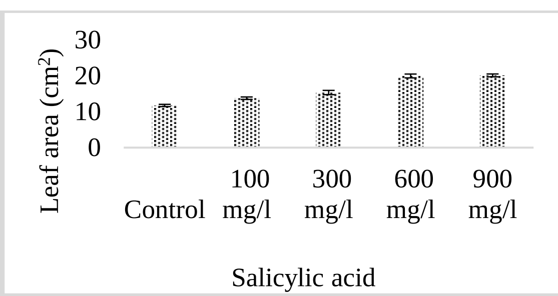


Fig. 3 Effect of foliar application of salicylic acid on leaf area (cm^2) of *Antirrhinum majus* L.

Production time (days)

Our results regarding production time described that T_3 (600 mg L^{-1}) 54.42 days have less time taken to produced flowers followed by T_2 (300 mg L^{-1}) 57.75 days, T_4 (900 mg L^{-1}) 59.83 days, T_1 (100 mg L^{-1}) 64.28 days as compared to T_0 (control) 65.49 days was maximum days taken to production of flowers (Fig. 5).

Stem diameter (mm)

The result showed that the highest stem diameter of T_4 (900 mg L^{-1}) 7.82 mm, followed by T_3 (600 mg L^{-1}) 7.70 mm, T_2 (300 mg L^{-1}) 6.57 mm, T_1 (100 mg L^{-1}) 6.35 mm, and 5.37 mm as compared to T_0 (control) which have lowest stem diameter (Fig. 6).

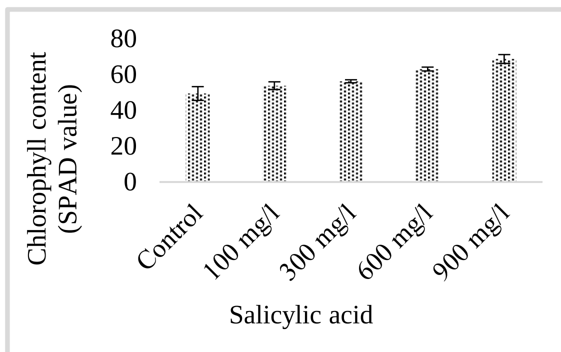


Fig. 4 Effect of foliar application of salicylic acid on chlorophyll content (SPAD Value) of *Antirrhinum majus* L.

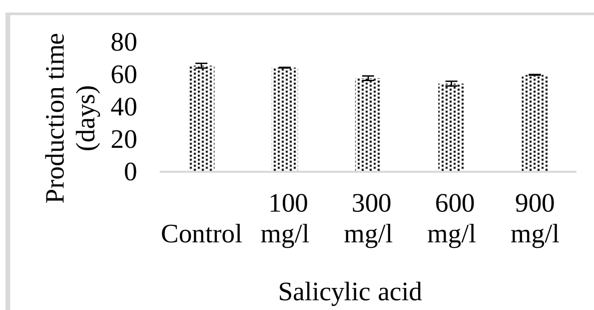


Fig. 5 Effect of foliar application of salicylic acid on production time (days) of *Antirrhinum majus* L.

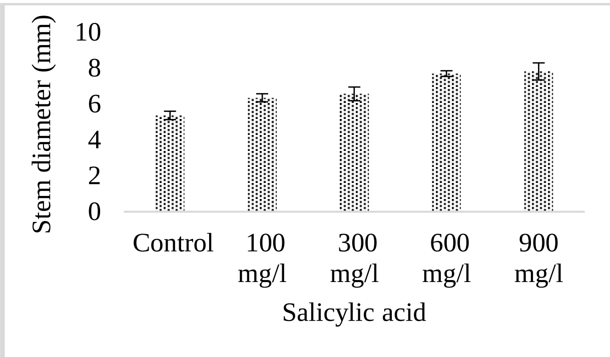


Fig. 6 Effect of foliar application of salicylic acid on stem diameter (mm) of *Antirrhinum majus* L.

Plant fresh weight (g)

Data regarding plant fresh weight was concerned, the maximum fresh plant weight T_3 (600 mg L^{-1}) 43.67 g, followed by T_1 (100 mg L^{-1}) 42.46 g, T_4 (900 mg L^{-1}) 39.17 g, as compared to the T_0 (control) 30.96 g which give minimum plant fresh mass (Fig. 7).

Plant dry weight (g)

Our investigation regarding the maximum plant dry weight in T_3 (600 mg L^{-1}) 6.58 g, followed by T_4 (900 mg L^{-1}) 6.12 g, T_1 (100 mg L^{-1}) 6.07g as compared to T_0 (control) 5.27 g shows minimum plant dry mass (Fig. 8).

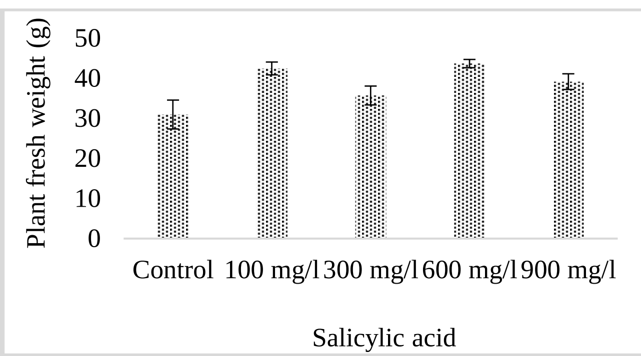


Fig. 7 Effect of foliar application of salicylic acid on plant fresh weight (g) of *Antirrhinum majus* L.

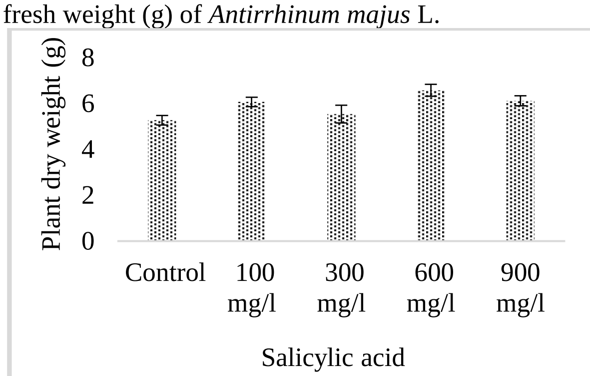


Fig. 8 Effect of foliar application of salicylic acid on plant dry weight of *Antirrhinum majus* L.

Flower spike length (cm)

The data regarding flower spike length was noted and it was observed that the highest flower stalk length in T_4 (900 mg L^{-1}) 15.68 cm, followed by T_1 (100 mg L^{-1}) 14.09 cm, T_3 (600 mg L^{-1}) 13.94 cm, T_2 (300 mg L^{-1}) 10.85 cm as compared to T_0 (control) 9.17 cm which is lowest flower spike length (Fig. 9).

Flower quality

Flower quality is the most promising metric in cut flower crops, as it is directly related to crop longevity and crop status. Our research findings exhibited that good quality of snapdragon flower in T_3 (600 mg L-1) 9.17, followed by T_4 (900 mg L-1) 8.50, T_1 (100 mg L-1) 7.66, T_2 (300 mg L-1) 7.08 as compared to T_0 (control) 5.92 which is the lowest quality of flowers (Fig. 10).

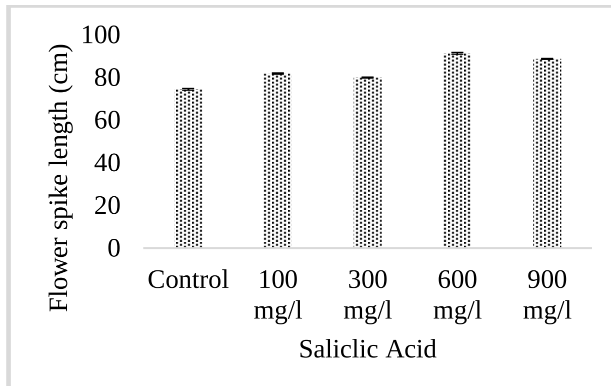


Fig. 9 Effect of foliar application of salicylic acid on flower spike length (cm) of *Antirrhinum majus* L.

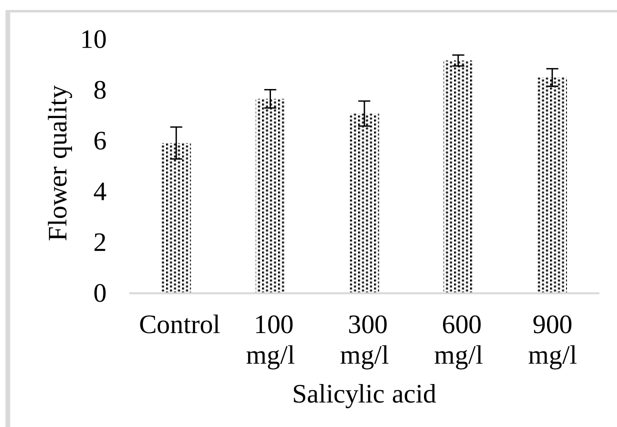


Fig. 10 Effect of foliar application of salicylic acid on flower quality of *Antirrhinum majus* L.

Flower diameter (mm)

Current indices result showed that the maximum flower diameter of T_1 (100 mg L^{-1}) 26.63 mm, followed by T_3 (600 mg L^{-1}) 25.62 mm as compared to T_0 (control) 20.18 mm which is minimum diameter of flowers (Fig. 11).

Total number of florets

The findings of this attribute showed that the total number of florets on T_4 (900 mg L^{-1}) 35.17, followed by T_1 (100 mg L^{-1}) 32.57, T_3 (600 mg L^{-1}) 28.58, T_2 (300 mg L^{-1}) 25.38 as compared to T_0 (control) 21.87 which is minimum number of florets were present (Fig. 12).

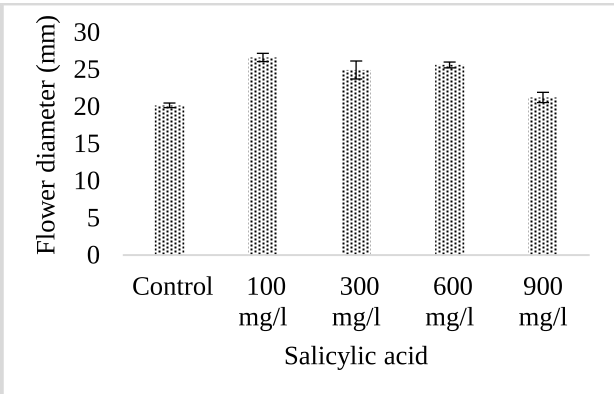


Fig. 11 Effect of foliar application of salicylic acid on flower diameter (mm) of *Antirrhinum majus* L.

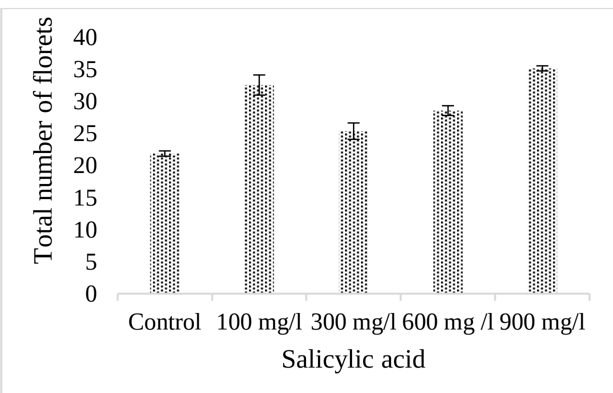


Fig. 12 Effect of foliar application of salicylic acid on total number of florets of *Antirrhinum majus* L.

Flower opening percentage

The data regarding flower opening percentage showed that the substantial superiority of T_1 (100 mg L^{-1}) 57.02, followed by T_3 (600 mg L^{-1}) 55.01, T_2 (300 mg L^{-1}) 54.38, T_0 (control) 48.40 as compared to T_4 (900 mg L^{-1}) 46.66 which is required less number of days to opening of flower. T_4 treatment of SA enhanced the opening of flowers in minimum days (Fig. 13). The investigation of this study was to check the effect of salicylic acid treatment enhanced flower opening percentage.

Leaf relative water content % (LRWC %)

Our research finding was shown that the highest leaf relative water content of T_3 (600 mg L^{-1}) 33.71 cm, followed by T_4 (900 mg L^{-1}) 33.67 cm, T_1 (100 mg L^{-1}) 32.23 cm, T_2 (300 mg L^{-1}) 31.49 cm as compared to T_0 (control) 29.31 cm which is the lowest LRWC (Fig. 14).

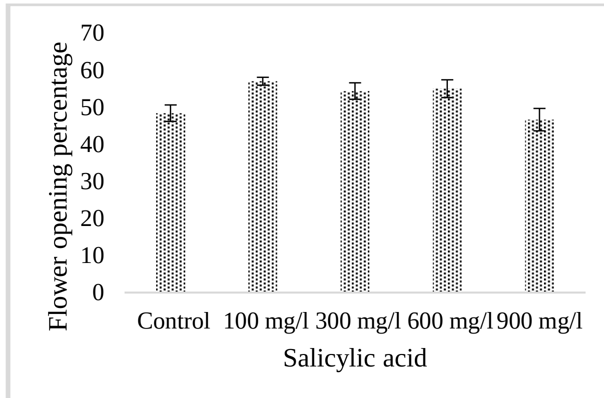


Fig. 13 Effect of foliar application of salicylic acid on flower opening percentage of *Antirrhinum majus* L.

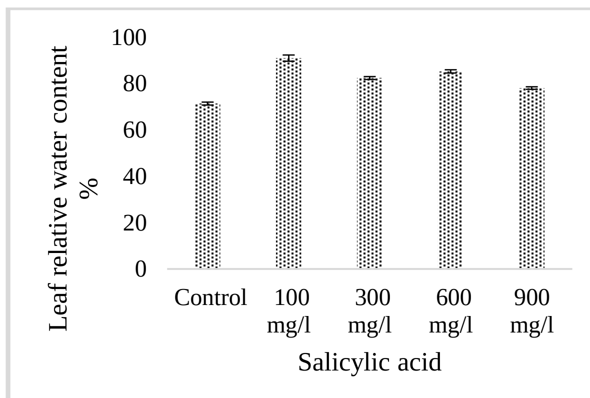


Fig. 14 Effect of foliar application of salicylic acid on leaf relative water content % of *Antirrhinum majus* L.

Membrane stability index %

The research result identified that the high membrane stability index of T_3 (600 mg L^{-1}) 33.71 cm, followed by T_4 (900 mg L^{-1}) 33.67 cm, T_1 (100 mg L^{-1}) 32.23 cm, T_2 (300 mg L^{-1}) 31.49 cm as compared to T_0 (control) 29.31 cm which is the less membrane stability index % (Fig. 15).

Solution uptake (ml)

The results of our study showed that the highest water uptake in solutions is T_1 (100 mg L^{-1}) 40.44 ml, followed by T_2 (300 mg L^{-1}) 35.17 ml, T_0 (control) 33.75 ml, T_3 (600 mg L^{-1}) 30.69 ml as compared to T_4 (900 mg L^{-1}) 29.96 ml having lowest water uptake in SA significantly improved solution absorption by reducing bacterial density in holding solutions containing solution and relatively increased in vase life of snapdragon flower (Fig. 16).

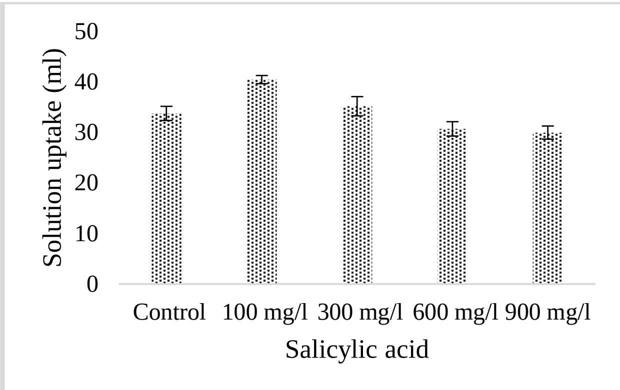


Fig. 15 Effect of foliar application of salicylic acid on membrane stability index % of *Antirrhinum majus* L.

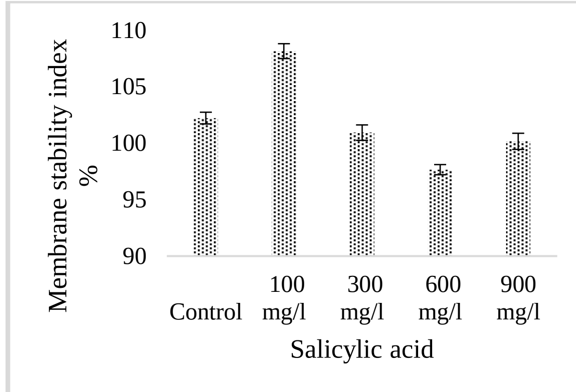


Fig. 16 Effect of foliar application of salicylic acid on solution uptake (ml) of *Antirrhinum majus* L.

Vase life (days)

As for as main post-harvest attribute vase life was concerned, our findings exhibited that the use of lower concentration of SA solution enhanced the vase life of *Antrrihinum majus* L. as in T_1 (100 mg L^{-1}) 8.75 days, followed by T_2 (300 mg L^{-1}) 8.52 days, T_0 (control) 7.92 days, T_3 (600 mg L^{-1}) 7.50 days, and 6.67 days in T_4 (900 mg L^{-1}) decreased the shelf life of flowers (Fig. 17).

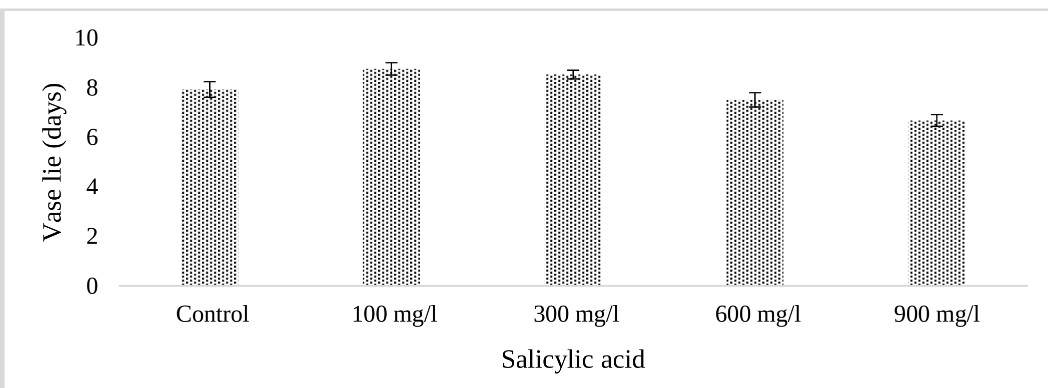


Fig. 17 Effect of foliar application of salicylic acid on vase life (days) of *Antirrhinum majus* L.

Discussion

In cut flowers, plant height is an important feature and a quality indication. It is an important criterion for determining the growth standard. Plant height varies depending on the kind or cultivar, as well as the application of varying degrees of growth-regulating substances. Anwar et al. (2014) studied the consequences of pre-harvest application of the salicylic acid on growth and shelf life of tuberose with aroma environment and shows that maximum plant height 91.30 cm was attained when salicylic acid at 1mM/L rate followed by 85.03 cm when salicylic acid at the rate of 0.5 mM/L while 77.11 cm plant height was recorded in control which is least one. The data regarding the number of leaves are similar according to Gharib (2008) Salicylic acid foliar spray increased the number of leaves per plant in sunflowers. Alike, Orabi et al. (2010) studied that SA increased the number of cucumber leaves per plant. Ram et al., (2012) investigated the effects of different spacing and SA levels on gladiolus growth and flowering and discovered that higher levels of salicylic acid at the rate of 100 ppm resulted in the utmost number of leaves in each plant (11.83), the longest leaf length (68.64 cm), and the widest leaf width (3.03 cm), while lower levels of salicylic acid (100 ppm) lead to the lowest number of leaves (8.73). A study indicated that in the consequences of pre-harvest salicylic acid application on tuberose growth and shelf life in an aroma environment and discovered that plants treated with 1 mM salicylic acid produced the most leaves (25), followed by 20.33 when treated with 0.5 mM, and the least number of leaves (17.87) in the control. The number of leaves is increased by raising the internodes distance, and the number of leaves is reduced by decreasing the internodes distance. At high SA concentrations, the number of leaves increased. At low levels of SA and control, the smallest leaves are obtained. It means that as the concentration of salicylic acid grew, the number of leaves increased as well while 1 mM SA produced the most leaves (Anwar et al., 2014). The correct application of various concentrations of stress-relieving substances such as salicylic acid has a substantial impact on the growth of leaves (Khan et al., 2003). The data regarding leaf area are similar with Arfan et al. (2007) found that the highest concentration of salicylic acid provides an acceptable amount of photosynthesis, which can be employed to produce significant outcomes. The results were consistent with the highest leaf area (cm^2) of Lilium attained with foliar salicylic acid treatment. Some research findings were of *Impatiens walleriana* plants grown in drought stress and proved that the uppermost and lowest values of Chl a, Chl b, total chlorophyll, and carotenoids were detected in 95% FC (field capacity) + salicylic acid (SA) 2mM. SA application increased chlorophyll concentration in both well water and water-stressed settings (Safari et al., 2022).

The data regarding production time (days) are similar to Siddique et al. (2007) found that exogenous administration of salicylic acid accelerated the development of floral buds in *A. hippeastrum*. And also studied flower bud emergence in the same flower and demonstrated that SA treatment improved flower bud emergence. A study was investigated in similar to the Sakhanokho and Kelley (2009) who observed that adding salicylic acid to antirrhinum decreased the number of days it took to flower. A study was investigated the consequences of benzyl-adenine and SA on the physiological and biochemical attributes of Asiatic hybrid Lilium 'Navona,' finding that foliar spray of SA at 0.10 mM results in the largest stem diameter (0.66 cm), while the control (0.52 cm) has the smallest of all treatments (Abbasi et al., 2020). The data regarding plant fresh weight are similar to Shakib et al. (2012) when foliar salicylic acid was applied to *cyclamen persicum*, similar results were obtained, and maximal fresh mass was produced. Exogenous administration of SA therapy to salinity-affected roses produced similar outcomes, with SA increasing fresh mass (Tehranifar et al., 2013). The visible components of the plant are the flower heads and foliage, and turgidity is vital for producing a desirable product. Salicylic acid's stress-relieving ability boosts plant fresh mass via increasing water uptake. Salicylic acid spray boosts the plant's fresh mass (Tehranifar et al., 2013). The data regarding plant dry weight (g) are similar to Fariduddin et al. (2003) when minor concentrations of SA were sprayed on *Brassica juncea*, found a considerable increase in dry matter accumulation. Higher salicylic acid concentrations, on the other hand, showed an inhibitory effect. Exogenous foliar spary of SA to saline-affected roses enhanced their dry mass, and the maximum value was attained at a substantial quantity of salicylic acid when employed at varied concentration levels to assist the plant against stress conditions (Tehranifar et al., 2013).

The data regarding flower spike length was according to Saeed et al. (2019) when studying the reaction of gerbera (*Gerbera jamesonii*) cv. 'Great Smoky Mountains' to the foliar treatment of spermidine, putrescine, and salicylic acid and discovered that application of salicylic acid exhibited substantial increases in this regard as compared with control. SA's foliar spray at a dosage of 200 mg/l resulted in the longest length of the flower stem, which was comparable to the 100 mg/l treatment. The study was investigated the response of morphological and physiological growth parameters in gladiolus cultivar 'White Prosperity' to the foliar treatment of plant growth regulators and discovered that SA enhanced spike length 48.63 cm compared to non-treated plants (Sajjad et al., 2014). The data regarding flower quality was similar to Ikram et al. (2012) when they studied tuberose flowers had the best value of flower quality when SA was used at a concentration of 100 mg L^{-1}. As plants respond to changes in hormonal balance, PGR balance affects the quality and size of flowers. Different amounts of salicylic acid are used to enhance the ornamental appearance of rose-cut flowers (Ram et al., 2012). The data regarding flower diameter (mm) are similar to Bandurska and Stroinski's (2005) studies when the favorable consequences of SA application and time on lilium flower diameter were proven. Exogenous application of salicylic acid considerably boosted the number of blooms in tomato cv. 'Super Strain' during two consecutive seasons (Mady, 2009). A study was shown in the effect salicylic acid increases the display life and improves the post-harvest quality of Antirrhinum majus and also has maximum flower diameter in the following treatment of 2 mM SA (Farooq et al., 2021).

The study of different spacing and SA concentration on gladiolus growth and flowering and discovered that with 100 ppm salicylic acids the highest number of florets per spike (14.97) was observed, while the minimum number of florets (11.95) was observed under control (Ram et al., 2012). The data regarding flower opening percentage are similar with Asif et al. (2016) studied the influence of pulsing with different preservatives on the postharvest performance of cut Polianthes tuberosa L. 'Single' spikes and found a highly significant difference among various treatments for flower opening percentage. The highest percentage (90 %) was obtained with 10 percent sucrose + 50 mg/l SA while the lowest flower opening percentage (70 %) was with control. The maximum level of SA was 150 mg L-1, which was 14 percent greater than control and statistically equivalent to SA level 100 mg L-1. A larger concentration of SA did not increase the proportion of open florets, but it did generate better results than the control (Saeed et al., 2016). The data regarding membrane stability index are concerned, Abdolmaleki et al. (2015) observed that control samples in the 'Dolce vita' cultivar had the most electrolyte leakage, whereas plants treated with SA at 150 mg L-1 SA and $CaCl_2$ at 0.75 percent concentration had the lowest. SA also aids membrane function maintenance (Gunes et al., 2007). SA also enhanced membrane permeability (Kazmi et al., 2011). When SA was administered to the chrysanthemum, it had a similar effect on membrane stability (Mansouri, 2012). An experiment was conducted on the anti-oxidative activity and qualitative deviations in the cut flower of gladiolus in response to SA treatment, finding that membrane leakage increased with time throughout the vase period but stayed reduced with SA administration in vase solution. When given 150 mg L-1 SA, ion leakage was significantly decreased, while it increased at lower concentrations and in the control group (Saeed et al., 2016).

Farooq et al. (2021) found that SA significantly increased the membrane stability index. The SA at 2 mM was found to be very effective in maintaining membrane stability in petal tissues compared to control by reducing membrane lipid peroxidation via inhibition of LOX activity. The investigated study of the consequences of pre-harvest foliar applications of calcium chloride and SA on the shelf life of cut rose cv. ‘Dolce vita,' found that both SA and CaCl2 increased the LRWC of the rose cultivar. When treated with salicylic acid at 150 mg/l SA with CaCl2 at 0.75 percent concentration, the greatest LRWC for ‘Dolce vita' was 79.17 percent. The control plants had the smallest amount of LRWC (Abdolmaleki et al., 2015). The data regarding solution uptake was similar to Jamshidi et al. (2012) studied the consequences of SA and malic acid (MA) on shelf life and bacterial and yeast populations of preserving solution in cut gerbera flower and found that maximum solution uptake per day was 5.08 ml was obtained when 1 mM salicylic acid and 2 mM MA concentration was used while in control solution uptake was 4.02 ml. The least amount of bacterial growth (Farooq et al., 2021). An experiment was examined the effect of hormone pre-harvest sprays on spike quality and vase life of Asiatic lilium cv. treor and discovered that the treatment of 100 μM salicylic acid (143.90 ml) resulted in the highest water uptake, while in control the lowest water uptake was 120 ml (Kumari et al., 2018).

The data regarding vase life is similar with Alaey et al. (2011), investigated the consequences of pre-harvest and postharvest SA spray on physio-chemical properties in connection to the shelf life of cut flowers of rose and discovered that treatment with SA, regardless of concentration, considerably enhanced the shelf life of cut flowers at 7ºC. Flowers that were sprayed with water and placed in vase solutions containing 50 μM SA (WS-50 μM SA) and 100 μM SA (WS-100 μ M SA) lasted 90 and 86 days, respectively. Cut flowers stored in non-treated and WS-50 μM SA vase solutions had a vase life of 6 and 26 days respectively at 22º ± 2ºC. are According to Abdolmaleki et al. (2015) found that the pre-harvest foliar application of calcium chloride and salicylic acid improved vase life of cut rose cv.'Dolce viva'. A study was investigated on the efficacy of SA in delaying petal senescence and extending the quality of *G. grandiflora* cv. wing's sensation' cut spikes, finding that 150 mg L^{-1} salicylic acid was the most effective for extending the shelf life of gladiolus cut spikes, followed by 100 and 200 mg L^{-1} (Hatamzadeh et al., 2012). Saeed et al., (2016) found that the 150 mg L-1 SA application gave gladiolus cut flowers the longest vase life during both years. The higher amount of SA did not extend the shelf life anymore, although it was better than the control in some concentrations, while the higher concentration was lower than the control. Farooq et al., (2021) also show similar results when they use SA at 1, 2 and 3 mM concentrations, it was discovered that spikes lasted 10.5, 14, and 12 days, respectively. In contrast to the control, spikes of *Antrrihinum majus* that had been clipped were preserved in distilled water for 8 days, showing that greater SA concentrations were most efficient at postponing floral senescence. They also described that the effect salicylic acid enhances the vase life and improves the postharvest attributes of *Antirrhinum majus*.

Conclusion

The findings led to the conclusion that salicylic acid is critical for Antirrhinum growth, development and vase life and flower longevity. It is possible to achieve a considerable yield from a flowering crop by using the right concentration of salicylic acid (SA). Salicylic acid increased the biomass production, improved flower quality, maintained membrane stability index, high stem length and delayed the senescence of the Snapdragon flower. According to the findings of the current study, 600 mg/l salicylic acid concentration gave best results, whereas for post-harvest parameters 100 mg/l salicylic acid concentration performed better. In summary, farmers need to provide 600 mg/l salicylic acid for more or better biomass production of Antirrhinum, while for better vase life of cut flowers 100 mg/l concentration of salicylic acid would be good enough. Using the best concentration of SA can improve vase life of cut flowers.

Conflict of Interest: The authors declare that there is no conflict of interest.

Reference

Abbasi, F., Khaleghi, A., Khadivi A., & Solgi, M. (2020). The effect of benzyl-adenine and salicylic acid on morphological and biochemical traits of Asiatic hybrid lilium ‘Navona’. *Gesunde Pflanzen, 72*, 219-225.

Abdelaal, K. A., Attia, K. A., Alamery, S. F., ElAfry, M. M., Ghazy, A. I., Tantawy, D. S., AlDoss, A. A., El-Shawy, E. S. E. A., Abu-Elsaoud, M., & Hafez, Y. M. (2020). Exogenous application of proline and salicylic acid can mitigate the injurious impacts of drought stress on barley plants associated with physiological and histological characters. *Sustainability*, *12*, 1736.

Abdolmaleki, M., Khosh-Khui, M., Eshghi, S., & Ramezanian, A. (2015). Improvement in vase life of cut rose cv. ‘Dolce Vita’ by pre-harvest foliar application of calcium chloride and salicylic acid. *International Journal of Horticultural Science*, *2*, 55-66.

Ahmad, I., & Dole, J. M. (2014). Optimal postharvest handling protocols for *Celosia argentea* var. cristata L. ‘Fire Chief’ and *Antirrhinum majus* L. cv. ‘Chantilly Yellow’. *Scientia Horticulturae, 172*, 308-316.

Ahmad, I. (2009). Production potential and postharvest management of cut rose flowers in Punjab (Pakistan).

Ph.D. Thesis, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan.

Alaey, M., Babalar, M., Naderi, R., & Kafi, M. (2011). Effect of pre- and postharvest salicylic acid treatment on physiochemical attributes in relation to vase life of rose cut flowers. *Postharvest Biology and Technology, 61*, 91-94.

Anwar, M., Sahito, H. A., Hasan, I., Abbasi, N. A., Ahmed, H. A., Bhatti, M. A., Hussain, A., Iqbal, Z., & Abro, A. H. (2014). Effect of pre-harvest treatment of salicylic acid on growth and vase life of tuberose with aroma environment. *World Journal of Agricultural Research, 3*, 50-57.

Arfan, M., Athar, H. R., & Ashraf, M. (2007). Does the exogenous application of salicylic acid through the rooting medium modulate growth and photosynthetic capacity in two differently adapted spring wheat cultivars under salt stress. *Journal of Plant Physiology, 164*, 685-694.

Asif, M., Ahmad, I., Qasim, M., & Ahmad, R. (2016). Effect of pulsing with various preservatives on postharvest performance of cut *Polianthes tuberose* L. 'Single' spikes. *Pakistan Journal of Agricultural Science, 53*, 331-338.

Bandurska, H., & Stroinski, A. (2005). The effect of salicylic acid on barley response to water deficit. *Acta Physiologiae Plantarum, 27*, 379-386.

Carleton, A. F., & Foote, W. H. (1965). A comparison of methods for estimating the total leaf area of barley plants. *Crop Science, 5*, 602-603.

Celikel, F. G., Cevallosa, C. J., & Michael, S. R. (2010). Temperature, ethylene and the postharvest performance of cut snapdragon (*Antirrhinum majus* L.). *Scientia Horticulturae, 125*, 429-433.

Cooper, R. J., & Spokas, L. A. (1991). Growth, quality and foliar iron concentration of Kentucky bluegrass treated with chelated iron source. *American Society for Horticultural Science, 116*, 1437-1448.

Dest, W. M., & Guillard, K. (1987). Nitrogen and Phosphorus nutritional influence on the bentgrass. *American Society for Horticultural Science, 112*, 769-773.

Dorling, K. (2008). RHS A-Z encyclopedia of garden plants. The United Kingdom. pp.1136.

Fariduddin, Q., Hayat, S., & Ahmad, A. (2003). Salicylic acid influences net photosynthetic rate, carboxylation activity in relation to vase life of gladiolus cut flowers. *Plant Growth Regulation. 51*, 99-108.

Farooq, S., Haq, A. U., Lone, M. L., Parveen, S., Altaf, F., & Tahir, I. (2021). Salicylic acid enhances the vase life and improves the postharvest attributes –A case study of *Antirrhinum majus* L. *East African Scholars Journal of Agriculture and Life Sciences, 5*, 87-96.

Gad, M. M., Abdul-hafeez, E. Y., & Ibrahim, O. H. M. (2016). Foliar application of salicylic acid and gibberellic acid enhances growth and flowering of *Ixora coccinea* L. plants. *Journal of Plant Production Mansoura University, 7*, 85-91.

Gharib, F. A. L. (2008). Effect of salicylic acid on the growth, metabolic activities and oil content of basil and marjoram. *International Journal of Agriculture and Biology, 4*, 485-492.

Gonzalez, L., & Gonzalez-Vilar, M. (2001). Determination of relative water content handbook of plant ecophysiology techniques reigoa, M.J. Kluwer Academic Publishers. Dordrecht, *The Netherlands*, 207-212.

Gunes, A., Inal, A., Alpaslan, M., Eraslan, F., Bagci, E. G., & Cicek, N. (2007). Salicylic acid-induced changes on some physiological parameters symptomatic for oxidative stress and mineral nutrition in maize (*Zea mays* L.) grown under salinity. *Journal of Plant Physiology, 164*, 728-736.

Hatamzadeh, A., Hatami, M., & Ghasemnezhad, M. (2012). Efficiency of salicylic acid delays petal senescence and extended quality of cut spikes of *Gladiolus grandiflora* cv. 'wing's sensation'. *African Journal of Agricultural Research, 7*, 540-545.

Heidarnezhadian, H., Eghbali, B., & Kazemi, M. (2017). Postharvest life of cut Gerbera flowers as affected by salicylic acid and citric acid. *Trakia Journal of Science, 15*(1), 27-29.

Hemati, E., Daneshvar, M. H., & Heidari, M. (2019). The roles of sodium nitroprusside, salicylic acid, and methyl jasmonate as hold solutions on vase life of Gerbera jamesonii 'Sun Spot'. *Advances in Horticultural Science, 33*, 187-195.

Ikram, S., Habib, U., & Khalid, N. (2012). Effect of different potting media combinations on growth and vase life of tuberose (*Polianthus tuberosa* L.). *Pakistan Journal of Agricultural Sciences, 49*, 121-125.

Jamshidi, M., Hadavi, E., & Naderi, R. (2012). Effects of salicylic acid and malic acid (MA) on vase life and bacterial and yeast populations of preservative solution in cut gerbera flower. *International Journal of Agricultural Sciences, 2*, 671-674.

Kazmi, M., Hadavi, E., & Hekmati, J. (2011). Role of salicylic acid in decreases of membrane senescence in cut carnation flowers. *American Journal of Plant Physiology, 6*, 106-112.

Khan, W., Prithiviraj, B., & Smith, D. L. (2003). Photosynthetic response of corn and soyabean to foliar application of salicylates. *Journal of Plant Physiology, 160*(5), 485-492.

Kumari, S., Kumar, S., & Singh, C. P. (2018). Effect of pre-harvest sprays of hormones on spike quality and vase life of Asiatic lilium cv. treor. *The Pharma Innovation Journal, 7*, 470-473.

Mady, M. A. (2009). Effect of foliar application of salicylic acid and vitamin E on growth and productivity of tomato (*Lycopersicum esculentum* Mill.) plant. *Journal of Agricultural Science, 34*, 6735-6746.

Mansouri, H. (2012). Salicylic acid and sodium nitroprusside improve post-harvest life of chrysanthemum. *Scientia Horticulturae, 145*, 29-33.

Mateo, A. F. D., Muhlenbock, P., Kular, B., Mullineaux, P. M., & Karpinski, S. (2006). Controlled levels of salicylic acid are required for optimal photosynthesis and redox homeostasis. *Journal of Experimental Botany, 57*, 1795-1807.

Metwally, A., Finkemeier, I., Georgi, M., & Dietz, K. (2003). Salicylic acid alleviates the cadmium toxicity in barley seedlings. *Plant Physiology, 132*, 271-281.

Orabi, S. A., Salman, S. R., & Shalaby, M. A. F. (2010). Increasing resistance to oxidative damage in cucumber (*Cucumis Sativus* L.) plants by exogenous application of salicylic acid and paclobutrazol. *World Journal of Agriculture Sciences, 6,* 252-259.

Radwan, D. E. M., Mohamed, A. K., Fayez, K. A., & Abdel Rahman, A. M. (2019). Oxidative stress caused by Basagran herbicide is altered by salicylic acid treatments in peanut plants. *Heliyon, 5*, 01791.

Ram, M., Pal, V., Singh, M. K., & Kumar, M. (2012). Response of different spacing and salicylic acid levels on growth and flowering of gladiolus (*Gladiolus grandiflora* L.). *HortFlora Research Spectrum, 1,* 270-273.

Saeed, A. A. J. M., Abdulhadi, M. D., & Salih, S. M. (2019). Response of Gerbera (*Gerbera jamesonii*) cv. 'Great Smoky Mountains' to foliar application of putrescine, spermidine and salicylic acid. In IOP Conference Series: *Earth and Environmental Science. 388*, 112-120.

Saeed, T., Hassan, I., Abbasi, N. A., & Jilani, G. (2016). Antioxidative activities and qualitative changes in gladiolus cut flowers in response to salicylic acid application. *Scientia Horticulturae, 210*, 236-241.

Safari, M., Mousavi-Fard, S., Nejad, A. R., Sorkheh, K., & Sofo, A. (2022). Exogenous salicylic acid positively affects morpho-physiological and molecular responses of *Impatiens walleriana* plants grown under drought stress. *International Journal of Environmental Science and Technology, 19,* 969-984.

Sajjad, Y., Jaskani, M. J., Ashraf, M. Y., Qasim, M., & Ahmad, R. (2014). Response of morphological and physiological growth attributes to foliar application of plant growth regulators in gladiolus cultivar 'White Prosperity. *Pakistan Journal of Agricultural Sciences, 51*, 123-129.

Sakhanokho, H. F., & Kelley, R. Y. (2009). Influence of salicylic acid on in vitro propagation and salt tolerance in *Hibiscus acetosella* and *Hibiscus moscheutos* (cv. 'Luna Red'). *African Journal of Biotechnology, 8*, 1474-1481.

Shakib, M. F., Naderi, R., & Boojar, M. M. A. (2012). Effect of salicylic acid application on morphological, physiological and biochemical characteristics of *Cyclamen persicum* Miller. *Annals of Biological Research, 3*, 5631-5639.

Siddique, M. N. A., Sultana, N., Haque, M. A., & Hossain, M. M. (2007). Ex vitro establishment of in vitro produced plantlets and bulblets of Hippeastrum (*Hippeastrum hybridum*). *International Journal of Sustainable Crop Production, 2*, 22-24.

Steel, R. G. D., Torrie, J. H., & Dickey, D. A. (1997). Principles and Procedures of Statistics. A Biometrical Approach. 3rd Ed. McGraw Hill Book Co., Inc., New York, USA. pp. 336-352.

Tehranifar, A., Vahdati, N., Selahvarzi, Y., & Bayat, H. (2013). Treatment with salicylic acid extends the vase life of important commercial cut flowers. *Advanced Crop Science, 3,* 405-413.