Response of Gerbera (Gerbera jamesonii) cv. 'Great Smoky Mountains' to Foliar Application of Putrescine, Spermidine and Salicylic Acid

A A J Mohammad Saeed¹; M D Abdulhadi¹ and S M Salih²

¹, Department of Horticulture and Landscape /College of Agriculture / University of Diyala. Iraq. ², General Directorate of Vocational Education / Ministry of Education. Iraq.

E-mail: kareemommadm56@yahoo.com

Abstract. The experiment was carried out in the lath house at the Station Research of Horticulture and Landscape Department/College of Agriculture/University of Diyala, Iraq for the fall season 2016-2017. The experiment included two factors, first one foliar application with polyamines (PAs), putrescine and spermidine, at concentrations of 0 (distilled water as control), 50 and 100 mg.l⁻¹ of putrescine, and 50, 100 mg.l⁻¹ of spermidine. The second factor was foliar spray with salicylic acid (SA) at concentrations of 0, 100 and 200 mg.l⁻¹. Foliar application of PAs (putrescine and spermidine) led to enhance all vegetative growth and flowering qualities of gerbera (Gerbera jamesonii) cv. 'Great Smoky Mountains'. Treatment with 100 mg.l⁻¹ of spermidine gave the best results in terms of number of leaves, leaves area, relative chlorophyll content of leaves, flowering date, length and diameter of flower stalk, percentage of dry material in flowers. While, treatment with 100 mg.l⁻¹ of putrescine gave the best results in terms of percentage of leaves dry material, number of flowers, and flower diameter. Foliar spray with SA affected positively in most vegetative and flowering qualities of gerbera, the best results were achieved when sprayed with 200 mg.l⁻¹ in terms of percentage of leaves dry material, number of flowers, flower diameter, flower stalk length, percentage of flowers dry material. While, spraying with 100 mg.l⁻¹ gave the best results in terms of number of leaves, leaves area, relative chlorophyll content of leaves, flowering date and diameter of flower stalk. Interaction between PAs (putrescine and spermidine) and SA showed significant improvement in all vegetative and flowering characters of gerbera. Treatment of 100 mg.l⁻¹ of spermidine combined with 100 mg.l⁻¹ of salicylic acid gave the best results in terms of number of leaves, leaf area, relative chlorophyll content in leaves, flowering date, flower diameter, length and diameter of flower stalk, percentage of flowers dry material. Treatment of 100 mg.l⁻¹ of putrescine combined with 200 mg.l⁻¹ of salicylic acid was surpassed in giving best total content of carbohydrate in leaves and number of flowers.

1. Introduction
Gerbera (Gerbera jamesonii Bolus ex. Hook f.) is one of ten popular cut flowers in the world and according to the global trends in floriculture; it ranks fourth in the international cut flower market and a popular cut flower in Holland, Germany and USA [1]. The flowers have a variety of colors including yellow, orange, pink, red, purple, and white. It is indigenous to the southern part of Africa, Madagascar, Asia, and Indonesia [2]. Despite the popularity of gerbera flower, this flower is short-
lived [3]. Variety in color has made this flowering plant attractive for use in garden decorations, such as herbaceous borders, bedding, and pots and for cut flowers as it has a long vase life [4; 5; 6]. Modern gerbera arose from Gerbera jamesonii hybridized with Gerbera viridifolia and possibly other species [7]. Gerbera belongs to the family Asteraceae and can be propagated by both sexual and asexual methods. Most of the commercially grown cultivars are propagated through vegetative means, to maintain uniformity and genetic purity [8].

Polyamines (PAs) are low molecular weight polycations, organic, biogenic amines that are found in all eukaryotic and most prokaryotic cells [9; 10] and have profound effects on growth, development and senescence in eukaryotic cells [11]. In plants, di-amine putrescine (Put), triamine spermidine (Spd) and tetra-amine spermine (Spm) are frequently present in amounts varying from micro molars to more than mill molars [12]. PAs (Put, Spm and Spd) are recognized as a new class of plant growth bioregulators [13]. They influence many biochemical and physiological processes such as cell division, cell elongation, flowering, fruit set and development, fruit ripening, and senescence, storage life [14; 15]. The various plant growth and developmental processes affected by PAs include stimulation the cell division, response to environmental stress and regulation of rhizogenesis, embryogenesis, fruit and flower development [16]. Several studies have examined the effect of PAs on the growth and flowering of many plants. These studies showed positive effects of these compounds in an improving vegetative and flowering growth of dahlia [10], chrysanthemum [17], rose [18], and gerbera [19].

Salicylic acid (SA) is a phenolic derivative, distributed in a wide range of plant species. It is a natural product of phenylpropanoid metabolism. SA has direct involvement in plant growth, thermogenesis, flower induction and uptake of ions. It affects ethylene biosynthesis, stomatal movement and also reverses the effects of ABA on leaf abscission. Enhancement of the level of chlorophyll and carotenoid pigments, photosynthetic rate and modifying the activity of some of the important enzymes are other roles assigned to SA [20]. Previous studies have indicated the response of many plants to the application of SA and its positive role in improving vegetative and flowering growth of china aster [21], Calendula officinalis [22], and rose [23]. The main objective of the study was to investigate the effect of foliar application of polyamines (putrescine and spermidine) and salicylic acid on growth and flowering of Gerbera jamesonii, cv. ‘Great Smoky Mountains’.

2. Materials and methods

The experiment was carried out in the lath house at the station research of Horticulture and Landscape Department/College of Agriculture/University of Diyala, Iraq for the fall season 2016-2017. Gerbera seeds (Gerbera jamesonii) cv. ‘Great Smoky Mountains’, were planted in cork plates containing Peat Moss. After seeds germination, seedlings were transferred to 25 cm diameter plastic pots containing a sandy loam soil. Soil culture was analyzed in the laboratory of Soil and Water Resources Department/College of Agriculture/University of Diyala, Iraq, Table (1).

Plants were fertilized with chemical fertilizer named King Life Fruit (GREEN company HAS ITALIA SPA- Italy) consisting of N, P, K (18 – 9.5 – 6) % with magnesium (Mg 4%), boron (B 2%), Iron (Fe 0.80%), manganese (Mn 0.80%), molybdenum (Mo 0.08%) and zinc (Zn 0.80%), as a foliar application every week throughout the experiment period, at a rate of 1g.l⁻¹ as recommended by the manufacturer. Service operations such as hoeing, weeding and control of insect and disease injuries were conducted whenever need arises. Plants irrigated by using drip irrigation system.

The experiment included two factors, first one spray with polyamines (PAs), putrescine and spermidine, at concentrations of 0 (distilled water as control), 50 and 100 mg.l⁻¹ of putrescine, and 50, 100 mg.l⁻¹ of spermidine symbolized by PAO, Put50, Put100, Spd50 and Spd100, respectively. Plants sprayed twice, after 60 days from transplanting and after 10 days from the first spray. The second factor was spray with salicylic acid (SA) at concentrations of 0, 100 and 200 mg.l⁻¹ symbolized by SA0, SA100 and SA200, respectively. Plants sprayed twice, the first was conducted two days after spraying plants with PAs and after 10 days from the first spray. Tween-20 was added at concentration of 0.1%, as a surfactant compound, plants sprayed with concentrations used until complete wetting by...
2 liters capacity hand sprayer. The experiment was designed as a factorial experiment in Randomized Complete Blocks Design (RCBD) with three replicates, 6 pots for each experimental unit. The data were analyzed according to the statistical program SAS (2003). Means were compared using Duncan's Multiple Range Test (DMRT) (P>0.05).

| Table 1 | Some of chemical and physical properties of soil culture. |
|---------------------------------|----------------------------------|-----------------|
| The character                   | The value                        | The unit        |
| P H (1:1)                       | 7.17                             | -               |
| EC (1:1)                        | 2.38                             | dS.m$^{-1}$     |
| Soil Separation                 |                                  |                 |
| Clay                            | 100.1                            | g.kg$^{-1}$     |
| Silt                            | 68.1                             | g.kg$^{-1}$     |
| Sand                            | 831.8                            | g.kg$^{-1}$     |
| Organic material                | 2.829                            | %               |
| Available N                     | 35.11                            | g.kg$^{-1}$     |
| Available P                     | 4.01                             | g.kg$^{-1}$     |
| Available K                     | 251.241                          | g.kg$^{-1}$     |
| Calcium                         | 5.01                             | Mmol.l$^{-1}$   |
| Magnesium                       | 4.2                              | Mmol.l$^{-1}$   |

The Experimental measures included the vegetative characters such as number of leaves.plant$^{-1}$, leaves area.plant$^{-1}$, relative content of chlorophyll in leaves, percentage of leaves dry material, total content of carbohydrates in leaves, and flowering characters such as flowering date, number of flowers.plant$^{-1}$, flower diameter, length and diameter of flower stalk and percentage of flowers dry material. Total carbohydrate content in leaves was estimated according to the method mentioned by [24].

3. Results

3.1. Vegetative characters:

3.1.1. Number of leaves per plant:
Data in table 2 indicate that number of leaves per plant was increased due to PAs treatments. However, the highest number of leaves per plant was registered by spermidine treatment at concentration of 100 mg.l$^{-1}$ (31.18). Moreover, all tested applications of SA showed significant increments in this respect. The highest number of leaves per plant was gained by 100 mg.l$^{-1}$ treatment (30.15) as compared with control. The interaction effect between PAs and SA at all concentrations led to increase the number of leaves per plant. However, the highest number of leaves per plant (35.55) was recorded by the interaction between spermidine at 100 mg.l$^{-1}$ combined with SA at 100 mg.l$^{-1}$ with control. Generally, the highest leaves area per plant (733.11 cm$^2$) was recorded by the combined treatment between 100 mg.l$^{-1}$ of spermidine and 100 mg.l$^{-1}$ of SA.

3.1.2. Leaf area (cm$^2$):
Data in table 2 illustrate that all tested PAs significantly succeeded in increasing the leaves area as compared with control. However, foliar spray with 100 mg.l$^{-1}$ of spermidine gave the highest leaf area (563.17 cm$^2$) which on par with treatment of 100 mg.l$^{-1}$ of putrescine (538.12 cm$^2$). Moreover, all SA treatments increased the leaves area per plant significantly, particularly SA treatment at concentration of 100 mg.l$^{-1}$ (535.04 cm$^2$). Referring to the interaction effect between PAs and SA, it was found that all interactions between PAs and SA increased the leaves area per plant as compared.
Table 2. Response of vegetative characters of gerbera (*Gerbera jamesonii* Bolus ex. Hook f.) cv. Great Smoky Mountains to foliar spray with putrescine, spermidine and salicylic acid.

| Characters | Treatments | Number of leaves per plant | Leaves area (cm²) | Relative chlorophyll content (SPAD unit) | Percentage of leaves dry material (%) | Total carbohydrate percentage in leaves (%) |
|------------|------------|----------------------------|------------------|----------------------------------------|--------------------------------------|---------------------------------------------|
| **Effect of PAs** | **PA0** | 23.26 d | 1403.78 d | 45.59 d | 17.33 c | 18.07 b  |
| | **Put50** | 26.70 b | 1512.78 b | 48.03 c | 18.95 ab | 20.44 a  |
| | **Put100** | 27.26 b | 1538.12 ab | 49.08 b | 19.27 a | 20.92 a  |
| | **Spd50** | 25.48 c | 1472.89 c | 47.29 c | 18.49 b | 20.99 a  |
| | **Spd100** | 28.18 a | 1563.17 a | 49.99 a | 19.21 a | 20.92 a  |
| **Effect of SA** | **SA0** | 24.42 b | 1440.67 | 45.98 b | 17.86 c | 19.85 a  |
| | **SA100** | 27.15 a | 1535.04 a | 49.03 a | 18.84 b | 20.26 a  |
| | **SA200** | 26.98 a | 1518.74 a | 48.99 a | 19.21 a | 20.69 a  |
| **Effect of PA × SA** | **PA0** | **SA0** | 19.55 f | 1280.77 i | 41.58 h | 15.59 h | 16.40 c  |
| | **SA10** | 23.89 e | 1414.98 | 46.25 fg | 17.06 g | 18.13 bc  |
| | **SA20** | 26.33 cd | 1515.61 | 48.95 bcd | 19.34 bc | 19.69 ab  |
| | **Put50** | **SA0** | 25.66 d | 1483.10 | 46.57 efg | 18.44 cdef | 20.25 ab |
| | **SA10** | 26.22 cd | 1506.50 | 47.41 def | 18.50 cdef | 20.32 ab  |
| | **SA20** | 28.22 b | 1548.75 | 50.10 b | 19.92 b | 20.76 a  |
| | **Put100** | **SA0** | 27.44 bc | 1550.86 | 49.26 bc | 19.31 bc | 20.70 a  |
| | **SA10** | 28.22 b | 1571.12 | 49.98 b | 19.80 b | 20.95 a  |
| | **SA20** | 26.11 cd | 1492.39 | 48.00 cde | 18.70 cde | 21.10 a  |
| | **Spd50** | **SA0** | 25.22 de | 1465.06 | 46.83 efg | 18.35 def | 20.90 a  |
| | **SA10** | 24.89 de | 1449.49 | 46.11 fg | 17.99 ef | 21.02 a  |
| | **SA20** | 26.33 cd | 1504.11 | 48.94 bcd | 19.13 bcd | 21.04 a  |
| | **Spd100** | **SA0** | 24.11 e | 1423.58 | 45.63 g | 17.60 fg | 21.00 a  |
| | **SA10** | 32.55 a | 1733.11 a | 55.42 a | 20.84 a | 20.90 a  |
| | **SA20** | 27.89 b | 1532.8 | 48.93 bcd | 19.17 bcd | 20.86 a  |

Means in each column followed by similar letters are not significantly different (P>0.05) according to Duncan's Multiple Range Test (DMRT).

3.1.3. Relative chlorophyll content (SPAD unit):
Data in table 2 indicate that all concentrations of PAs caused significant effects on relative chlorophyll content in leaves as compared with control. However, the highest relative chlorophyll content in leaves was registered by spermidine treatment at concentration of 100 mg.l⁻¹ (49.99 SPAD unit). Moreover, all tested applications of SA showed significant increments in this respect. The highest relative chlorophyll content in leaves was gained by 100 mg.l⁻¹ treatment (49.03 SPAD unit).
as compared with control. Combinations between PAs and SA caused significant increments in relative chlorophyll content in leaves as compared with control. However, the highest value of relative chlorophyll content in leaves (55.42 SPAD unit) was recorded by spermidine at 100 mg.l\(^{-1}\) combined with SA at 100 mg.l\(^{-1}\).

3.1.4. Percentage of leaves dry material (%): Data in table 2 show that the percentage of leaves dry material significantly increased by foliar spray with putrescine at concentration of 100 mg.l\(^{-1}\) (17.27%) as compared with control. Moreover, all SA treatments significantly increased the percentage of leaves dry material, particularly SA treatment at concentration of 200 mg.l\(^{-1}\) (17.25%) as compared with control. Interaction between PAs and SA concentrations, showed significant increase in the percentage of leaves dry material as compared with control. However, the highest value of the percentage of leaves dry material (18.86%) was recorded by the combined treatment between 100 mg.l\(^{-1}\) of spermidine and 100 mg.l\(^{-1}\) of SA.

3.1.5. Total carbohydrate percentage in leaves (%): Data in table 2 illustrate that all the concentrations of the PAs affected significantly in the total carbohydrate percentage in leaves as compared with control. However, the highest total carbohydrate percentage in leaves was registered by spermidine treatment at concentration of 50 mg.l\(^{-1}\) (18.99 %) which on par with the rest of PAs treatments. Moreover, there were no significant differences in total carbohydrate percentage in leaves when plants treated with SA. Combinations between PAs and SA caused significant increments in total carbohydrate percentage in leaves as compared with control. However, the highest value of total carbohydrate percentage in leaves (19.10 %) was recorded by putrescine at 100 mg.l\(^{-1}\) combined with SA at 200 mg.l\(^{-1}\).

3.2. Flowering characters:

3.2.1. Flowering date (day): Data in table 3 show that all the concentrations of the PAs were significantly affected the flowering date as compared with control. However, the least number of days for flowering was registered by spermidine treatment at concentration of 100 mg.l\(^{-1}\) (77.14 days). Moreover, all SA treatments significantly affected the flowering date and gave the least number of days for flowering, particularly SA treatment at concentration of 100 mg.l\(^{-1}\) (74.54 days) as compared with control. Interaction between PAs and SA concentrations showed significant decrease in flowering date compared with control. However, the least number for flowering days (71.90 days) was recorded by the combined treatment between 100 mg.l\(^{-1}\) of spermidine and 100 mg.l\(^{-1}\) of SA.

3.2.2. Number of flowers per plant: Data in table 3 indicate that number of flowers per plant increased significantly when plants treated with 100 mg.l\(^{-1}\) of putrescine (7.66) as compared with control. Moreover, all SA treatments significantly increased number of flowers per plant, particularly SA treatment at concentration of 200 mg.l\(^{-1}\) (6.82). Combinations between PAs and SA caused significant increments in number of flowers per plant as compared with control. However, the highest value of number of flowers per plant (7.77) was recorded by putrescine at 100 mg.l\(^{-1}\) combined with SA at 200 mg.l\(^{-1}\).

3.2.3. Flower diameter (cm): Data in table 3 illustrate that flower diameter increased significantly when plants treated with 100 mg.l\(^{-1}\) of putrescine (7.64 cm) as compared with control. Data show that foliar spray with SA had significant effect on flower diameter, particularly SA treatment at concentration of 200 mg.l\(^{-1}\) (7.58 cm) as compared with control. Interaction between PAs and SA concentrations, showed significant increments in flower diameter as compared with control. However, the highest value of flower
diameter (8.50 cm) was recorded by the combined treatment between 100 mg.l\(^{-1}\) of Spermidine and 100 mg.l\(^{-1}\) of SA.

**Table 3.** Response of flowering characters of gerbera (*Gerbera jamesonii* Bolus ex. Hook f.) cv. Great Smoky Mountains to foliar spray with putrescine, spermidine and salicylic acid.

| Effect of PAs | Characters | Flowering date (day) | Number of flowers per plant | Flower diameter (cm) | Length of flower stalk (cm) | Flower stalk diameter (mm) | Percentage of flowers dry material (%) |
|---------------|------------|----------------------|-----------------------------|----------------------|-----------------------------|---------------------------|-------------------------------------|
| PA0           |            | 76.62 a              | 15.48 c                     | 7.57 c               | 40.16 c                     | 5.92 d                    | 7.53 d                              |
| Put50         |            | 75.15 c              | 16.15 b                     | 8.40 ab              | 43.73 b                     | 6.83 b                    | 9.25 c                              |
| Put100        |            | 74.45 d              | 17.66 a                     | 8.64 a               | 44.50 a                     | 7.01 b                    | 11.41 b                             |
| Spd50         |            | 75.51 b              | 15.74 c                     | 8.17 b               | 43.01 b                     | 6.63 c                    | 11.00 b                             |
| Spd100        |            | 74.14 e              | 16.48 b                     | 8.53 a               | 44.53 a                     | 7.33 a                    | 12.97 a                             |

**Effect of SA**

|                |            |                      |                            |                      |                            |                          |                                     |
|----------------|------------|----------------------|-----------------------------|----------------------|-----------------------------|---------------------------|-------------------------------------|
| SA0            |            | 76.02 a              | 15.64 c                     | 7.80 b               | 41.50 b                     | 6.28 b                    | 8.64 b                              |
| SA100          |            | 74.54 c              | 16.44 b                     | 8.42 a               | 43.90 a                     | 7.00 a                    | 11.18 a                             |
| SA200          |            | 74.97 b              | 16.82 a                     | 8.58 a               | 44.15 a                     | 6.96 a                    | 11.48 a                             |

**Effect of PA × SA**

|                |            |                      |                            |                      |                            |                          |                                     |
|----------------|------------|----------------------|-----------------------------|----------------------|-----------------------------|---------------------------|-------------------------------------|
| PA0            | SA0        | 77.23 a              | 14.44 f                     | 6.68 h               | 35.72 g                     | 4.67 g                    | 5.48 i                              |
|                | SA100      | 76.79 ab             | 15.55 e                     | 7.60 g               | 41.05 f                     | 6.27 f                    | 7.55 h                              |
|                | SA200      | 75.86 cde            | 16.44 cd                    | 8.44 bcde            | 43.71 bcd                   | 6.83 cd                   | 9.55 fg                             |
|                | Put50      | 76.33 bc             | 15.44 e                     | 8.11 def             | 42.83 de                    | 6.63 de                   | 8.04 gh                             |
|                | SA0        | 75.64 ef             | 16.00 de                    | 8.29 cdef            | 43.35 cde                   | 6.67 de                   | 8.30 gh                             |
|                | SA100      | 73.49 i              | 17.00 bc                    | 8.80 bc              | 45.00 b                     | 7.20 b                    | 11.41 de                            |
|                | SA200      | 74.81 g              | 17.55 ab                    | 8.66 bc              | 44.69 bc                    | 7.07 bc                   | 11.61 de                            |
|                | Put100     | 72.64 j              | 17.66 ab                    | 8.87 b               | 45.04 b                     | 7.20 b                    | 12.64 bcde                          |
|                | SA0        | 75.92 cde            | 17.77 a                     | 8.40 bcde            | 43.77 bcd                   | 6.77 de                   | 9.89 ef                             |
|                | SA100      | 75.54 ef             | 15.44 e                     | 8.09 ef              | 42.84 de                    | 6.57 def                  | 9.64 fg                             |
|                | SA200      | 75.71 def            | 15.33 e                     | 7.82 fg              | 42.12 ef                    | 6.43 ef                   | 10.02 ef                            |
|                | Spd50      | 75.78 fg             | 16.44 cd                    | 8.61 bcd             | 44.06 bcd                   | 6.90 bcd                  | 13.34 b                             |
|                | SA0        | 76.20 cd             | 15.33 e                     | 7.45 g               | 41.44 f                     | 6.47 ef                   | 8.45 fgh                            |
|                | Spd100     | 71.90 k              | 17.66 ab                    | 9.50 a               | 47.95 a                     | 8.43 a                    | 17.36 a                             |
|                | SA0        | 76.31 h              | 16.44 cd                    | 8.64 bc              | 44.20 bcd                   | 7.10 bc                   | 13.11 bc                            |

Means in each column followed by similar letters are not significantly different (P>0.05) according to Duncan's Multiple Range Test (DMRT).

### 3.2.4. Length of flower stalk (cm):

Data in table 3 indicate that all the concentrations of PAs have significantly affected the length of flower stalk as compared with control. However, the longest flower stalk length was registered by spermidine treatment at concentration of 100 mg.l\(^{-1}\) (44.53 cm) which on par with treatment of putrescine at concentration of 100 mg.l\(^{-1}\) (44.50 cm). Moreover, all tested applications of SA showed significant increments in this respect as compared with control. However, foliar spray at concentration
of 200 mg.l\(^{-1}\) by SA gave the longest flower stalk length (44.15 cm) which on par with treatment of 100 mg.l\(^{-1}\) (43.90 cm). Interaction between PAs and SA concentrations caused significant increase in length of flower stalk as compared with control. However, the longest flower stalk length (47.95 cm) was recorded by the combined treatment between 100 mg.l\(^{-1}\) of spermidine and 100 mg.l\(^{-1}\) of SA.

3.2.5. flower stalk diameter (mm):
Data presented in table 3 elucidate that flower stalk diameter increased significantly when plants treated with 100 mg.l\(^{-1}\) of spermidine (7.33 mm) as compared with control. Data show that foliar spray with SA had significant effect on flower stalk diameter, particularly SA treatment at concentration of 100 mg.l\(^{-1}\) (7.00 mm) which on par with treatment of 200 mg.l\(^{-1}\) (6.96 mm) as compared with control. Interaction between PAs and SA concentrations, showed significant increase in flower stalk diameter as compared with control. However, the highest value of flower stalk diameter (8.43 mm) was recorded by the combined treatment between 100 mg.l\(^{-1}\) of spermidine and 100 mg.l\(^{-1}\) of SA.

3.2.6. Percentage of flowers dry material (%):
Data presented in table 3 show that the percentage of flowers dry material significantly increased by foliar spray with 100 mg.l\(^{-1}\) of spermidine (12.97%) as compared with control. Moreover, all SA treatments significantly increased the percentage of flowers dry material, particularly SA treatment at concentration of 200 mg.l\(^{-1}\) (11.48%) which on par with treatment of 100 mg.l\(^{-1}\) (11.18%) as compared with control. Interaction between PAs and SA concentrations, showed significant increase in the percentage of flowers dry material as compared with control. However, the highest value of the percentage of flowers dry material (17.36%) was recorded by the combined treatment between 100 mg.l\(^{-1}\) of spermidine and 100 mg.l\(^{-1}\) of SA.

4. Discussion
Data indicate that treatment with PAs (putrescine and spermidine) combined with SA positively affected the vegetative and flowering growth qualities of gerbera cv. Great Smoky Mountains. The positive effect of PAs on vegetative growth and flowering qualities may indicate that PAs are considered now as a new class of growth substances and are also well known for their anti-senescence and anti-stress effects, where their acid neutralizing and antioxidant properties, as well as to their membrane and cell wall stabilizing abilities [25]. Again, PAs have been implicated in a large range of growth and developmental processes such as cell division, stimulation, support and development of flower buds, embryogenesis, plant morphogenesis and response to environmental stress [26]. Also, PAs inhibit senescence in plants [27]. It is reported that foliar application of PAs has increased some nutrients, particularly K uptake, which its vital role in photosynthesis by directly enhancing the growth and photosynthetic pigments and carbon dioxide absorption has been found [28]. PAs are able to increase the activity of metabolic processes in plants, and accordingly physiological function of these plants is improved because of the increased efficiency of roots to absorb macronutrients from the soil [29].

Application of PAs on gerbera promoted number of leaves per plant, leaves area and percentage of leaves dry material significantly. These results may be due to PAs direct effect on cell division and growth, followed by differentiation, so that cell division and growth affects the morphological and physiological characteristics of the plant and lead to increase in vegetative characteristics. With the increase in the vegetative characteristics, the active photosynthesis with stimulation of protein synthesis, and metabolism of nitrogen components, the percentage of leaves dry material also increased [30; 10]. These results are in agreement with those obtained by [31] on Matthioha incana, [30] on periwinkle plants, [32] on chrysanthemum and [10] on carnation plants.

The results of this study showed that treatment with PAs caused increase in relative chlorophyll content of the leaves and this could be due to PAs capability to stable protoplast and prevent both loss of chlorophyll during senescence in protoplast and leaves [33]. suggested that the effect of PAs in inhibiting chlorophyll degradation may be related to the inhibition of peroxidase activity [34].
The results indicate that PAs significantly increased total carbohydrate percentage in the leaves as compared with control. This increment in total carbohydrates percentage may be attributed to the increase in photosynthetic process efficiency, which led to increase assimilation of leaf CO₂. These results are in agreement with those obtained by [35] on Dianthus caryophyllus and [36] on Syngonium podophyllum, they obtained an increases in total carbohydrates content in the plants treated with different concentrations of putrescine (as polyamine).

The results show that foliar spray of gerbera with PAs promoted flowering date, number of flowers per plant, flower diameter, Length and diameter of flower stalk, and percentage of flowers dry material, this could be due to the effect of PAs on the indol acetic acid (IAA) synthesis, which increases the enzyme of IAA synthesis and increasing the tryptophan levels, which are precursors of IAA hormone [17], or may be due to their stimulation of physiological processes, which are reflected the improving vegetative growth that followed by active translocation of photosynthetic products from source to sink as in sunflower plant [37]. PAs exhibit their effect on growth through enhancing cell division and expansion in cells [14] and they can also act as source of nitrogen which stimulates growth [38]. These results are in agreement with those obtained by [31] on chrysanthemum, [10] on Dianthus caryophyllus, and [39] on gladiolus.

The results showed that foliar application of SA had a positive effect on most vegetative and flowering characters of gerbera. These results may be due to the role of SA in increasing the plant content of internal hormones such as gibberellin, auxin and cytokine, thus increasing cell division and elongation and ultimately promoting plant growth and development [20]. It is proposed that the increase in productivity of plants is mainly due to the positive effect of SA on root length and its density [40]. There is evidence of a cross-talk between SA and auxin signaling pathways during plant vegetative growth [41]. Improvement of vegetative growth due to foliar spray with SA in this study are in agreement with those obtained by [42] on African violet, [43] on Calendula officinalis, and [44] on Dianthus caryophyllus.

The results of this study showed that treatment with SA caused increase in number and diameter of flowers. This result may be due to the role of SA in improving vegetative growth and that lead to an increase in the absorption of nutrients, also it promotes photosynthesis in plant that lead to carbohydrate manufacturing which affected clearly in the differentiation of flowers and increased their number. SA also involve in auxin increasing, which enhance flower growth [20; 45]. The flowering promoting effect after SA application can also be indirect as SA alters the synthesis and/or signaling pathways of other plant hormones including jasmonic acid, ethylene and auxin [46]. In addition, the exogenous application of SA can raise the content of endogenous bioactive GA in response, changing the hormonal status of the plant [47; 48]. Increased content of endogenous SA as a result of its exogenous application were correlated to the positive influence on the plant growth and flowering [48]. Improvement of flowering growth qualities of gerbera due to foliar spray with SA in this study are in agreement with those obtained by [49] on Calendula officinalis, [50] on Petunia plants, and [44] on Dianthus caryophyllus.

5. Conclusions

The foliar application of PAs (putrescine and spermidine) and SA, individually or as combinations, affected positively on vegetative and flowering characters of gerbera. Treatment with 100 mg.l⁻¹ of spermidine combined with SA at 100 mg.l⁻¹ gave the best results in respect of number of leaves per plant, leaves area, relative chlorophyll content in leaves, percentage of leaves dry material, flowering date, flower diameter, length and diameter of flower stalk, and percentage of flowers dry material. Moreover, treatment with 100 mg.l⁻¹ of putrescine combined with SA at 200 mg.l⁻¹ gave a highest total carbohydrate percentage in leaves and number of flowers per plant.

References

[1] Choudhary M L, and Prasad KV 2000 Protected cultivation of ornamental crops-an insight Indian Journal of Horticulture 45(1):49-53
[2] Dole J M and F H Wilkins 1999 Floriculture, Principles and Species New Jersey: Prentice Hall Upper Saddle River

[3] He S, Joyce D C, Irving D E and Faragher J D 2006 Stem end blockage in cut Grevillea ‘Crimson Yul-lo’ inflowers Postharvest Biology and Technology 41:78–84

[4] Bose T K, Yadav L P, Pal P, Pathasarathy V P and Das P 2003 Commercial flowers (2nd Ed ) Naya Udyog, Calcutta, India

[5] Chung Y M, Yi Y B, Cho Y C, Kim J B and Kwon O C 2005 A new high-yielding red cut flower gerbera cultivar with strong peduncle Misty Red Korean Journal of Breeding 37(4): 273-274

[6] Chauhan, N 2005 Performance of gerbera genotypes under protected cultivation Dept Hort College of Agri Dharwad University of Agricultural Science Dharwad India

[7] Leffring L 1973 Flower production in gerbera: Correlation between shoot, leaf and flower formation in seedlings Scientia Horticulturae 1: 221-229

[8] Peper H, Brandis A V, Dopke H 1971 Clonal propagation of gerberas can be profitable Result from Ahlem on the culture and clonal propagation of gerberas Tuspo 105: 7

[9] Kumar A, Altabella T, Taylor M A and Tiburcio A F 1997 Recent advances in polyamine research Trends Plant Sci 2: 124-130

[10] Mahgoub M H, Abd El Aziz N G and Mazhar M A 2011 Response of Dahlia pinnata L plant to foliar spray with Putrescine and Thiamine on growth, flowering and photosynthetic pigments American-Eurasian J Agric and Environ Sci 10(5): 769-775

[11] Casiro R A, and Marton L J 2007 Targeting polyamines metabolism and function in cancer and other hyper-proliferative diseases Nat Rev Drug Disc 6: 373-390

[12] Kakkar R K and Sawhney K V 2002 Polyamine research in plants-a changing perspective Physiologia Plantarum 116(3): 281-292

[13] Dantuluri V S R, Misra R L and Singh V P 2008 Effect of polyamines on post-harvest life of gladiolus spikes Journal of Ornamental Horticulture 11(1): 66-68

[14] Cohen S 1998 A guide to the polyamines Oxford University Press New York pp: 595

[15] Nambeesan S, Datsenka T, Ferruzzi M G, Malladi A, Mattoo A K and Handa A K 2010 Overexpression of yeast spermidine synthase impacts ripening, senescence and decay symptoms in tomato Plant Journal 63: 836-847

[16] Bouchereau A, Aziz A, Larher F and Matin-Tanguy J 1999 Polyamines and environmental challenges; Recent Development Plant Sci 140: 103-125

[17] Mahros K M, Badawy E M, Mahgoub M H, Habib A M and Sayed I M E 2011 Effect of Putrescine and uniconazole treatments on flower characters and photosynthetic pigments of chrysanthemum indicum L. plant Journal of American Science 7(3): 399-408

[18] Farahi M H, Khalighi A, Barin B K h, Boojar M M and Eshghi S 2013 Morphological Responses and vase life of Rosa hybrid cv Dolc vita to polyamines spray in Hydroponic system World Appl Sci J 21(11): 1681-1686

[19] Vieira M R, Da Silva A, Diniz N B, Belfort M M, de Moura F B, Simões A N, Da Silva S L F 2015 Effects of putrescine and spermine polyamines and boron on postharvest quality of potted plant gerberas cv ‘Kosak’ (Gerbera jamesonii Bolus) Congresso Brasileiro de Processamento mínimo e Pós-colheita de frutas, flores e hortaliças, 001 Anais Aracajú-SE

[20] Hayat S, and Ahmed A 2007 Salicylic Acid: Biosynthesis Metabolism and physiological Role in plants Springer Netherland

[21] Ramesh K M, Selvarajan M and Chezhiyan N 2001 Effect of certain growth substances and salicylic acid on growth and yield of China aster cv Kamini Orissa J Hort 29(2): 14-18

[22] Nofal F H, El-Segai M U and Seleem E A 2015 Response of Calendula officinalis L Plants to Growth Stimulants under Salinity Stress Am-Euras J Agric & Environ Sci 15(9): 1767-1778

[23] Tabibzadeh A R, Mortazaeinezhad F and Jari S K 2015 The effect of salicylic acid pre-harvest treatment on qualitative traits and yield of rose cut flowers (Rosa hybrida L ) cv Angelina
Inter J Agri Bio sci 4(3): 102-107

[24] Joslyn M A 1970 Method in food analysis: Physical, Chemical and instrumental method of analysis 2nd Ed Academic Press New York and London

[25] Velikova V, Yordanov I and Edreva A 2000 Oxidative stress and some oxidant system in acid rain-treated bean plants Protective role of exogenous polyamine Plant Sci 115: 59-66

[26] Ozturk L and Demir Y 2003 Effect of putrescine and ethephon on some oxidative stress enzyme activities and protein content in salt stressed spinach leaves Plant Growth Regulators 40: 89-95

[27] Sood S and Nagar P K 2003 The effect of polyamines on leaf senescence in two diverse rose species Plant Growth Regulation 39: 155–160

[28] Salama Karima H A 1999 Amelioration of salinity effect in wheat plant by polyamines Ph D Thesis Faculty of Agriculture Ain-al Shams University Cairo Egypt 176 p

[29] Youssef E A E 2007 Increasing drought tolerance of gladiolus plants through application of some growth regulators: The third Conference of Sustainable Agricultural Development Agadir Morocco pp: 299-326

[30] Talaat I M, Bekheta M A and Mahgoub M H 2005 Physiological response of periwinkle plants (Catharanthus roseus L) to tryptophan and putrescine International Journal of Agriculture and Biology 7(2): 210-213

[31] Youssef A A, Mahgoub M H and Talaat I M 2004 Physiological and biochemical aspects of Matthiola incana plants under the effect of putrescine and kinetin treatments Egypt J Appl Sci 19(9B): 492-510

[32] El-Sayed I M 2009 Physiological and Biological and Studies on Chrysanthemum Plant (Chrysanthemum indicum L.) M Sc Thesis Fac Agric Cairo Univ Egypt 132 p

[33] Kaur-Sawhney R, Flores H E, Galston A W 1980 Polyamine induced DNA synthesis and mitosis in Oat leaf protoplasts Plant Physiol 65: 368-371

[34] Ma J Y, Zhou R and Cheng B S 1996 Effect of spermine on the peroxidase activity of detached wheat leaves J Shandang Agric Univ 27: 176–180

[35] Mahgoub M H, El-Ghorab A H and Bekheta M A 2006 Effect of some bioregulators on the endogenous phytohormones chemical composition essential oil and its antioxidant activity of carnation (Dianthus caryophyllus L.) J Agric Sci Mansoura Univ Egypt 31(7): 4229-4245

[36] El-Quesni F E, Mahgoub M H and Kandil M M 2010 Impact of foliar spray of inorganic fertilizer and bioregulator on vegetative growth and chemical composition of Syngonium podophyllum L. plant at Nubaria Journal of American Science 6(8):288-294

[37] El-Bassiouny H M S Mostafa H A El-Khawas S A Hassanein R A Khalil S I and Abd El–Monem A A 2008 Physiological responses of wheat plant to foliar treatments with arginine or putrescine Austral J of Basic and Applied Sci 2(4): 1390-1403

[38] Smith T A 1982 The function and metabolism of polyamines in higher plants In: Wareing P F (ed ) Plant Growth Substances p 683 Academic Press New York

[39] Abd El-Aziz N G, Lobna S T and Soad M M L 2009 Some studies on the effect of putrescine, ascorbic acid and thamine of gladiolus plant Ozean J App Sci 2(2): 169–179

[40] Larqué-Savedra A, Martin-Méx R 2007 Effects of salicylic acid on bio productivity of plants In: Hayat S, Ahmad A (Eds) Salicylic acid: a plant hormone Springer Dordrecht pp:15-23

[41] Rivas-San Vicente M and Plasencia J 2011 Salicylic acid beyond defense: its role in plant growth and development J Experim Bot 62: 3321-3338

[42] Martín-Mex R, Villanueva-Couobb E, Herrera-Camposb T and Larqué’-Savaedra A 2005 Positive effect of salicylates on the flowering of African violet Sci Hort 103: 499-502

[43] Hashish K I, Mazhar A A M, Abdel Aziza N G, Mahgoub M H 2015 The influence of different levels of foliar-application SA on the flowering and some chemical compositions of Calendula officinalis L. under salinity irrigation Int J Chem Tech Res 8(6): 890-897

[44] Qureshi U S, Izhar S, Chughtai S, Mir A R and Qureshi A R 2015 Efficacy of boron and salicylic acid on quality production of sim carnation (Dianthus caryophyllus) Int J Biosci
[45] Zamani S, Hadavi E, Kazemi M and Hekmati J 2011 Effect of some chemical treatments on keeping quality and vase life of Chrysanthemum cut flowers World Appl Sci J 12(11): 1962-1966

[46] Vlot A C, Dempsey M A, Klessig D F 2009 Salicylic acid, a multifaceted hormone to combat disease Annu Rev Phytopathol 47: 177–206

[47] Mukherjee D, Kumar R 2007 Kinetin regulates plant growth and biochemical changes during maturation and senescence of leaves, flowers, and pods of Cajanus cajan L. Biol Plant 50:80-85

[48] Kim Y H, Hamayun M, Khan A L, Na C I, Kang S M, Han H H, Lee I J 2009 Exogenous application of plant growth regulators increased the total flavonoid content in Taraxacum officinale (Wigg) Afr J Biotechnol 8: 5727-5732

[49] Pacheco, A C , Cabral C D S , Fermino É S D S and Aleman C C 2013 Salicylic acid-induced changes to growth, flowering and flavonoids production in marigold plants Glob J Med Plants Res , 1(1): 95-100

[50] Sardoei A S, Shahdadneghad M, Yazdi M R and Gholamshahi S 2014 Growth Response of Petunia hybrid to Zinc Sulphate and Salicylic Acid Int J Adv Biol Biom Res 2(3):622-627