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Growth and Quality of *Zinnia elegans L.* in Response to Different Growth Stimulants

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Abstract. *Zinnia elegans* L. is a cut flower, to improve the growth parameters of this flower salicylic acid (SA) and calcium chloride ($CaCl_2$) can act as growth stimulants. The purpose of this study was to assess the effects of pre-harvest SA and $CaCl_2$ treatments in extending the vase life, quality and quantity of cut *Zinnia* flowers. Therefore, completely randomized design was made with SA at the rate of 0.5 mg/L, 1 mg/L and 1.5 mg/L and $CaCl_2$ at the rate of 0.5 mg/L, 1 mg/L and 1.5 mg/L with 3 replicates in each treatment. Changes in growth morphology (such as shoot length, root length, dry weigh of root and plant, fresh weight of root and plant, total number of flowers and total number of flower cluster per plant), Physiology (chlorophyll content, PPO activity and protein) and phosphorous and potassium concentration were checked. The research study led to following conclusions that the foliar application of calcium chloride @ 1.5 mg/L + salicylic acid @ 0.5 mg/L resulted in highest growth parameters of *Zinnia*. The quality parameters like chlorophyll, total protein, phosphorous and catalase content also showed maximum value during the course of the study. It can be concluded in nutshell that calcium chloride in combination with salicylic acid results in better growth and quality of zinnia under the agro-climatic conditions of Lahore. These results suggest that SA and $CaCl_2$ could be used as potential growth promoters to improve quantity and quality of *Zinnia elegans* L.

Keywords: *Zinnia elegans*, summer annuals, vase life, physiology and morphology

Introduction

Zinnia is an yearly flower of the family Asteraceae, order Asterales, class Magnoliopsida and genus zinnia (Khan *et al.*, 2018). It is native to north America and Mexico (Dhillon *et al*., 2011). Leading grower of *Zinnia* are Kenya, Malaysia, India, Australia and many European countries. In Pakistan, *Zinnia* are grown easily in Lahore, Islamabad and Karachi. These nursery blossoms are accessible in excess of 100 distinct varieties alongside 20 to 30 species. *Zinnia* can grown-up in the beds, mud and plastic pots, even in wooden boxes and in the rock gardens as well. *Zinnia* is perhaps the easiest bloom to develop every year. Its blossoms are available in multi colours having pink to red, clear orange, bright yellow, white or smooth cream colour shades. *Zinnia* leaves differ in nature and don't have a stalk and the varies 15 cm to 30 cm. Its seeds can be sown into nursery after winter in solid and firm soil that is free from clusters. The seeds are covered with 6-7 mm of soil since *Zinnia* seeds need light to grow. *Zinnia* can develop in constrained water supply with high temperature (Riaz *et al*., 2011). *Zinnia* is utilized in scents, shampoos and cleansers. It is also used as astringent and natural wound healer. It is also consumed as a tea and as a salad. *Zinnia* is the one most significant highlights in cut blossom creation is proper stock of sustenance during the developing time frame (Abbasi *et al.*, 2004). Many plant development controllers have realized impact to build the container life of blossoms and they can be productively used to upgrade the time span of usability of blooming crops. (Peng *et al.*, 2007). A few synthetic chemicals that are utilized in the venture incorporate calcium chloride and salicylic corrosive and their mixes with various focuses.

SA plays a very important monitoring role in plant metabolism (Popova *et al.*, 1997). It's phenolic in nature which takes an interest in the guideline of physiological procedures in plant (Shakirova *et al.*, 2003). It also plays the role as a natural pointer of the thermogenesis to demonstrate blooming in the scope of plants, to control particle take-up by roots, stomatal conductivity (Raskin *et al.*, 1990) and signal regulation of genes expression in the course of leaf senescence (Morris *et al*., 2000). Calcium is central elements of the cell wall which plays a major role in the vase life of flowers (Mehran, 2008) and effectively draw out the jar life due to impeding the senescence parameters by expanding

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in arrangement take-up, leaf and petal water content, keeping up petal solvent proteins and furthermore leaf and petal starches (Kalatehjari *et al.*, 2008) If $CaCl_2$ is applied to plant on vegetative development then it builds its stem and root development, plant tallness, number of leaves and furthermore expands timeframe of realistic usability and jar life of plant (Rab and Haq, 2012).

In the past literature different concentration of salicylic acid was applied to flower at (100, 150 and 200 mg/L). The results were significant when they were compared with the control treatments. The salicylic acid significantly affected the plant height, length of stalk and maximum number of leaves, diameter and fresh and dry weight. Moreover, salicylic acid increased the vase life of flower too (Mahroof *et al.*, 2017). Another experiment was carried in CRD design, the three applications of salicylic acid were applied (at the start of the development and soon after berry setting and at one month later) and with this regard best results were obtained (Akl *et al.*, 2014). It is studied from the past literature application of calcium chloride was applied in different concentration to Rose cut flower which resulted in improved plant growth and more flowers. The application significantly increased macro nutrients concentration, chlorophyll content. Flower vase life, buds and number of shoots were increased mainly because of calcium (Abdolmaleki, 2015). Calcium (Ca) plays a significant job role in the plant physiology, memorizing inclusion for the reactions to salt pressure and controls various procedures. To conquest the negative effect of high saltiness the expansion of supplements' than calcium is the best salt to check results (Daoud and Medjimi, 2009). The use of $CaCl_2$ alone expanded the structure of the plant and significantly affected it and increased the outcome of organic products (Rab and Haq, 2012). The calcium chloride also significantly impacts the physiological characteristics of plants and it also increases membrane permeability and root hydraulic conductivity at high salinity.

An experiment was designed to check the effect of SA and $CaCl_2$. The experiment was designed in the factorial test which was totally depending on the randomized structure with salicylic acid at (150, 300 and 450 mg/L) and $CaCl_2$ at (0.75, 1.5 and 2.25%) each treatment with 4 replications. The prominent physical changes were recorded in the development and fixation of macro-nutrient, total chlorophyll content, bloom quality, the life of container and the solidness of film were also recorded and examined in "Dolce Vita". The application of these increases the shoots and blossoms. The foliar application of the SA and $CaCl_2$ increased the nitrogen potassium and calcium magnesium content in samples. The application of SA and $CaCl_2$ also expanded plant development, (like, shoots and buds blossom). The experiment showed that the salicylic acid and calcium chloride can be used as a best growth premotor to increase flower vase life and other parameters (Abdolmaleki *et al.*, 2015).

Material and Methods

Selection of seeds. *Zinnia elegans* L. seeds were bought from the New Pak Seed Company, Lahore and were kept under control environment to avoid any fungal attack.

Preparation of seed samples. Surface sterilized (3 min) and treated (1% sodium hypochlorite) were sown on coconut husk and peat moss of equal percentage as a germination substrate. Around 7 cm seedlings were transplanted to 25 cm pots.

Plan of study. Seeds were sown in a triplicated experiment in completely randomized design (CRD). The experimental area received the exogenous application of salicylic acid and calcium chloride as growth stimulants to all experimental pots and were used separately and in interaction with each other for a set of 16 treatments.

Data collection. The data on growth, yield and quality parameter of *Zinnia* was collected using standard principles and procedures as shown in Table 1.

Results and Discussion

The plant height is main part of the plant's ecological strategy, it is strongly related with the life span of plant, mass of seed and time to maturity. Plant height is very important for the exposure of the leaves to the sunlight which results in better photosynthesis and also to compete/suppress with the competitive plants/weeds. Plant height is also important for the ecosystem variables like carbon storage. The results regarding plant height (cm) of *Zinnia elegans* in response to different growth stimulants depicted in Fig. 1 indicates that treatment application of 1.5 mg/L $CaCl_2$ + 0.5 mg/L SA (T_{10}) led to maximum plant height with mean value (29.47). Whereas minimum, plant height was observed in the pots where no growth stimulant was applied (T_1: control) which was significantly similar with that of T_{16} (1.5 mg/L $CaCl_2$ + 1.5 mg/L SA).

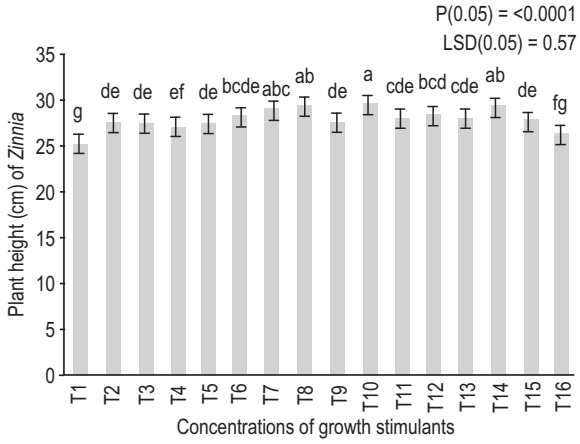
Table 1. Concentrations of salicylic acid and calcium chloride and their combinations

Code	Treatment	Concentration (mg/L)
T_1	Control	0.0
T_2	Calcium chloride	0.5
T_3	Calcium chloride	1.0
T_4	Calcium chloride	1.5
T_5	Salicylic acid	0.5
T_6	Salicylic acid	1.0
T_7	Salicylic acid	1.5
T_8	Calcium chloride + Salicylic acid	0.5 + 0.5
T_9	Calcium chloride + Salicylic acid	0.5 + 1.0
T_{10}	Calcium chloride + Salicylic acid	0.5 + 1.5
T_{11}	Calcium chloride + Salicylic acid	1.0 + 0.5
T_{12}	Calcium chloride + Salicylic acid	1.0 + 1.0
T_{13}	Calcium chloride + Salicylic acid	1.0 + 1.5
T_{14}	Calcium chloride + Salicylic acid	1.5 + 0.5
T_{15}	Calcium chloride + Salicylic acid	1.5 + 1.0
T_{16}	Calcium chloride + Salicylic acid	1.5 + 1.5

The other treatments of the growth stimulants used during the course of the research study showed intermediate plant height that ranged between the maximum and minimum one (as shown in Fig. 1).

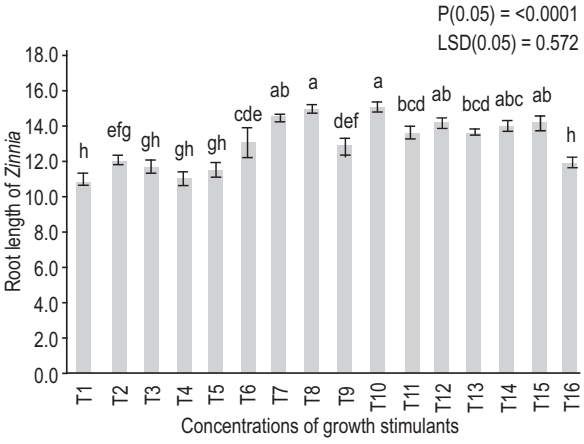
The findings of the research confirm the previous work which states that calcium chloride more good result when it is used in combination with other chemicals instead of its sole application. (Kazemi, 2013).

Roots play an important part in the growth and development of the plant as they provide anchorage to the plant on one hand and absorb water and nutrients from the soil on the other. The more the length of the roots the more surface area of the soil will be covered by those to absorb water and plant nutrition. The results regarding to the root length (cm) of *Zinnia elegans* in response to different growth stimulants showed in Fig. 2 indicates that treatment application of $CaCl_2$ @ 0.5 mg/L + SA @ 0.5 mg/L and in $CaCl_2$ @ 1.5 mg/L + SA 0.5 @ mg/L in *Zinnia elegans* L. showed highest root length at mean value of 15.30 and 15.7. The minimum root length was obtained in the control plant treatment. Whereas, salicylic acid increased root length when compared with the control plants but both salicylic acid and calcium chloride showed more prominent result in combination. These results have been supported by the previous research study which proved that salicylic acid act as a growth regulator and promotes vegetative growth of the plant (Kazemi, 2013).



T_1=Control; T_2=$CaCl_2$ (0.5); T_3=$CaCl_2$ (1.0); T_4=$CaCl_2$ (1.5); T_5=SA (0.5); T_6=SA (1.0); T_7=SA (1.5); T_8=$CaCl_2$ (0.5) + SA (0.5); T_9=$CaCl_2$ (1.0) + SA (0.5); T_{10}=$CaCl_2$ (1.5) + SA (0.5); T_{11}=$CaCl_2$ (0.5) + SA (1.0); T_{12}=$CaCl_2$ (1.0) + SA (1.0); T_{13}=$CaCl_2$ (1.5) + SA (1.0); T_{14}=$CaCl_2$ (0.5) + SA (1.5); T_{15}=$CaCl_2$ (1.0) + (SA 1.5); T_{16}=$CaCl_2$ (1.5) + SA (1.5)

Fig. 1. Effect of different concentrations of growth stimulants treatment on plant height (cm) of *Zinnia elegans*.



T_1=Control; T_2=$CaCl_2$ (0.5); T_3=$CaCl_2$ (1.0); T_4=$CaCl_2$ (1.5); T_5=SA (0.5); T_6=SA (1.0); T_7=SA (1.5); T_8=$CaCl_2$ (0.5) + SA (0.5); T_9=$CaCl_2$ (1.0) + SA (0.5); T_{10}=$CaCl_2$ (1.5) + SA (0.5); T_{11}=$CaCl_2$ (0.5) + SA (1.0); T_{12}=$CaCl_2$ (1.0) + SA (1.0); T_{13}=$CaCl_2$ (1.5) + SA (1.0); T_{14}=$CaCl_2$ (0.5) + SA (1.5); T_{15}=$CaCl_2$ (1.0) + (SA 1.5); T_{16}=$CaCl_2$ (1.5) + SA (1.5)

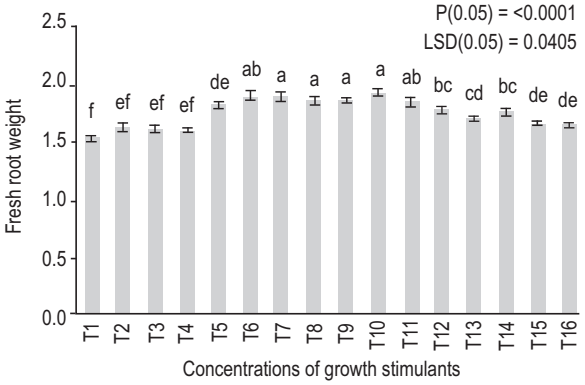
Fig. 2. Effect of different concentrations of growth stimulants on treatment of root length (cm) of *Zinnia elegans* L.

The more the fresh weight of the roots the more will be the nutrients uptake of the plant from soil which ultimately results in healthy plant and hence more radiation absorption for photosynthesis. The fresh root weight (g) of *Zinnia elegans* in response to different growth stimulants showed in Fig. 3 elaborate that maximum fresh root weight (g) was obtained in the treatment applications where SA was applied at 1.5 mg/L, $CaCl_2$ at the rate of 0.5 mg/L + SA at rate of 0.5 mg/L, $CaCl_2$ @ 1.0 mg/L + SA @ 0.5 mg/L and $CaCl_2$ @ 1.5 mg/L + SA @ 0.5 mg/L. The present research experiment revealed that minimum fresh root weight was observed in control plant at (1.54 g). These results are in line with the previous findings which reported that salicylic acid increases the fresh root weight of the plant and calcium chloride work more efficiently when applied in combinations with other chemicals when compared with its sole application.

Similar results of $CaCl_2$ on the fresh root weight was also reported in the snap bean by (El-Tohamy *et al*., 2001), in cucumber by (Kazemi, 2013) and in strawberry by (Kazemi, 2015).

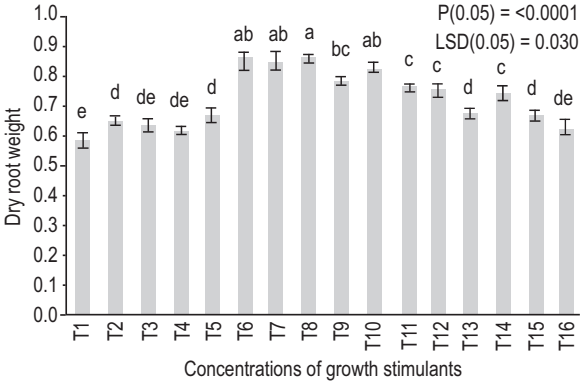
The roots with higher dry matter contents will be healthier than those with low dry matter contents. These roots will anchor plants in soil which will lead to good upright stature of the plant and will absorb more sunlight for photosynthesis. Application of different growth stimulants affected the dry root weight (g) of *Zinnia elegans* L. significantly as shown in Fig. 4. Highest dry root weight (0.87 g) in this case was observed in application of 0.5 mg/L $CaCl_2$ + 0.5 mg/L SA. The minimum fresh root (0.59 g) was obtained in control which was statistically same with that of T_3 (0.64 g), T_4 (0.63 g) and in T_{16} (0.64 g). These results are in line with those of (Almeida *et al*., 2016) who reported that application of SA and $CaCl_2$ leads to higher yield in dry weight in lettuce (Youssef *et al.*, 2017).

The fresh plant weight (g) was measured by applying different growth stimulants on *Zinnia elegans* L. showed in (Fig. 5.) depicts that treatment application $CaCl_2$ @ 1.5 mg/L + SA @ 0.5 mg/L resulted in more fresh plant weight (34.23 g) minimum weight was obtained in control plant (28.49 g). The present study coincides with those of reported by (Kazemi, 2013) in strawberry. The similar results were found in globe artichoke. The salicylic acid and calcium chloride significantly effects fresh plant weight of the plants. Moreover, some studies also tells that calcium chloride in combination to salicylic acid shows more significant result when compared with other treated plants (Qureshi *et al.*, 2013). It is proved



T_1=Control; T_2=$CaCl_2$ (0.5); T_3=$CaCl_2$ (1.0); T_4=$CaCl_2$ (1.5); T_5=SA (0.5); T_6=SA (1.0); T_7=SA (1.5); T_8=$CaCl_2$ (0.5) + SA (0.5); T_9=$CaCl_2$ (1.0) + SA (0.5); T_{10}=$CaCl_2$ (1.5) + SA (0.5); T_{11}=$CaCl_2$ (0.5) + SA (1.0); T_{12}=$CaCl_2$ (1.0) + SA (1.0); T_{13}=$CaCl_2$ (1.5) + SA (1.0); T_{14}=$CaCl_2$ (0.5) + SA (1.5); T_{15}=$CaCl_2$ (1.0) + (SA 1.5); T_{16}=$CaCl_2$ (1.5) + SA (1.5)

Fig. 3. Effect of different concentrations of growth stimulants on treatment of fresh root weight (g) of *Zinnia elegans* L.



T_1=Control; T_2=$CaCl_2$ (0.5); T_3=$CaCl_2$ (1.0); T_4=$CaCl_2$ (1.5); T_5=SA (0.5); T_6=SA (1.0); T_7=SA (1.5); T_8=$CaCl_2$ (0.5) + SA (0.5); T_9=$CaCl_2$ (1.0) + SA (0.5); T_{10}=$CaCl_2$ (1.5) + SA (0.5); T_{11}=$CaCl_2$ (0.5) + SA (1.0); T_{12}=$CaCl_2$ (1.0) + SA (1.0); T_{13}=$CaCl_2$ (1.5) + SA (1.0); T_{14}=$CaCl_2$ (0.5) + SA (1.5); T_{15}=$CaCl_2$ (1.0) + (SA 1.5); T_{16}=$CaCl_2$ (1.5) + SA (1.5)

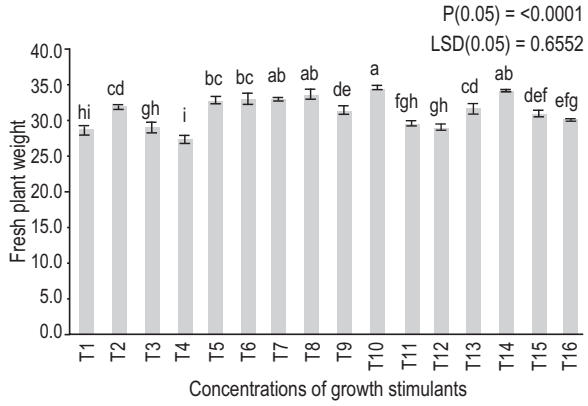
Fig. 4. Effect of different concentrations of growth stimulants treatment of dry root weight (g) of *Zinnia elegans* L.

previously that plant treated with salicylic acid increase the weight of the plant reported by (Yildirim *et al*., 2008). The fresh plant weight of plants treated with $CaCl_2$ alone was less than treated in combination to SA reported by the (Salachna *et al*., 2015).

The results related to dry plant weight (g) of *Zinnia elegans* in response to different growth stimulants showed in Fig. 6 which proves that treatment application of $CaCl_2$ @ 1.5 mg/L + SA @ 0.5 mg/L and in $CaCl_2$ @ 0.5 mg/L + SA @1.0 mg/L was statistically weight highest. The minimum dry weight was recorded in non-treated plants at (10.95 g). Previous literature showed that the dry root weight shows significant results when plants are treated with salicylic acid and calcium chloride when compared with the control and other chemical treated plants (Qureshi *et al*., 2013), (Mohammad *et al*., 2021). These findings are similar with the results of on rose (Abdolmaleki *et al*., 2014).

Flowers play important role in the plant because these contain male and female reproductive organ and without flower pollination and fertilization is not possible due to which new seeds and fruits are not formed. Flowers are the most attractive part of any plant. Flowers have different ranges of colors and sizes and fragrance's that contain nectar which helps bees to pollination other plants. So basically, flowers help to propagate through seeds. The results of flower per plant of *Zinnia elegans* in response to different growth stimulants showed in Fig. 7 specifies all-out results were counted in in contrast to salicylic acid results were comparatively better alone than calcium chloride when compared with non-treated plant. The calcium chloride and salicylic acid at high level decreases the number of flowers. In addition to this past studies also depicted that salicylic acid and calcium chloride improves quantity and quality of plants (Mortazavi *et al*., 2015). Few of the studies shows that salicylic acid at high level also gives non-significant result when treated at higher concentration due to salt stress reported by (Salachna *et al*., 2015).

In some flower species flowers when more than two or three formed on one axis than usually these are termed as flowers cluster and collectively called as an inflorescence. The results of flower cluster per plant of *Zinnia elegans* in response to different growth stimulants produced in Fig. 8 indicates the minimum results were found when both growth stimulants were used at high level $CaCl_2$ @ 1.5 mg/L + SA @ 1.5 mg/L. The increase in number of flowers cluster per plant are reported by (Salachna *et al*., 2015) in speckled spur flower findings are similar to present conducted results. The salicylic acid at high level resulted decrease in number of flower



T_1=Control; T_2=$CaCl_2$ (0.5); T_3=$CaCl_2$ (1.0); T_4=$CaCl_2$ (1.5); T_5=SA (0.5); T_6=SA (1.0); T_7=SA (1.5); T_8=$CaCl_2$ (0.5) + SA (0.5); T_9=$CaCl_2$ (1.0) + SA (0.5); T_{10}=$CaCl_2$ (1.5) + SA (0.5); T_{11}=$CaCl_2$ (0.5) + SA (1.0); T_{12}=$CaCl_2$ (1.0) + SA (1.0); T_{13}=$CaCl_2$ (1.5) + SA (1.0); T_{14}=$CaCl_2$ (0.5) + SA (1.5); T_{15}=$CaCl_2$ (1.0) + (SA 1.5); T_{16}=$CaCl_2$ (1.5) + SA (1.5)

Fig. 5. Effect of different concentrations of growth stimulants on treatment fresh plant weight (g) of *Zinnia elegans* L.

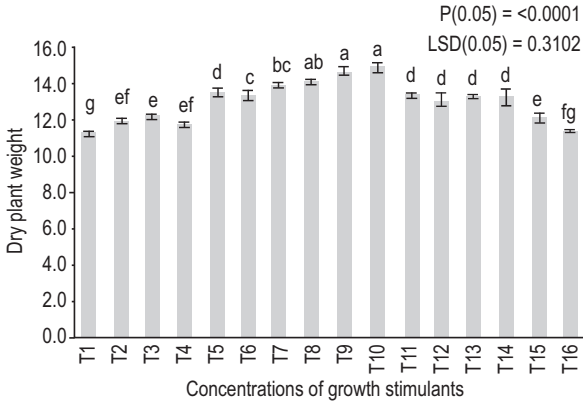


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Fig. 6. Effect of different concentrations of growth stimulants treatment dry plant weight (g) of *Zinnia elegans* L.

cluster per plant when treated at higher concentration due to salt stress (Salachna *et al.*, 2015).

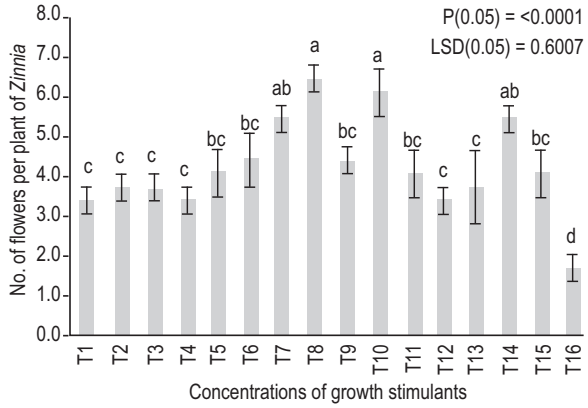

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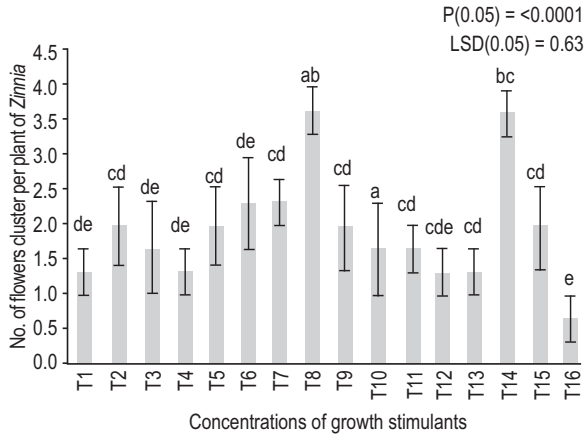
Fig. 7. Effect of different concentrations of growth stimulants on treatment number of flowers per plant of *Zinnia elegans* L.

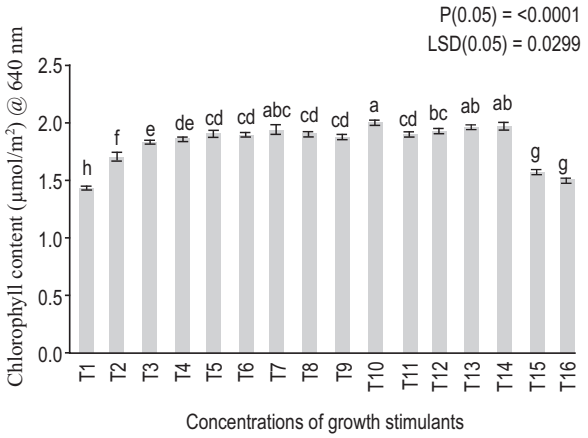
Chlorophyll and carotenoid content. Chlorophylls are green in colour and contain porphyrin ring. The ring is formed of particles on which electrons are attached and they are allowed to move. Due to movement of electron in the ring could easily loss or gain electron and due to this different atom are formed. This is the important procedure due to which chlorophyll gets the energy of daylight. Carotenoids have different colors like red, orange and yellow color pigment. These compounds are composed of six carbon atoms with ring that is connected in a chain structure. The carotenes carotenoids cannot transfer direct energy of the sunlight to the pathway of photosynthetic but they must pass their energy to the chlorophyll. The leaf chlorophyll content of *Zinnia elegance* L. in response to different growth stimulants were counted shown in Fig. 9 overall chlorophyll content was increased in salicylic acid and in combined treatments of SA and $CaCl_2$.

In the present experiment chlorophyll level was detected at three different wavelengths such as 640, 645 and 663 nm. The minimum chlorophyll content was found in control plants in all wavelengths 640 nm (1.40 µmol/m^2), 645 nm (141 µmol/m^2) and 663 nm (1.47 µmol/m^2) as shown in Fig. 9, 10 and 11 respectively. The previous literature showed that plant treated with salicylic acid



T_1=Control; T_2=$CaCl_2$ (0.5); T_3=$CaCl_2$ (1.0); T_4=$CaCl_2$ (1.5); T_5=SA (0.5); T_6=SA (1.0); T_7=SA (1.5); T_8=$CaCl_2$ (0.5) + SA (0.5); T_9=$CaCl_2$ (1.0) + SA (0.5); T_{10}=$CaCl_2$ (1.5) + SA (0.5); T_{11}=$CaCl_2$ (0.5) + SA (1.0); T_{12}=$CaCl_2$ (1.0) + SA (1.0); T_{13}=$CaCl_2$ (1.5) + SA (1.0); T_{14}=$CaCl_2$ (0.5) + SA (1.5); T_{15}=$CaCl_2$ (1.0) + (SA 1.5); T_{16}=$CaCl_2$ (1.5) + SA (1.5)

Fig. 8. Effect of different concentrations of growth stimulants on treatment number of flowers cluster per plant of *Zinnia elegans* L.

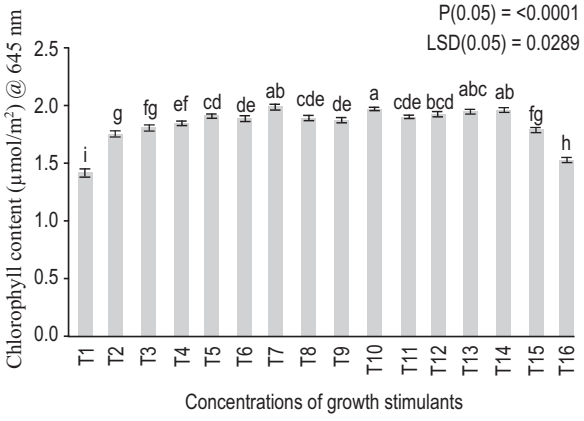


T_1=Control; T_2=$CaCl_2$ (0.5); T_3=$CaCl_2$ (1.0); T_4=$CaCl_2$ (1.5); T_5=SA (0.5); T_6=SA (1.0); T_7=SA (1.5); T_8=$CaCl_2$ (0.5) + SA (0.5); T_9=$CaCl_2$ (1.0) + SA (0.5); T_{10}=$CaCl_2$ (1.5) + SA (0.5); T_{11}=$CaCl_2$ (0.5) + SA (1.0); T_{12}=$CaCl_2$ (1.0) + SA (1.0); T_{13}=$CaCl_2$ (1.5) + SA (1.0); T_{14}=$CaCl_2$ (0.5) + SA (1.5); T_{15}=$CaCl_2$ (1.0) + (SA 1.5); T_{16}=$CaCl_2$ (1.5) + SA (1.5)

Fig. 9. Effect of different concentrations of growth stimulants treatment on chlorophyll content (µmol/m^2) @ 640 nm of *Zinnia elegans* L.

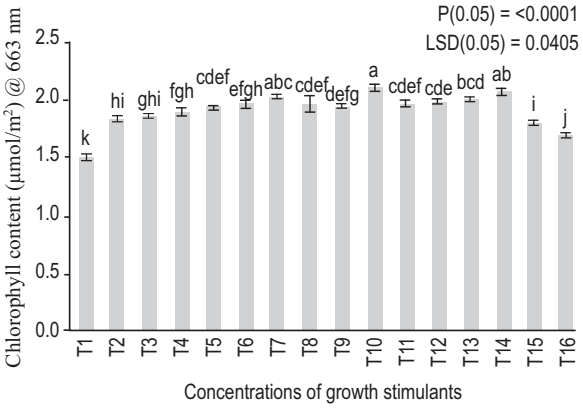
had high chlorophyll content instead of treated with sole application of $CaCl_2$ but when $CaCl_2$ is used in combination to SA resulted more chlorophyll content reported by (Salachna *et al*., 2015) on spur flower. The increase in the chlorophyll content after the application of SA and $CaCl_2$ was reported by (Yildirim *et al.*, 2008). The plants treated with salicylic acid reported by (Li *et al*., 2014) were found to have highest chlorophyll content in the *Torreya grandis*.

The proteins present in all cells carry variety of cellular functions. Within one cell there can be thousands of different proteins that have different sizes, structures and different functions. Proteins are the integral part of the cell wall. Proteins are one of the most abundant of the macro molecules. Within cell proteins function as metabolic reactions, whereas other act as a transport reporters, storage and carrier of electron. The results of total protein content of plant leaf of *Zinnia elegans* L. in response to different growth stimulants exhibited in Fig. 12 and the lowest protein level was detected in $CaCl_2$ @ 1.5 mg/L + SA @ 1.5 mg/L whereas, calcium alone decreased the protein content and salicylic acid alone increased the content of protein but when calcium combinedly used with combination to salicylic acid than calcium shows more significant results reported by (Salachna *et al*., 2015).



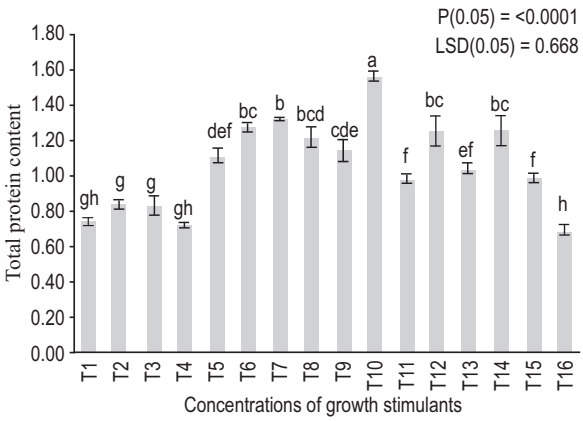
T_1=Control; T_2=$CaCl_2$ (0.5); T_3=$CaCl_2$ (1.0); T_4=$CaCl_2$ (1.5); T_5=SA (0.5); T_6=SA (1.0); T_7=SA (1.5); T_8=$CaCl_2$ (0.5) + SA (0.5); T_9=$CaCl_2$ (1.0) + SA (0.5); T_{10}=$CaCl_2$ (1.5) + SA (0.5); T_{11}=$CaCl_2$ (0.5) + SA (1.0); T_{12}=$CaCl_2$ (1.0) + SA (1.0); T_{13}=$CaCl_2$ (1.5) + SA (1.0); T_{14}=$CaCl_2$ (0.5) + SA (1.5); T_{15}=$CaCl_2$ (1.0) + (SA 1.5); T_{16}=$CaCl_2$ (1.5) + SA (1.5)

Fig. 10. Effect of different concentrations of growth stimulants treatment on chlorophyll content (µmol/m²) @ 645 nm of *Zinnia elegans* L.



T_1=Control; T_2=$CaCl_2$ (0.5); T_3=$CaCl_2$ (1.0); T_4=$CaCl_2$ (1.5); T_5=SA (0.5); T_6=SA (1.0); T_7=SA (1.5); T_8=$CaCl_2$ (0.5) + SA (0.5); T_9=$CaCl_2$ (1.0) + SA (0.5); T_{10}=$CaCl_2$ (1.5) + SA (0.5); T_{11}=$CaCl_2$ (0.5) + SA (1.0); T_{12}=$CaCl_2$ (1.0) + SA (1.0); T_{13}=$CaCl_2$ (1.5) + SA (1.0); T_{14}=$CaCl_2$ (0.5) + SA (1.5); T_{15}=$CaCl_2$ (1.0) + (SA 1.5); T_{16}=$CaCl_2$ (1.5) + SA (1.5)

Fig. 11. Effect of different concentrations of growth stimulants on treatment chlorophyll content (µmol/m²) @ 663 nm of *Zinnia elegans* L.



T_1=Control; T_2=$CaCl_2$ (0.5); T_3=$CaCl_2$ (1.0); T_4=$CaCl_2$ (1.5); T_5=SA (0.5); T_6=SA (1.0); T_7=SA (1.5); T_8=$CaCl_2$ (0.5) + SA (0.5); T_9=$CaCl_2$ (1.0) + SA (0.5); T_{10}=$CaCl_2$ (1.5) + SA (0.5); T_{11}=$CaCl_2$ (0.5) + SA (1.0); T_{12}=$CaCl_2$ (1.0) + SA (1.0); T_{13}=$CaCl_2$ (1.5) + SA (1.0); T_{14}=$CaCl_2$ (0.5) + SA (1.5); T_{15}=$CaCl_2$ (1.0) + (SA 1.5); T_{16}=$CaCl_2$ (1.5) + SA (1.5)

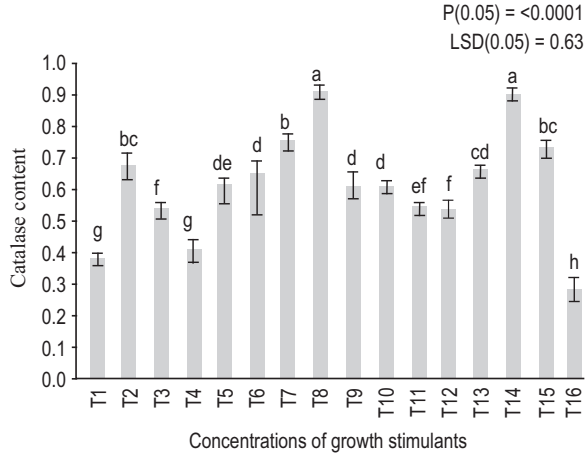
Fig. 12. Effect of different concentrations of growth stimulants treatment total protein content of *Zinnia elegans* L.

Previous studies reported that salicylic acid significantly increased the level of protein and calcium chloride when used with mixture of salicylic acid it also increases the protein level (Salachna *et al.*, 2015)

The catalase is an enzyme that is present in almost all living cells for example plants, animals, bacteria. The function of enzyme is to catalyze the decomposition of H_2O_2 to H_2O and O_2. Its helpful enzyme it protects the cell from the oxidative damage which occurs due to reactive oxygen species. The results of *Zinnia elegans* L. in response to different growth catalase content in Fig. 13 indicates 0.5 mg/L and T_{10} $CaCl_2$ @ 1.5 mg/L + SA @ 0.5 mg/L shows highest catalase activity. When plants were compared with the control all the treated plants showed significant results and catalase activity was increased in plants treated with SA and $CaCl_2$. The findings of previous experiment is similar to present study that treated seedlings with salicylic acid and calcium chloride increases catalase activity as compared to the control one which lead to the conclusion that the oxidative stress could be an influential component reported by in barley (El-Feky *et al*., 2014).

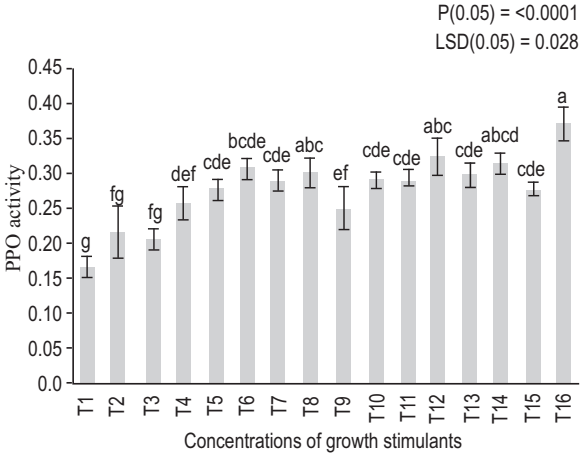
The enzyme polyphenol oxidase (PPO) catalyzes the process of oxidation of the phenolic compounds into the highly reactive quinones. Polymerization of the PPO-resulting quinones reasons the postharvest browning of cut and fruit bruised but still the inherent physiological functions of PPOs in unharmed, complete plant cells are unstated. The results of *Zinnia elegans* L. in response to different growth stimulants to polyphenol activity shown in Fig. 14. The plants treated with T_{16} $CaCl_2$ at the rate 1.5 mg/L + SA at the rate 1.5 mg/L increased polyphenol activity. Overall PPO activity increased in all treated plants as compared to non-treated plants. Plants treated with salicylic acid can increase the rate of polyphenol oxidase (Taşgın *et al*., 2006) on wheat leaves. The previous experiments show that pectin metabolism was boosted up and down by the calcium chloride at different levels as compared to control one. Moreover, (Langer *et al*., 2019) enhanced the calcium ions by PPO activity which resulted that it could prevent plant against fungal or pathogen reported in strawberry fruit (Langer *et al*., 2019).

Potassium plays unique role in the body of plant it helps in opening and closing of stomata and also helps in regulation of carbon dioxide. Potassium helps enzyme to activate for ATP which is an important source of energy for chemical which took place in the tissue of



T_1=Control; T_2=$CaCl_2$ (0.5); T_3=$CaCl_2$ (1.0); T_4=$CaCl_2$ (1.5); T_5=SA (0.5); T_6=SA (1.0); T_7=SA (1.5); T_8=$CaCl_2$ (0.5) + SA (0.5); T_9=$CaCl_2$ (1.0) + SA (0.5); T_{10}=$CaCl_2$ (1.5) + SA (0.5); T_{11}=$CaCl_2$ (0.5) + SA (1.0); T_{12}=$CaCl_2$ (1.0) + SA (1.0); T_{13}=$CaCl_2$ (1.5) + SA (1.0); T_{14}=$CaCl_2$ (0.5) + SA (1.5); T_{15}=$CaCl_2$ (1.0) + (SA 1.5); T_{16}=$CaCl_2$ (1.5) + SA (1.5)

Fig. 13. Effect of different concentrations of growth stimulants treatment catalase content of *Zinnia elegans* L.

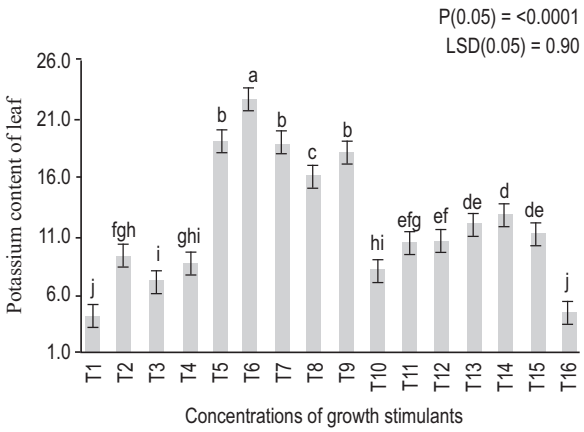


T_1=Control; T_2=$CaCl_2$ (0.5); T_3=$CaCl_2$ (1.0); T_4=$CaCl_2$ (1.5); T_5=SA (0.5); T_6=SA (1.0); T_7=SA (1.5); T_8=$CaCl_2$ (0.5) + SA (0.5); T_9=$CaCl_2$ (1.0) + SA (0.5); T_{10}=$CaCl_2$ (1.5) + SA (0.5); T_{11}=$CaCl_2$ (0.5) + SA (1.0); T_{12}=$CaCl_2$ (1.0) + SA (1.0); T_{13}=$CaCl_2$ (1.5) + SA (1.0); T_{14}=$CaCl_2$ (0.5) + SA (1.5); T_{15}=$CaCl_2$ (1.0) + (SA 1.5); T_{16}=$CaCl_2$ (1.5) + SA (1.5)

Fig. 14. Effect of different concentrations of growth stimulants treatment PPO activity of *Zinnia elegans* L.

the plant. Potassium also play role in the osmo-regulation, it also helps in up taking of water through roots of the plant and its loss through the stomata. The 'K' also helps plant to resist against drought. Potassium is vital at practically every stage of the synthesis of protein. Use of salicylic acid increase the leaf potassium concentration in plants.

The maximum potassium content in response to different growth stimulants in *Zinnia elegans* L. was found in T_6 SA (1.0) showed in a Fig. 15. These conclusions are comparable with those of (Amiri *et al*., 2014) and (Mirdad, 2014), who reported earlier SA enhanced potassium in grapevine and broccoli. The lowermost K was found in the plants treated with $CaCl_2$ (Tsialtas *et al*., 2016), who described reduced potassium concentration in the leaves of P. ambitious exposed to salt stress. Literature specify that high concentration of Cl^- ions might limit other ions uptake, particularly K (Kronzucker *et al.*, 2013). Potassium is an essential ion determining cellular osmotic potential and stomata functioning (Oosterhuis *et al*., 2014). The previous literature depicted that plants treated with many salt might face the low stomatal conductance the reason might be the reduce amount of potassium supply (Salachna *et al.*, 2015).



T_1=Control; T_2=$CaCl_2$ (0.5); T_3=$CaCl_2$ (1.0); T_4=$CaCl_2$ (1.5); T_5=SA (0.5); T_6=SA (1.0); T_7=SA (1.5); T_8=$CaCl_2$ (0.5) + SA (0.5); T_9=$CaCl_2$ (1.0) + SA (0.5); T_{10}=$CaCl_2$ (1.5) + SA (0.5); T_{11}=$CaCl_2$ (0.5) + SA (1.0); T_{12}=$CaCl_2$ (1.0) + SA (1.0); T_{13}=$CaCl_2$ (1.5) + SA (1.0); T_{14}=$CaCl_2$ (0.5) + SA (1.5); T_{15}=$CaCl_2$ (1.0) + (SA 1.5); T_{16}=$CaCl_2$ (1.5) + SA (1.5)

Fig. 15. Effect of different concentrations of growth stimulants treatment potassium content of leaf on (*Zinnia elegans* L.).

Phosphorous is an important element for plant. Proper amount of phosphorous is required for normal growth of plant. It plays role the process of photosynthesis, storage of energy and its transfer, respiration and also plays vital role in the cell division, enlargement of the cell and it also helps in many other functions of the plant. The plant treated with T_{14} $CaCl_2$ @ 0.5 mg/L + SA @ 1.5 mg/L shows maximum phosphorous content and lowest was observed in $CaCl_2$ @ 1.5 mg/L + SA @ 1.5 mg/L. In 2013 experiment was laid out which showed that effect of SA and $CaCl_2$ shows remarkable results when applied in required amount and also improves respiration rate of the plants and improves the elongation of cells (Metwally *et al*., 2013).

Conclusion

The research study led to following conclusions that foliar application of calcium chloride @ 1.5 mg/L + salicylic acid @ 0.5 mg/L resulted in highest growth parameters of *Zinnia*. The quality parameters like chlorophyll, total protein, phosphorous and catalase content also showed maximum value during the course of the study. It can be concluded in nutshell that calcium chloride in combination with salicylic acid results in better growth and quality of *zinnia* under the agro-climatic conditions of Lahore.

Conflict of Interest. The authors declare that they have no conflict of interest.

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