The influence of salicylic acid and nutritional requirement on the growth, flowering and chemical composition of geranium (*Pelargonium zonale*, L.) plants

Eman B.A. Hamid and Gabriel F.M. Imhmd [1]

ABSTRACT

The current research aimed to investigate the impact of salicylic acid at concentrations of 0.00, 50.00, 100.00, and 150.00 mgl^{-1} via foliar spray, as well as nutritional requirement of NPK (19:19:19) at 0.00, 2.00, 3.00, and 4.00 g/pot. NPK monthly throughout the growing season, and their combined influence on the growth, flowering, and chemical composition of leaves of *Pelargonium zonale,* L. plants under full sun conditions in an open field. The findings indicated that the application of salicylic acid and/or NPK fertilizer led to a significant increase in most studied parameters compared to the control. In terms of *Pelargonium zonale*, L. plants, it was observed that spraying SA at 100.0 mgl^{-1} while using 3 g/pot mineral NPK monthly during the growing season resulted in the highest significant values for plant height, root volume, and root dry weight. Furthermore, results showed that plants receiving SA 150 mgl^{-1} combined with a medium rate of NPK application (3g/plant) monthly during the growing season had the highest significant values for stem diameter, leaf number per plant, leaf area and leaf dry weights, inflorescences number, and inflorescences diameter. The data total chlorophyll, carotenoids, leaf NPK contents revealed that the highest significant values were achieved in plants treated with SA 150 mgl^{-1} combined with medium and/or the highest rate of NPK application in comparison to untreated plants.

Keywords: Geranium; *Pelargonium zonale*; Perennials; Inflorescences & Ornamental plants: salicylic acid; Photosynthetic pigments; Mineral fertilization.

Abbreviations: SA= salicylic acid, MF= Mineral fertilization, L.S.D $_{(0.05)}$ = Least significant differences at 0.05 probability level, NS=Not Significant.

INTRODUCTION

Geranium plants, also known as *Pelargonium zonale*, L. (Herit ex. Ait), from the Geraniaceae family, are well-known and popular ornamental plants that originally came from South Africa before being introduced to Europe. They are now widely cultivated in various temperate and subtropical regions worldwide (Clifford, 1972). Numerous modern varieties of geranium (*Pelargonium zonale*, L.) are suitable for various arrangements and decorations. This upright perennial plant has fibrous roots and simple, nearly round leaves with palmate venation, featuring horseshoe-shaped dark markings and scent glands. The flowers of geraniums come in shades ranging from rose-pink to different red hues and pure white, with irregular blooms typically clustered in an umbel-like inflorescence. Geranium plants are commonly used in gardens in various locations, such as beds around trees and palms, along pathways and walkway edges, on lawns, in pots, window boxes, and wall gardens. Pelargonium can also be combined with other plants in beds and borders, it can grow in hard lands, and endure drought conditions, due to storing of water in its succulent stems and grow in a wide range of soil pH, but a pH of 6.50 to 7.00 is preferable (Nooh and El-Naggar, 2021). *Pelargonium zonale,* L. propagated vegetatively by stem cuttings from Feb. to Nov. It can slao be propagated by seeds for producing new varieties.

Salicylic acid (SA) is an endogenous phenolic compound produced by root cells in a large number of plants, and it plays a variety of roles in plant growth and development as a para-hormonal substance that regulates a variety of physiological processes in plants (Shakirova *et al.*, 2003), including plant growth and development, ion uptake, photosynthesis, germination, and defensive responses (Miura and Tada, 2014). It's thought to act as a natural thermogenesis indicator inducing flowering in many plants and controlling ion uptake by roots and stomatal transmission (Raskin, 1992). Salicylic acid (SA) is a vital phenolic compound extensively involved in plant growth, development and stress responses. SA a signaling molecule and plant hormone, regulates a variety of physiological processes, including plant growth and development, nutrients uptake, photosynthesis, germination and defensive responses (Okuma *et al.*, 2014; Shama *et al.*, 2016 and Filgueiras *et al.*, 2019). Physiological and biochemical traits are also regulated when they are exposed to abiotic stress (Hashempour *et al.*, 2014). It is white powder dissolves in water with a molecular formula of $C_7H_6O_3$. SA increases root size that favours the absorption and accumulation of macro and micro-nutreients that contribute of biomass production. SA application enhances crop yield and quality and contributes to the sustainable management of

DOI: 10.21608/asejaiqjsae.2024.377804
[1]Fac.of Agric., Omar- Almuktar Univ. Bayda- Libya.
Received, August 05, 2024, Accepted, September 02, 2024.

agricultural systems by increasing the generation of secondary metabolites and fortifying plant defense mechanisms (Skrypnik *et al.,* 2022).

Growth and development of geranium are mainly affected by hormonal substance, nutrients and other environmental factors. However, published data for *Pelargonium zonale* plants indicated that mineral nutrition, especially N, P and K, is likely to be important for vegetative growth and flowering (Nooh and El-Naggar, 2021).

The nutritional needs of herbaceous plants are seen as a crucial factor that limits their growth and flower production. Nitrogen plays a vital role in various key plant compounds like amino acids, enzymes, nucleic acids, and chlorophyll, as well as in the utilization of carbohydrates within the plant. Numerous researchers studying ornamental plants have highlighted the significance of nitrogen in the growth and development of plants, particularly during the initial phases. The optimal application rate for nitrogen is between 100 and 200 kg per feddan, as exceeding this amount may lead to reduced productivity, adverse effects, and decreased benefits. Nitrogen has been observed to enhance vegetative growth, boost flower yield, and improve flowering traits, while also elevating the nitrogen content in leaves. Potassium is an essential element for nitrate reduction, photosynthesis, starch synthesis, sugars translocation and carbohydrates transformation. Therefore, it was found by many investigators that nitrogen and potassium played an important role in improving the vegetative growth, the productivity of flower yield of geranium plant. Also, increasing phosphorus efficiency through the use of optimum P fertilizer level is one of the most important factors that limit geranium productivity. Because P is one of basic plant nutrient, it considers one of the major constituents of nucleic proteins, phospholipida, phosphorylase enzyme, also, enter in process of transferring energy in ATP compound and work as coenzyme for zymase enzyme. P deficient cause weak growth and small size plants, leaves are colored by daek green and blue, also appear yellow or red or brown spots on leaves (Minni and Rehna, 2016).

The major goal of this study would be how four different concentrations of salicylic acid (SA) and NPK treatment affected vegetative growth, blooming, and chemical constituents of *Pelargonium zonale,* L. plants alone and in combination throughout the growth period as it is one of the most important of ornamental plants.

MATERIAL AND METHODS

Plant material and cultural aspects:

The used plants in this experiment were genera, i.e., *Pelargonium zonale,* L. one local cultivar was used because of its high landscape potentials in gardens. The rooted cuttings of P. *Zonale* displayed a consistent shape and size, measuring an average length of 10 cm and featuring 5 leaves each. A single plant per pot was grown in plastic containers with a diameter of 30 cm, filled with a mixture of peatmoss (pH 6.6, EC 0.6 dS/m) and sand (pH 8.10, EC 1.25 dS/m) in a 2:1 v/v ratio at private nursery - Shahat - AL jabal AL Akhdar - Libya.

The foliar application of salicylic acid (SA) was carried out using four different concentrations, which included a control (0.00, 50.00, 100.00, and 150.00 mgl^{-1}). These applications were sprayed three times in each season, with the first spray occurring one month after planting, the second spray one month later, and the third spray added a month after the second spraying. Additionally, NPK-fertilizer treatments of 0.00, 2.00, 3.00, and 4.00 g/pot were applied six times at monthly intervals by mixing each amount with the top portion of the growing medium surface before irrigation throughout the growing season. Chemical fertilizer NPK 19:19:19, containing 19% N in amide, NH_4, and NO_3 forms, 19% P in $NH_4H_2PO_4$ form, and 19% K in K_2SO_4 and KNO_3 forms, was utilized. Fertilization treatments commenced on April 20, 2022, and April 25, 2023, for two years, respectively, until reaching the flowering stage. The experiment concluded on October 20, 2022, and October 25, 2023, for both seasons, respectively.

Experiment layout:

Two factors were involved in the present study, the first was four rate of NPK fertilizer as main factor, the second was four salicylic acid spraying treatments as sub factor.

All treatments had three replicates, each experimental unites consisted of 6 pots. Commercial insect and disease agriculture methods were used as needed.

Growth, flowering and roots characteristics:

The data collected for both years of *Pelargonium zonale*, L. plants at the conclusion of the experiments in two consecutive seasons encompassed various parameters, including plant height (cm), stem diameter(cm), leaf number per plant, leaf area (cm^2), leaves dry weights (g), number of days to flowering (day), inflorescences number, inflorescences diameter (cm). In addition, root volium (cm^3) and roots dry weight (g) were obtained.

Chemical composition:

The analysis of leaves included determining the total chlorophyll and carotenoides content in fresh leaf samples (mg/100g F.W.L) using methods outlined by Greig *et al.* (1968) and Moran & Porath (1980). Additionally, the nitrogen, phosphorus, potassium, and total carbohydrate contents of *Pelargonium zonale*, L. plants were recorded. The nitrogen and phosphorus levels in oven-dried leaves were determined following the procedures by Chapman & Pratt (1961) and Bringham (1982). The potassium levels were measured using a flame photometer, as per Brown & Lilleland (1946) and Chapman & Pratt (1961). The total carbohydrate content in dried leaf samples was assessed following the guidelines of Herbert *et al.* (1971).

The same procedures and methodologies used in the initial experimental year (2022) were replicated in the subsequent year (2023). Data analysis was conducted according to the techniques described by Snedecor and Cochran (1990), utilizing L.S.D. for comparing treatment means.

RESULTS AND DISCUSSION

I-Impact of salicylic acid and NPK treatments and their interactions on the vegetative growth of *Pelargonium zonale*, L. plants:

Data in Table (1, 2) showed that different salicylic acid concentrations, NPK treatments and the interaction had significant effect on growth of geranium plant in the two seasons.

The data presented in Table (1) indicates that all examined NPK treatments (0.00, 2.00, 3.00, and 4.00 g/plant) had a significant impact on height of *Pelargonium zonale*, L. plants when compared to untreated plants in both seasons. The most notable increase in plant height was observed with the application of 3.0 g/plant, with mean values of 49.15 cm and 50.33 cm in the first and second years, respectively. Salicylic acid (SA) also showed a significant effect on plant height in treated pelargonium plants compared to the control in both seasons. Highest mean of plant height values (48.68 cm and 50.86 cm) were recorded with the addition of 100 mgl^{-1} of SA to the geranium plants. Additionally, there was no significant difference between SA concentrations of 100 and 150 mgl^{-1} in both seasons, as shown in Table (1). The interaction between SA and NPK revealed that the combination of NPK at 3.0 g/plant and 100.00 mgl^{-1} of SA was the most effective treatment for enhancing plant height in the 1st and 2nd seasons. These treatments resulted in plant height increases of 57.58 cm and 59.29 cm compared to 32.34 cm and 33.07 cm from the untreated plant in the first and second years, respectively. The next best results were achieved with 4.0 g/plant mineral fertilizer and 100.00 mgl^{-1} SA in both seasons. Hilman and Galston (1961) suggested that the increase in growth could be attributed to the role of nitrogen in the formation of essential molecules like phospholipids, nucleotides, nucleic acid, and certain co-enzymes, which are crucial for plant metabolism. A deficiency in nitrogen leads to a decrease in auxin and subsequently stunts growth, a concept supported by Kadu *et al.* (2009), who stated that the improvement in plant height may be linked to the effects of NPK and SA on enhancing cell division rate and cell enlargement. These findings were consistent with those published by Bhaskar *et al.* (1998) on scented Geranium, and El-Mergawi and Abdel-Wahed (2003) on *Catharanthus roseus* plants. Amarjeet and Godaro (1995) found similar outcomes, stating that higher levels of (N), (P), and (K) resulted in increased tuberose plant height.

The results recorded in the two seasons Tables (1, 2) show that spraying plants with SA separately or in combination with different level of NPK- fertilizer had a considerable effect on stem diameter, leaf number/plant, leaves area as well as leaves fresh and dry weights.

In most cases, application of the different concentrations of SA combined with NPK treatments promoted growth, and resulted in significant increases in the values recorded for the above mentioned parameters, compared to the untreated control plants.

The highest values were obtained by receiving the plants SA 150 mgl^{-1} combined with the medium rate of application 3 g NPK for several growth characteristics, such as stem diameter (cm), leaf number/plant, leaves area (cm^2) and dry weights of leaves per plant (g) giving values of 00.75 cm, 65.39, 548.30 cm^2 and 68.39 g, respectively in the first season, and 00.77 cm, 67.98, 548.95 cm^2 and 69.19 g, respectively, in the second season for the above mentioned parameters.

These findings could be attributed to the combined effect of SA and NPK fertilizer in appropriate proportions, which promote plant growth and the accumulation of dry matter. The consistent application of 150 mgl^{-1} SA led to the highest values for these growth parameters, surpassing the control treatments significantly. Moreover, a higher dosage of fertilizer may enhance growth by improving nutrient availability, thus stimulating leaf development and expanding the photosynthesizing area. These outcomes align with previous studies conducted by El-Khateeb *et al.* (1991) on *Freesia hybrida* cv."Arora" and Ali (1998) on *Lawsonia inermis*.

In addition, the stimulating effects of both SA and/or mineral fertilization could be attributed to their role in activating apical meristems, promoting protoplasm formation, cell division, and elongation of meristem cells, as well as boosting protein and carbohydrate synthesis. These results are in line with the research by El-Naggar & El-Nasharty (2009) on *Hippeastrum vittatum*; Kordi *et al.* (2013); Gharib (2006) on *Ocimum basilicum*, and *Majorana hortensis*, all contributing to enhanced plant growth. Similar findings were reported by Hosni & El-Shoura (1996), and Verma *et al.* (2000) in studies on carnation (*Dianthus caryophyllus*) plants.

2-Impact of salicylic acid and NPK treatments and their interactions on flowers productivity of *Pelargonium zonale,* L. plants:

The data presented in Table (2) demonstrates that all treatments had a significant impact on the trait under study during both seasons. Additionally, it was observed that salicylic acid treatments, as well as the interaction between NPK fertilizer treatments, significantly influenced the flowers production of geranium plants across the two seasons.

Table 1. Means of plant height (cm), stem diameter (cm) and branches number/plant and number of leaves/ plant of *Pelargonium zonale,* L. plants as influenced by concentrations of salicylic acid and NPK treatments and interaction between them during the two successive years of 2022 and 2023

Plant height (cm)										
	First year					**Second year**				
NPK	**Salicylic acid (SA , $mg.l^{-1}$)**									
g/ plant	**0.00**	**50.00**	**100.00**	**150.00**	**mean**	**0.00**	**50.00**	**100.00**	**150.00**	**mean**
0.00	32.34	36.19	39.15	39.92	36.90	33.07	38.47	42.38	41.97	38.97
2.00	36.46	38.70	44.17	42.92	40.56	38.77	40.05	46.88	47.38	43.27
3.00	39.25	45.00	57.58	54.75	49.15	38.55	47.30	59.29	56.18	50.33
4.00	38.18	46.67	53.83	51.42	47.50	37.38	40.80	54.87	53.80	46.71
mean	36.56	41.64	48.68	47.25		36.94	41.66	50.86	49.83	
$LSD_{0.05}$	For:	MF=1.23	SA=1.41	Intr.= 2.12		For:	MF=1.28	SA=1.53	Intr.= 1.98	
Stem dimeter (cm)										
	First year					**Second year**				
NPK	**Salicylic acid (SA , $mg.l^{-1}$)**									
g/ plant	**0.00**	**50.00**	**100.00**	**150.00**	**mean**	**0.00**	**50.00**	**100.00**	**150.00**	**mean**
0.00	0.48	0.53	0.57	0.61	0.55	0.52	0.58	0.58	0.62	0.58
2.00	0.53	0.64	0.66	0.65	0.62	0.54	0.51	0.69	0.67	0.60
3.00	0.61	0.69	0.72	0.75	0.69	0.64	0.67	0.73	0.77	0.70
4.00	0.62	0.67	0.68	0.68	0.66	0.61	0.64	0.69	0.69	0.66
mean	0.56	0.63	0.66	0.75		0.58	0.60	0.67	0.69	
$LSD_{0.05}$	For:	MF=0.02	SA=0.03	Intr.= 0.05			MF=0.02	SA=0.04	Intr.= 0.05	
Number of branches/ plant										
	First year					**Second year**				
NPK	**Salicylic acid (SA , $mg.l^{-1}$)**									
g/ plant	**0.00**	**50.00**	**100.00**	**150.00**	**mean**	**0.00**	**50.00**	**100.00**	**150.00**	**mean**
0.00	4.76	6.15	8.80	9.40	7.28	5.32	7.34	8.76	9.62	7.77
2.00	6.61	9.56	9.69	11.02	9.22	7.87	9.89	9.50	13.54	10.20
3.00	8.29	11.98	13.14	14.49	11.98	8.84	12.32	15.00	15.23	12.85
4.00	7.67	10.61	13.40	13.48	11.29	8.39	11.45	13.67	13.39	11.73
mean	6.83	9.58	11.25	12.10		7.61	10.25	11.73	12.96	
$LSD_{0.05}$	For:	MF=NS	SA=1.13	Intr.= 2.43		For:	MF=NS	SA=1.10	Intr.= 2.22	
Number of leaves/ plant										
	First year					**Second year**				
NPK g/	**Salicylic acid (SA , $mg.l^{-1}$)**									
plant	**0.00**	**50.00**	**100.00**	**150.00**	**mean**	**0.00**	**50.00**	**100.00**	**150.00**	**mean**
0.00	36.84	37.18	44.12	45.87	41.00	38.58	39.70	48.28	46.93	43.37
2.00	36.99	42.60	48.49	46.65	43.69	39.93	45.88	54.38	47.51	46.93
3.00	46.49	48.39	59.97	65.39	55.06	45.62	50.00	61.35	67.98	56.24
4.00	51.80	54.60	63.76	59.71	57.47	52.27	56.02	66.87	62.28	59.36
mean	43.03	45.69	54.34	54.41		44.10	47.90	57.72	56.18	
$LSD_{0.05}$	For:	MF=NS	SA=1.10	Intr.= 2.40		For:	MF=NS	SA=1.12	Intr.= 2.36	

The results indicate that the application of *Pelargonium zonale*, L. plants with either SA and/or NPK fertilizer led to notable improvements in the number of inflorescences per plant, and their size compared to the control group. Furthermore, the findings in Table (3) show that the number of flowers per plant and inflorescences diameter in the two seasons was significantly increased with adding of SA alone or in conjunction with NPK fertilizer. The maximum increased of inflorescences number and size was achieved by using 100 and/or 150 mg l^{-1} SA in combination with NPK treatment (2.0, 3.0, and 4.0 g per plant) compared to untreated group for both years, respectively.

Table 2. Means of leaves area and leaves dry weights, inflorescences number and inflorescences diameter of *Pelargonium zonale*, L plants as influenced by concentrations of salicylic acid and NPK treatments and interaction between them during the two successive years of 2022 and 2023

Leaves area (cm^2)

	First year					**Second year**				
NPK	**Salicylic acid (SA , $mg.l^{-1}$)**									
g/ plant	**0.00**	**50.00**	**100.00**	**150.00**	**mean**	**0.00**	**50.00**	**100.00**	**150.00**	**mean**
0.00	312.50	342.76	385.53	390.86	357.91	315.67	347.50	392.42	398.78	363.59
2.00	356.91	373.85	429.56	438.59	399.73	353.92	372.85	475.18	484.74	421.67
3.00	370.76	433.27	479.32	548.30	457.91	369.96	442.59	483.29	548.95	461.20
4.00	397.42	476.74	498.54	467.94	460.16	401.79	481.34	502.80	482.86	467.20
mean	359.40	406.66	448.24	461.42		360.34	411.07	463.59	478.83	
$LSD_{0.05}$	For:	MF=22.92	SA=13.70	Intr.= 24.46		For:	MF=28.41	SA=15.84	Intr.= 31.78	

Leaves dry weights (g)

	First year					**Second year**				
NPK	**Salicylic acid (SA , $mg.l^{-1}$)**									
g/ plant	**0.00**	**50.00**	**100.00**	**150.00**	**mean**	**0.00**	**50.00**	**100.00**	**150.00**	**mean**
0.00	36.92	37.23	42.45	47.1٩	40.95	37.35	40.69	43.78	48.56	42.60
2.00	40.85	43.76	55.23	45.36	46.30	41.82	46.70	54.45	56.42	52.10
3.00	52.77	54.88	63.82	68.39	59.97	53.56	53.62	64.28	69.19	60.16
4.00	59.20	62.45	64.55	64.90	67.02	58.73	61.90	63.86	62.36	61.71
mean	47.43	49.58	56.51	63.21		47.87	50.73	56.59	57.70	
$LSD_{0.05}$	MF=2.23		SA=1.61	Intr.= 2.42		MF=2.23		SA=1.70	Intr.= 2.32	

Inflorescences number

	First year					**Second year**				
NPK	**Salicylic acid (SA , $mg.l^{-1}$)**									
g/ plant	**0.00**	**50.00**	**100.00**	**150.00**	**mean**	**0.00**	**50.00**	**100.00**	**150.00**	**mean**
0.00	6.34	7.59	10.92	11.04	8.97	6.87	8.68	10.95	11.79	9.57
2.00	9.16	11.88	13.03	13.78	9.67	9.97	12.19	13.10	13.98	12.31
3.00	12.98	14.03	15.37	17.19	14.89	12.83	14.50	16.76	17.89	15.50
4.00	14.71	16.29	1٥.01	14.35	15.09	10.79	11.33	1٦.53	14.86	13.38
mean	10.80	12.45	13.58	14.09		10.12	11.68	14.33	14.63	
$LSD_{0.05}$	MF= NS		SA=NS	Intr.= 1.37		MF= NS		SA=1.01	Intr.= 1.42	

Inflorescences diameter (cm)

	First year					**Second year**				
NPK g/	**Salicylic acid (SA , $mg.l^{-1}$)**									
plant	**0.00**	**50.00**	**100.00**	**150.00**	**mean**	**0.00**	**50.00**	**100.00**	**150.00**	**mean**
0.00	5.13	5.76	6.28	6.19	5.84	5.26	5.87	6.53	5.59	5.81
2.00	5.33	6.68	7.88	7.11	6.75	5.43	6.73	7.96	7.29	6.85
3.00	5.47	6.97	9.21	9.86	7.88	5.56	7.06	9.30	9.92	7.96
4.00	5.83	7.42	9.87	9.13	8.08	5.90	7.39	9.98	9.10	8.10
mean	5.44	6.71	8.31	8.07		5.56	6.76	8.44	7.98	
$LSD_{0.05}$	MF=0.43		SA= 0.43	Intr.= 1.16		MF=0.43		SA=0.38	Intr.= 1.10	

Moreover, the combination of 100 mgl^{-1} SA and 3 g per plant of NPK treatment significantly increased inflorescences production compared to other treatments. The enhanced inflorescences number and size due to the appropriate concentration of SA with NPK fertilizer at optimal levels may be linked to the role of SA and essential nutrients like phosphorus and potassium, crucial for protein synthesis and cytokinin production, ultimately promoting cell division and enhancing inflorescences yield. These results align with previous studies on various plants such as rose, carnation, tuberose, and marigold (Taha, 2005 and El-Gedawey *et al.,* 2022).

3 -Impact of salicylic acid and NPK treatments and their interactions on the root volume (cm^3) and root dry weight (g) of *Pelargonium zonale,* L. plants:

The data presented in Table (3) demonstrates notable increases in root volume and root dry weight when plants were treated with SA in comparison to the control group. The most significant enhancements were observed when SA was sprayed at a concentration of 100 mgl^{-1}, resulting in root volume and root dry weight values of 35.75 cm^3 and 24.67 g, respectively, during the first season and 37.06 cm^3 and 24.81 g, respectively, during the second season.

These improvements can be attributed to the positive impact of SA on photosynthetic and respiratory rates, leaf carbohydrates, nutrient uptake, and transport, ultimately promoting robust vegetative growth and increased food storage in the roots, hence leading to higher root volume and dry weight. In terms of fertilization rates, significant increases in root volume and root dry weight characteristics were observed compared to untreated plants.

The application of medium to high levels of NPK fertilizer resulted in the highest values for root volume and dry weight across both seasons, surpassing other treatment groups. This outcome is likely due to the effectiveness of potassium in high-rate foliar fertilization, which is well-balanced with other nutrients and influences root volume and dry weight per plant. Similar findings were reported in previous studies by Thabet *et al.* (1994) with onion plants and Manoly (1996) with iris plants. The combined application of SA and NPK fertilizer rates revealed significant differences in root parameters.

The most favorable outcomes were achieved when SA was applied at concentrations of 100 and 150 mg l^{-1} in conjunction with NPK fertilizer at 3 g per plant. Conversely, the control group exhibited the lowest values for root volume and root dry weight per plant in both seasons. This can be attributed to the synergistic effect of utilizing SA at appropriate concentrations along with the addition of NPK mineral fertilizer at optimal levels, leading to increased growth and activation of the root system.

4 -Impact of salicylic acid and NPK treatments and their interactions on chemical constituents of leaves of *Pelargonium zonale,* L. plants:

A-Total chlorophyll and carotenoides (mg/100g L.F.W.) content:

The data in Table (3) clearly shows that the levels of total chlorophylls and carotenoids in mg/100 g LFW of leaves increased progressively with higher fertilizer rates in both seasons. The plants grown with a rate of 4 g/plant NPK showed the highest values of total chlorophyll and carotenoids, with 186.47 and 172.24 mg/100 g LFW of chlorophyll content and 34.27 and 34.61 mg/100 g LFW of carotenoids in the first and second seasons, respectively, compared to other treatments in the two growing seasons. These findings may be attributed to the involvement of N, P, and K in the synthesis of phospholipids in membranes, sugar phosphates, various nucleotides, and co-enzymes, consequently leading to an increase in total chlorophyll (a+b) and carotenoids. Additionally, this could also be linked to the beneficial effects of proper nutrition on enhancing the content of plastid pigments (total chlorophyll).

Regarding SA treatments, an incremental rise was noted in the total chlorophyll (a+b) content and carotenoids of leaves as the SA concentration increased from 50 mgl^{-1} to 150 mgl^{-1} compared to the control. This outcome might be attributed to SA's ability to boost plastid pigment content by increasing nucleic acids, particularly RNA, and influencing enzyme synthesis. These findings align with previous studies by Wahabe *et al.* (2002) on *Antholyza aethiopica* and Taha (2005) on *Polianthus tuberosa* plants. In terms of the interaction, analysis in Table (3) indicated a significant increase in total chlorophyll (a+b) content and carotenoids (mg/100 g LFW) of leaves with 3g NKK-fertilizer rates combined with150 mgl^{-1} SA. This regimen resulted in an increase in chlorophyll pigment to 177.80 and 179.33 mg/100 g LFW, as well as an increase in carotenoid content to 38.86 and 39.16 mg/100 g LFW in the first and second seasons, respectively.

The results observed could be the outcome of the positive impact of NPK fertilizer and SA at appropriate concentrations on the uptake of essential elements such as nitrogen, phosphorus, and potassium. These elements are vital for various metabolic processes, including the synthesis of chlorophylls, enzyme activation, and the formation of chloroplasts. Additionally, the use of suitable SA may assist in enhancing the absorption of water and necessary nutrient elements by plants for chlorophyll production, leading to an increase in green pigments like chlorophyll and carotenoids. The combination of SA with mineral fertilizer contributed to an elevation in potassium levels in the leaves by promoting chlorophyll production. This aligns with findings from a study conducted by Taha (2005) on *Polianthus tuberose*.

B - Mineral content:

N, P, and K levels in leaves, as illustrated in Table (4), experienced a significant increase when geranium plants were subjected to SA and NPK fertilizer, either separately or in various combinations. It is evident that the percentages of N, P, and K in the leaves saw an increase with the application of mineral fertilization doses up to 4 g/plant, either alone or in conjunction with SA at concentrations of 50, 100, and 150 mgl^{-1}, compared to untreated plants across both growing seasons. These findings align with the results of Koriesh *et al.* (1990) concerning rose cv. "Baccara," where they observed a rise in N, P, and K levels in leaves with differing NPK fertilizer levels. This outcome could be linked to the cation exchange capacity (CEC) of the soil and/or plant roots, leading to the adsorption and subsequent absorption of the necessary nutrients for growth. Furthermore, optimal levels of SA alone or in combination with NPK fertilizer enhanced the N, P, and K content in leaves compared to other SA concentrations, possibly due to SA's role in stimulating root activity. Similar results were reported by El-Naggar and El-Naggar (2004) on carnation.

Table 3. Means of root volume (cm^3), root dry weight (g), chlorophyll and carotenoids (mg/100 g FLW) of *Pelargonium zonale,* L. plants as influenced by concentrations of salicylic acid and NPK treatments and interaction between them during the two successive years of 2022 and 2023

Root volume (cm^3)										
	First year					**Second year**				
NPK	**Salicylic acid (SA , $mg.l^{-1}$)**									
g/ plant	**0.00**	**50.00**	**100.00**	**150.00**	**mean**	**0.00**	**50.00**	**100.00**	**150.00**	**mean**
0.00	22.13	24.16	29.74	28.83	26.22	23.00	25.68	31.50	30.65	27.71
2.00	24.50	31.66	34.15	32.74	30.77	25.38	34.01	35.26	33.88	32.11
3.00	26.72	35.00	40.23	39.75	35.42	29.96	34.76	41.96	38.68	36.34
4.00	31.56	36.10	38.91	37.16	35.93	32.43	36.21	39.53	37.85	36.51
mean	26.23	31.73	35.75	34.62		27.69	32.67	37.06	35.27	
$LSD_{0.05}$	For :	MF=1.22	SA=2.98	Intr.= 3.35		For :	MF=1.89	SA=2.30	Intr.= 3.97	
Root dry weights (g)										
	First year					**Second year**				
NPK	**Salicylic acid (SA , $mg.l^{-1}$)**									
g/ plant	**0.00**	**50.00**	**100.00**	**150.00**	**mean**	**0.00**	**50.00**	**100.00**	**150.00**	**mean**
0.00	12.30	15.83	19.39	20.18	16.43	12.63	16.95	19.16	21.81	17.64
2.00	14.22	16.54	22.65	25.17	19.52	13.40	17.76	23.83	24.10	19.75
3.00	17.35	20.82	28.84	27.01	23.51	17.26	20.91	28.93	27.49	23.60
4.00	19.43	22.57	27.86	25.37	23.81	20.65	24.83	27.30	25.70	24.62
mean	15.83	18.94	24.67	24.43		13.24	20.11	24.81	24.78	
$LSD_{0.05}$	For:	MF=1.08	SA=1.08	Intr.= 1.41		For:	MF=0.97	SA=0.97	Intr.= 1.12	
Total chlorophylls (mg/100 g FLW)										
	First year					**Second year**				
NPK	**Salicylic acid (SA , $mg.l^{-1}$)**									
g/ plant	**0.00**	**50.00**	**100.00**	**150.00**	**mean**	**0.00**	**50.00**	**100.00**	**150.00**	**mean**
0.00	78.26	98.55	116.94	129.83	105.90	75.16	97.10	119.94	128.45	105.16
2.00	118.62	137.10	149.74	153.22	139.67	11٧.68	139.19	151.62	156.76	141.31
3.00	146.52	163.28	176.19	177.80	165.95	148.52	166.28	180.16	179.33	168.55
4.00	159.41	167.72	174.87	172.93	186.74	159.42	170.93	178.87	178.74	171.99
mean	125.70	141.64	126.94	158.45		125.20	143.38	157.65	160.82	
$LSD_{0.05}$	For:	MF=4.27	SA=8.70	Intr.= 13.45		For:	MF=4.23	SA=9.32	Intr.= 13.42	

Table 3.

Total carotenoides										
	First year					Second year				
NPK	Salicylic acid (SA , mg.l^{-1})									
g/ plant	0.00	50.00	100.00	150.00	mean	0.00	50.00	100.00	150.00	mean
0.00	18.35	20.82	26.96	26.84	23.24	18.٢١	20.٩٨	2٧.٥٠	26.٩١	23.40
2.00	20.٧7	25.53	31.70	32.١٥	27.54	20.9٨	25.٦١	31.7٩	32.74	29.53
3.00	28.76	29.12	35.93	38.86	33.17	27.٢٣	29.82	3٦.68	3٩.١6	33.22
4.00	30.55	31.80	36.52	38.19	34.27	30.٨5	31.٧٦	36.٨9	38.٩٤	34.61
mean	24.61	26.82	32.78	34.01		24.32	27.04	33.22	34.44	
$LSD_{0.05}$	For:	MF=2.13	SA=1.19	Intr.= 3.12		For:	MF=2.29	SA=1.70	Intr.= 3.24	

Table (4): Means of N, P and K content (%) in leaves of *Pelargonium zonale,* L. plants as influenced by concentrations of salicylic acid and NPK treatments and interaction between them during the two successive years of 2022 and 2023

N content (%)										
	First year					Second year				
NPK	Salicylic acid (SA , mg.l^{-1})									
g/ plant	0.00	50.00	100.00	150.00	mean	0.00	50.00	100.00	150.00	mean
0.00	1.892	1.962	2.364	2.401	2.155	1.910	1.959	2.372	2.423	2.166
2.00	2.383	2.546	2.819	2.877	2.656	2.390	2.653	2.813	2.891	2.687
3.00	2.597	2.917	3.480	3.351	3.086	2.595	2.982	3.495	3.367	3.359
4.00	2.725	2.987	3.490	3.668	3.218	2.764	2.993	3.503	3.671	3.247
mean	2.399	2.603	3.038	3.074		2.414	2.647	3.048	3.088	
$LSD_{0.05}$	For:	MF=0.041	SA=0.082	Intr.= 0.132		For:	MF=0.032	SA=0.050	Intr.=0.094	
P content (%)										
	First year					Second year				
NPK	Salicylic acid (SA , mg.l^{-1})									
g/ plant	0.00	50.00	100.00	150.00	mean	0.00	50.00	100.00	150.00	mean
0.00	0.102	0.137	0.160	0163	0.141	0.111	0.141	0.166	0.169	0.147
2.00	0.167	0.282	0.313	0.316	0.270	0.165	0.286	0.318	0.319	0.272
3.00	0.290	0.338	0.349	0.330	0.327	0.278	0.334	0.352	0.332	0.324
4.00	0.295	0.314	0.358	0.354	0.330	0.294	0.317	0.359	0.357	0.332
mean	0.193	0.268	0.295	0.291		0.212	0.270	0.299	0.294	
$LSD_{0.05}$	For :	MF=0.004	SA=0.006	Intr.= 0.268		For:	MF=0.003	SA=0.004	Intr.= 0.191	
K content (%)										
	First year					Second year				
NPK	Salicylic acid (SA , mg.l^{-1})									
g/ plant	0.00	50.00	100.00	150.00	mean	0.00	50.00	100.00	150.00	mean
0.00	1.053	1.617	1.934	1.912	1.629	1.080	1.620	1.964	1.915	1.645
2.00	2.120	2.307	2.540	2.616	2.396	2.119	2.313	2.551	2.609	2.398
3.00	2.421	2.778	2.917	2.822	2.735	2.430	2.781	2.920	2.828	2.740
4.00	2.577	2.865	2.983	2.849	2.819	2.575	2.869	2.989	2.855	2.822
mean	2.043	2.391	2.643	2.575		2.051	2.418	2.606	2.577	
$LSD_{0.05}$	For:	MF=0.046	SA=0.065	Intr.= 0.094		For:	MF=0.053	SA=0.072	Intr.= 0.102	

CONCLUSION

To achieve the production of high-quality Geranium (*Pelargonium zonale*, L.) plants for various decorative purposes in landscaping, it is recommended to cultivate *P. zonale*, L. plants as potted plants in a mixture of sand and peat moss (2:1 v/v). Additionally, the application of salicylic acid at a concentration of 150 mgl^{-1} as a foliar spray and the use of 3 g/plant NPK fertilizer as a dressing application should be carried out six times during the growing season.

REFERENCES

Ali, H. M.H. 1998. Effect of some horticultural treatments on henna plants, M. Sc. Thesis. Fac. Agric., Suez Canal Univ.

Amarjeet, S. and N. R.Godara. 1995. Studies on the nutritional requirement of tuberose (*Polianthes tuberosa* L.) cv. Single during growth. Haryana Agric. Univ. J. Res. 25(4):171-174.

Bhaskar, S., T.Vasanthakumar and H.C. Srivastava 1998. Growth and yield of scented geranium in relation to nitrogen fertilization.J. Med.Aro. Pl. Sci. 20:731-734.

Bringham, F.T. 1982. Methods of Soil Analysis, Part 2., Agronomy. 9:431:447.

Brown, J.O. and O.Lilleland. 1946. Rapid determination of potassium and sodium in plant material and soil extracts by Flame photometry. proc. Armer. Soc.48:341-346.

Chapman, H. D. and P. F. Pratt. 1961. Methods of analysis for soils, plants and waters. Div. of Agric. Sci., Priced. Pub. 4034. Univ. of California, U.S.A.

Clifford, D. 1972. Pelargonium including popular "Geranium". Text Book Blandford Press Limited 2nd edition. U.K.

El-Gedawey, H.A., B.E. El-Deeb and A.H. El-Naggar. 2022. Effect of Salt Stress and Salicylic acid on Growth of Marigold (*Tagetes erecta* L.) Plant. J. of Horticultural Sci. & Ornamental Plants 14(2): 61-74. ISSN 2079-2158.

El-Khateeb, M. A., A. S. El-Leithy and E. M.Badawy. 1991. Effect of nitrogen and potassium fertilization on growth, flowering and chemical composition of *Freesia hybrida* cv. Aurora. Bull. Fac. Agric., Univ. Cairo. 42 (4):1321-1342

El-Mergawi, R.A. and M.S.A. Abd El-Wahed. 2003. Influence of salicylic acid on *Catharanthus roseus* growth and vineristine formation under different water regimes. J. Hort. (30):179-196.

El-Naggar, A.H. and A.A.M. El-Naggar. 2004. Physiological response of carnation plants to Gibberellic acid and potassium fertilization under greenhouse conditions. J. Adv. Agric. Res. (Fac. Ag. Saba.Basha). 9: 931-950.

El-Naggar, A.H. and A.B. El-Nasharty. 2009. Effect of growing media and mineral fertilization on growth, flowering, bulbs productivity and chemical constituents of *Hippeastrumvittatum*, herb. American-Eurasian J. Agric. and Environ. Sci. 6(3):360-371.

Filgueiras, C.C., A.D. Martins, R.V. Pereira and D.S. Willett. 2019. The ecology of salicylic acid signaling: primary, secondary and tertiary effects with applications in agriculture. International J. of Molecular Sci. 20(23): 5851.

Gharib, F. 2006. Effect of salicylic acid on the growth, metabolic activities and oil content of basil and marjoram Int.Agric.Biol. 4: 485 492

Greig, J., J. Motes and A.Tikiriti. 1968. Effect of nitrogen levels and micronutrients on yield, chlorophyll and mineral contents of spinach. Proc. Amer. Soc. Hort. Sci. 92: 508-515.

Hashempour, A., M.Ghasemnezhad, R.Fotouhi Ghazvini and M. M.Sohani. 2014. The physiological and biochemical responses to freezing stress of olive plants treated with salicylic acid. Russian J. of Plant Physiology. 61(4): 443-450.

Herbert, D., P.J.Philipps and R.E.Strange. 1971. Determination of total carbohydrates. Methods in Microbiology. 5 B:204-244.

Hilman, W.S. and A.W. Galston. 1961. The effect of external factors on the flowering quality in forcing of tulips. Bloombollen Culture. 89(34):906.

Hosni, A.M. and H.A.S. El-Shoura. 1996. Effect of potassium ferilization on yield, quality and anatomical structure of carnation (*Dianthus caryophyllus* L) cv. "Lucena ". Annals of Agricultural Sci. (Cairo). 41: 351-365.

Kadu, A.P., P.R. Kadu and A.S. Sable. 2009. Effect of nitrogen, phosphorus and potassium on growth, flowering and bulb production in tuberose cv. single. J. Soil and Crops. 19(2):367-370.

Kordi, S., M. Saidi and F. Ghanbari. 2013. Induction of drought tolerance in sweet basil (*OcimumbasilicumL*) by salicylic acid. Int. J. Agric. & Food Res.2(2):18-26.

Koriesh, E. M., M. El- Sakhry and M. A. Zaghlool. 1990. The effect of nitrogen, phosphorus and potassium fertilization levels on growth, flowering and chemical composition of the rose cv. Baccara, grown in sandy soil. Zagazig. J. Agric, Res. 17:211-224.

Manoly, N. D. 1996. Effect of soil type, fertilization, bulb size and growth regulators on growth, flowering and chemical composition of Iris plants. Ph. D. Thesis, Fac. of Agric., Minia Univ.

Minni, N. and N. Rehna. 2016. Detection of Nutrient Deficiencies in Plant Leaves using Image Processing. Int. J. Comput. Algorithm. 5(2):84-87.

Miura, K. and Y. Tada. 2014. Regulation of water, salinity, and cold stress responses by salicylic acid. Frontiers in plant sci. 23(5): p.4.

Moran, R. and D. Porath. 1980. Chlorophyll determination in intact tissues using NN- dimethyl formamid. Plant Physiol. 65: 478-479.

Nooh, A.E. and A.H. El-Naggar. 2021. Technology of production of ornamental plants. Knowledge Facility-Alex. Egypt. 391 P.

Okuma, E., R. Nozawa, Y.Murata and K. Miura. 2014. Accumulation of endogenous salicylic acid confers drought tolerance to Arabidopsis. Plant Signaling and Behavior. 9, e28085.

Raskin, I. 1992. Role of salicylic acid in plants Ann. Rev. Pl. Physiol. Mol. Biol. 43: 439–463.

Shakirova, F. M., A. R. Sakhabutdinova, M. V. Bezrukova, R. A. Fatkhutdinova and D. R. Fatkhutdinova. 2003. Changes in the hormonal status of wheat seedlings induced by salicylic acid and salinity. Plant sci. 164(3):317-322.

Shama, M.A, S.A.M. Moussa and N.I. Abo El Fadel. 2016. Salicylic acid efficacy on resistance of garlic plants (Allium sativum, L.) to water salinity stress on growth, yield and its quality. Alexandria Sci. Exchange J. 37 (2):165-174.

Skrypnik, L., A. Golovin and T. Savina. 2022. Effect of salicylic acid on phenolic compounds, antioxidant and antihyperglycemic activity of Lamiaceae plants grown in a temperate climate. Front. Biosci. (Elite Ed). 14(1): 003.

Snedecor, G.W. and W.G. Cochran. 1990. "Statistical methods" 8th Eds Iowa state Univ., press. Ames Iowa U.S.A.593 P.

Taha, A.M.A. 2005. Effect of concentration and application methods of ascorbic acid thiamine and tryptophane on the growth of tuberose plants. M.Sc.Thesis, Alex . Univ., Egypt. 122 p.

Thabet, E. M. A., A. A. G. Abdallah and A. R. A. G. Mohamed. 1994. Productivity of onion grown in reclaimed sandy soil using tafla as affected by water regimes and nitrogen levels. Annals of Agricultural Sci. (Cairo). 39(1):337-344.

Verma, V.K., O.P. Sehgal and S.R. Shiman. 2000. Effect of nitrogen and GA3 on carnation. (1):64.

Wahabe, H.E., S.M. Mohamed, G.E. Attoa and A. Frahat. 2002. Response of Antholyza aethiopica, to foliar spray with some amino acids and mineral nutrients with sulphur. Annals Agric. Sci., Ain Shams Univ., Cairo. 47 (3): 929-944.

الملخص العربي

تأثير حامض السالسيلك والإحتياجات الغذائية على النمو والإزهار والمحتوى الكيماوى لنباتات الجارونيا

إيمان بدر حامد و جبريل فرج أمحمد

أجرى هذا البحث بهدف دراسة تأثير حامض السالسيلك عند أربع تركيزات صفر، ٥٠، ١٠٠ ، ١٥٠ مليجم/ لتر رشاً على المجموع الخضرى وأربع معدلات التسميد بالسماد المعدنى NPK (١٩:١٩:١٩) بمعدل ٠,٠ ، ٢,٠ ، ٣,٠ و٤,٠ جم / نبات والتفاعل بينهم على النمو والإزهار ومحتوى الأوراق الكيماوى لنباتات الجارونيا *Pelargonium zonale,* L. . وقد أشارت النتائج المتحصل عليها أن حامض السالسيلك والسماد المعدنى أدى الى زيادة معنوية في معظم الصفات المدروسة بالمقارنة بمعاملة الكنترول. وأشارت النتائج المتحصل عليها أن رش حامض السالسيلك بتركيز ١٠٠ مليجم / لتر مع تسميد النباتات بمعدل ٣ جم/ نبات بسماد معدنى NPK شهرياً خلال موسم النمو قد أدى الى أقصى زيادة معنوية في ارتفاع النبات وحجم الجذور والوزن الجاف للجذور في الموسمين . فى حين أدت المعاملة بالتركيز العالى من حامض السالسيلك بتركيز ١٥٠ مليجم / لتر مع تسميد النباتات بمعدل ٣ جم/ نبات بسماد معدنى NPK إلى أفضل النتائج من حيث قطر الساق، عدد الفرع /نبات، عدد الأوراق /نبات، المساحة الورقية / نبات والوزن الجاف للأوراق وكذلك زيادة معنوية فى الإنتاج الزهرى متمثل فى عدد النورات لكل نبات وقطرها كذلك أعلى زيادة معنوية في المحتوى الكلى للأوراق من الكلورفيلات والكاروتينات وتحققت أعلى زيادة معنوية في محتوى الأوراق من عناصر النتروجين و الفوسفور والبوتاسيوم عند الرش بحامض السالسيلك بتركيز ١٥٠ مليجم / لتر مع إضافة السماد المعدنى NPK (١٩:١٩:١٩) بمعدل ٣ أو ٤ جم/ نبات شهرياً خلال موسم النمو مقارنة بالنباتات غير المعالجة.