Pak. J. Bot., 45(4): 1179-1185, 2013.

IMPACT OF EXOGENOUS APPLICATION OF SALT AND GROWTH REGULATORS ON GROWTH AND YIELD OF STRAWBERRY

KHALID MAHMOOD QURESHI*, SAMAN CHUGHTAI, USMAN SHOUKAT QURESHI AND NADEEM AKHTAR ABBASI

Department of Horticulture, PMAS-Arid Agriculture University Rawalpindi, Pakistan
**Corresponding author, E-mail: kmq_2008@hotmail.co.uk*

Abstract

Strawberry is perishable crop which is exceedingly in demand for its taste, profitability, high yield and good quality. For production at commercial level growth regulators have been used in the past but in present more attention paid towards pre and post-harvest techniques by using combination of growth regulators with salt. Keeping in view, present research was laid at research area of horticulture department, Pir Mehr Ali Shah Arid Agriculture University Rawalpindi, during 2010 – 2011. The experiment was carried out to check the impact of exogenous application of salt and growth regulators on growth and yield of strawberry. The treatments thus formed were T_1: Control/ untreated; T_2: Gibberellic acid 50ppm; T_3: Salicylic acid 1mMol^{-L}; T_4: Calcium chloride 0.4%; T_5: Gibberellic acid 50ppm + Calcium chloride 0.4%; T_6: Salicylic acid 1mMol^{-L} + Calcium chloride 0.4%. Randomized Complete Block Design (RCBD) was applied to verify the treatments. Results showed that application of growth regulators combined with salt was more effective in increasing growth and yield. GA_3 either applied singly or among calcium chloride, radically increased the vegetative growth parameters by increasing plant height, crown diameter, canopy spread, fresh and dry weight of plant and leaves, leaf area, fruit set percentage, number of, runners, trusses, flowers and fruits; as compared to salicylic acid followed by Calcium chloride. However, fruit size, weight and yield were reduced. Among combined sprays of growth regulator and salt, Salicylic acid + Calcium chloride showed significant results in all parameters viz; vegetative growth, yield and fruit quality parameters, than Gibberellic acid + Calcium chloride followed by control. Salicylic acid + $CaCl_2$ also improve the fruit quality by significantly increasing ascorbic acid content and Total Soluble Solids while titratable acidity showed non-significant result.

Introduction

Strawberry is popular among growers of Pakistan who get high return on their investments due to its short growing season. Limited quantities of strawberries are produced in Pakistan which are either eaten fresh or used in processed food. *Fragaria ananassa* Duch., is the seasonal fruiting variety of the strawberry which produce single crop each summer and is a short-day plant. Limited vegetative growth occurs during this short period. As a result, the fruit produced is not of good quality and have minimum marketable yield (Asrey *et al.,* 2004; Singh *et al.,* 2007) and fetch less price in market thus causing severe loss to grower. Application of Growth regulators has been practiced commercially to increase the production and quality of strawberry crop. These growth regulators excite the natural plant hormones and allow synchronization of plant development to occur. Gibberellic acid (GA_3) is a growth regulator which stimulate the effect of long day lengths in short day plants by improving vegetative development and increasing runner production. Gibberellic acid progressively increased the plant height, canopy spread, leaf area, number of leaves, petiole length and induces stem elongation when applied exogenously to strawberry plants. Gibberellic acid initiate early flowering and thus early fruit development and harvesting occur. It also increase the truss heights, number of flowering trusses per crown, fruit set percentage, total number of fruits per plant but consequently fruit size and fruit weight decreased (Kasim *et al.,* 2007; Paroussi *et al.,* 2002; Sharma & Singh, 2009). It also enhanced the number of runners in all strawberry varieties by specifically stimulating the stolon forming systems during long days. It is also responsible for increasing the number of runners per crown at higher rates of application. (Hytonen *et al.,* 2009). Gibberellic acid also increase the fruit quality by producing firmer fruit with high ascorbic acid and total soluble sugars, whereas, inducing no significant affect on titratable acidity (Usenik *et al.,* 2005; Sharma & Singh, 2009; Ouzounidou *et al*., 2010).

Salicylic acid is a signal molecule that involves in plant defense system. When a pathogen attacked plant, a naturally occurring defense system of plant is activated this induced systemic acquired resistance (SAR) in undamaged tissues to control or confine disease expansion (Tsuda *et al.,* 2008; Aman *et al*. 2013). Exogenous application of salicylic acid increased the level of endogenous salicylic acid moreover; pathogenesis related genes (PR-genes) were also activated at sites of pathogen attack or invasion thus, inducing disease or pathogenic resistance in plant (Van Loon *et al.,* 2006). Exogenous application of salicylic acid significantly increased overall growth; shoot length, leaf area, fresh and dry weights of root, shoot and overall plant (Amborabe *et al.,* 2002; Khodary, 2004; Eraslan *et al.,* 2007; Karlidag *et al.,* 2009b; Niakan *et al.,* 2010). Salicylic acid induce flowering and fruit setting (Martin-Mex *et al.,* 2005a; Martin-Mex *et al.,* 2005b) in many plant Salicylic acid also increased the fruit weight and yield (Fariduddin *et al.,* 2003; Larque-Saavedra and Martin-Mex, 2007). It increases the fruit firmness, total soluble solids and ascorbic acid contents but did not significantly affect the titrable acidity of fruits (Karlidag *et al*., 2009a; Shafiee *et al.,* 2010).

In plants, calcium is generally obtained from soil solution via root systems from where it reached shoots through xylem. Lack of calcium in the root system causes

malformation in plant's normal life cycle. Calcium in cationic form (Ca^{2+}) plays an important role in plants physiology by helping in cell division and expansion, connecting environmental stimuli to their suitable physiological responses (White, 2000). Calcium chloride doses increases the leaf area index whereas there is no significant effect on plant growth and showed reduction in fruit production there is no significant effect of calcium chloride on total soluble solids (TSS) and the ratio TTS/TA (Andriolo *et al.*, 2010; Siddiq *et al*., 2012). It also increase average fruit weight and size of strawberry fruits with no significant affect on titratable acidity (Dunn & Able, 2006; Ramezanian *et al.*, 2009).

Therefore, the present study is purposed to investigate the impact of exogenous application of salt and growth regulators on growth and yield of strawberry

Materials and Methods

Present study was conducted at research area of Horticulture Department, Pir Mehr Ali Shah Arid Agriculture University Rawalpindi, during 2010-2011. The runner plants of the strawberry (*Fragaria ananassa* Duch) cv. "Chandler" were collected from Swat, Khyber-Pakhtoonkhwa. Plants were grown in clay pots having capacity to hold 3 liter planting media. Media used was sand, soil and silt at ratio of 1:1:1. Foliar sprays of gibberellic acid (GA_3), salicylic acid (SA) and calcium chloride ($CaCl_2$) was made before flowering. To check the combined effect of growth regulator and salt, the spray was done during fruit setting. The treatments formed were T_1 = Control, T_2 = Gibberellic acid (50ppm), T_3 = Salicylic acid ($1mMol^{-L}$), T_4 = Calcium chloride (0.4%), T_5 = Gibberellic acid (50ppm) + Calcium chloride (0.4%) and T_6 = Salicylic acid ($1mMol^{-L}$) + Calcium chloride (0.4%). Each treatment was consisted of 3 replications and ten plants per replication. The experiment was arranged according to the Randomized Complete Block Design (RCBD). Data was taken on the weekly basis of following parameters during entire period of research study. The vegetative growth characteristics include plant height, leaf area, crown diameter, canopy spread, number of leaves, number of runners, fresh and dry weight of plant and leaves; while reproductive traits include number of trusses, flowers and fruits, fruit set percentage, fruit weight and fruit size; and quality parameters including total soluble solids, titratable acidity and ascorbic acid contents were observed.

Results

Vegetative parameters: The mean values of vegetative growth characteristics are listed in Table 1. The application of growth regulators (GA_3 and SA) alone or combined with salt ($CaCl_2$) significantly increased plant height, number of leaves, leaf area, number of runners, canopy spread and fresh and dry weight of plant. Among treatments, GA_3 + $CaCl_2$ showed more plant height (18.47 cm) followed by GA_3 (18.37 cm), SA + $CaCl_2$ (12.24 cm), SA (11.70 cm), $CaCl_2$ (11.20 cm) and Control (10.93 cm). Maximum leaf area was observed in, gibberellic acid (63.63 cm^2) and gibberellic acid + $CaCl_2$ (50.52 cm^2) which was highly significant with salicylic acid (45.38 cm^2) and salicylic acid + $CaCl_2$ (43.75 cm^2). Significantly higher numbers of leaves, runners and canopy spread were found in plants treated with gibberellic acid alone or in combination followed by salicylic acid alone or in combination with salt. Lowest number of leaves, runners and canopy spread was obtained in $CaCl_2$ treated plants as compared to control and other treatments. It was cleared from data pertaining to fresh weight of strawberry plants that a non-significant observation was noted between combined application of growth regulator (GA_3) and salt ($CaCl_2$) (23.31 gms) and GA_3 alone (22.13 gms). Similarly, combined application of growth regulator (SA) and salt ($CaCl_2$) (20.70) and SA alone (19.72 gms) were non-significant with each other. Salt ($CaCl_2$) when sprayed alone decreased the fresh weight of plants with (10.40 gms) value which was significant over all other treated plants. Control showed significantly lower fresh weight of the plants (8.017 gms). Highly significant increase in dry weight of plants were noticed in the plants treated with gibberellic acid together with $CaCl_2$ (8.629 gms) as compared to other treatments. The values showed by other treatments were such as; control (3.760 gms), calcium chloride (4.276 gms), salicylic acid alone (7.130 gms), salicylic acid together with $CaCl_2$ (8.163 gms) and gibberellic acid alone showed (8.270 gms) of dry weight of the plants.

Table 1. Vegetative growth parameters as affected by exogenous application of salt and growth regulators on strawberry.

Treatents	Plant height (cm)	No. of leaves	Leaf area (cm^2)	No. of runners	Canopy spread (cm)	Fresh weight of plants (gms)	Dry weight of plants (gms)
T_1	10.93 ± 0.23b	3.970 ± 0.15b	34.28 ± 0.76e	0.200 ± 0.06d	18.92 ± 0.55c	8.017 ± 0.48e	3.760 ± 0.04e
T_2	18.37 ± 1.05a	4.877 ± 0.27a	63.63 ± 0.27a	2.033 ± 0.09a	27.81 ± 0.52a	22.13 ± 0.25ab	8.370 ± 0.07ab
T_3	11.70 ± 0.11b	4.637 ± 0.05a	43.75 ± 0.25c	0.633 ± 0.15c	23.00 ± 2.31bc	19.72 ± 0.42c	7.130 ± 0.11c
T_4	11.20 ± 0.56b	4.377 ± 0.18ab	38.76 ± 0.55d	0.167 ± 0.07d	19.09 ± 1.31c	10.40 ± 0.54d	4.276 ± 0.15d
T_5	18.47 ± 0.81a	4.663 ± 0.39a	50.52 ± 2.27b	1.633 ± 0.09b	29.61 ± 0.58a	23.31 ± 0.73a	8.629 ± 0.09a
T_6	12.24 ± 0.90b	3.970 ± 0.15b	45.38 ± 1.08c	0.800 ± 0.15c	25.01 ± 2.17ab	20.70 ± 0.85bc	8.163 ± 0.25b

Reproductive parameters: The reproductive parameters as shown in Table 2 explained that minimum numbers of days were required by plants treated with gibberellic acid with (54 days) to open first flower in strawberry plants followed by plants treated with gibberellic acid combined with $CaCl_2$ to open first flower after (66 days) of plantation. Besides that salicylic acid combined with $CaCl_2$ required (71.33 days) to open first flower in strawberry plants followed by calcium chloride and salicylic acid alone with (72.33 days) and (74 days). Maximum days were required by the control (80.67 days) which was highly significant to others. Application of gibberellic acid alone showed maximum number of trusses, flowers and fruit set percentage per plant followed by combined spray of GA_3 and $CaCl_2$, salicylic acid in combination with $CaCl_2$ salt salicylic acid alone, $CaCl_2$ and control. Reduction in number of fruits was observed in plants treated with $CaCl_2$ followed by control plants with (1.433) and (1.700) number of fruits per plant respectively. An evidence of non-significant results was seemed between gibberellic acid + $CaCl_2$ with (2.400) number of fruits per plant and salicylic acid with (2.367) number of fruits, which are at non-significant level with plants treated with salicylic acid + $CaCl_2$ with (2.933) average number of fruits per plant. Control produced non-significantly more fruits (1.700) than $CaCl_2$ treated plants (1.433). Strawberry fruit size was significantly increased in plants treated with combined spray of salicylic acid and $CaCl_2$ salt as presented in (Table 2). It showed (2.683 cm) increase in fruit size followed by plants treated with GA_3 alone (2.220 cm). Non significant observations were noted within plants treated with $CaCl_2$ (2.167 cm), salicylic acid (2.060 cm) and gibberellic acid combined with $CaCl_2$ (2.027 cm). Control plants produced minimum fruit size with (1.840 cm). strawberry fruit was increased in plants treated with salicylic acid combined with salt ($CaCl_2$) (4.413 gms) followed by plants treated with $CaCl_2$ salt alone (4.270 gms), plants treated with salicylic acid (4.163 gms) and gibberellic acid (3.967 gms) alone and plants treated by gibberellic acid combined with $CaCl_2$ (3.503 gms). Control showed significantly lower fruit weight (2.987 gms).

Table 2. Reproductive growth parameters as affected by exogenous application of salt and growth regulators on strawberry.

Treatments	No. of days req. to open 1st flower	No. of truss	No. of flowers	Fruit set percentage (%)	No. of fruits	Fruit weight (g)	Fruit size (cm)
T_1	80.67±1.45a	1.170±0.05c	2.747±0.05c	65.89±2.69b	1.700±0.10cd	2.987±0.11e	1.840±0.10c
T_2	54.00±2.31d	1.893±0.06a	3.843± 0.01a	92.17±2.51a	4.767±0.23a	3.967±0.09c	2.220±0.09b
T_3	74.00±1.53b	1.443±0.08bc	3.047±0.06bc	75.80±1.47ab	2.367±0.23bc	4.163±0.04b	2.060±0.18bc
T_4	72.33±0.67b	1.180±0.15c	2.830±0.10c	73.90±3.01ab	1.433±0.22d	4.270±0.03ab	2.167±0.12bc
T_5	66.00±1.73c	1.860±0.07a	3.760±0.17a	83.04±3.25ab	2.400±0.46bc	3.503±0.01d	2.027±0.10bc
T_6	71.33±0.88b	1.533±0.08b	3.300±0.11b	83.93±3.67ab	2.933±0.12b	4.413±0.04a	2.683±0.06a

Fruit quality parameters: Fruit quality parameters were shown in Table 3 which explained that all treatments, except control (0.5 kg) had high firmness values. Higher firmness was observed in fruits treated with gibberellic acid alone (0.883 kg) followed by GA_3 + $CaCl_2$ (0.700 kg). No significant difference in firmness was observed among fruits obtained from plants treated with $CaCl_2$ alone (0.75 kg), SA + $CaCl_2$ (0.633 kg) and salicylic acid alone (0.617 kg). Higher total soluble solids percentage was found in plants treated with GA_3 + $CaCl_2$ salt (8.376 ºBrix) followed by plants treated with SA + $CaCl_2$ salt (6.933 ºBrix) which was non-significant with plants treated with gibberellic acid, salicylic acid and calcium chloride separately and control. Significantly high ascorbic acid contents were observed in plants treated with SA + $CaCl_2$ with a value of (72.47 mg 100^{-1} ml juice) followed by GA_3 + $CaCl_2$ with value of (69.41 mg 100^{-1} ml juice). Both treatments are significant to each other. Non-significant results were obtained in plants treated with calcium chloride, gibberellic acid and salicylic acid. Control showed significantly minimum effected value (51.82 mg 100^{-1} ml juice). Exogenous application of salt and growth regulators did not showed the significant effect on titratable acidity of strawberry fruits. Non-significant results were obtained among plants treated with calcium chloride (2.130%), salicylic acid (2.113%), salicylic acid + $CaCl_2$ (1.853%), gibberellic acid + $CaCl_2$ (1.810%) and gibberellic acid alone (1.750%). Highly significant more titratable acidity value was observed on control (2.710%) as compared to other treatments.

Table 3. Fruit quality parameters as affected by exogenous application of salt and growth regulators on strawberry.

Treatments	Fruit firmness (kg)	Total soluble solids (^{0}Brix)	Titratable acidity (%)	Ascorbic acid (mg 100^{-1} ml juice)
T_1	0.500 ± 0.00c	5.367 ± 0.22e	2.710 ± 0.23a	51.82 ± 0.40d
T_2	0.883 ± 0.02a	6.400 ± 0.40bc	1.750 ± 0.08b	61.38 ± 0.50c
T_3	0.617 ± 0.02bc	6.133 ± 0.19cd	2.113 ± 0.04b	60.68 ± 0.30c
T_4	0.750 ± 0.03ab	5.500 ± 0.17de	2.130 ± 0.17b	62.21 ± 0.73c
T_5	0.700 ± 0.10b	8.367 ± 0.19a	1.810 ± 0.08b	69.41 ± 1.08b
T_6	0.633 ± 0.09bc	6.933 ± 0.07b	1.853 ± 0.17b	72.47 ± 0.61a

Discussion

According to the results mentioned in above section it was concluded that plant height, number of leaves, leaf area, number of runners, canopy spread and fresh and dry weight of plants was maximum in gibberellic acid treated plants either combined with salt or alone, as it induced the effect of long day in short day plants thus promoting vegetative growth and runners production (Guttridge & Thompson, 1964). Our results also agreed with those of others who observed increased plant height in capsicum (Ouzounidou *et al.,* 2010) and globe artichoke (Kasim *et al.,* 2007). Paroussi *et al*., (2002) and Sharma and Singh (2009) found that GA_3 increased the total leaf area per plant. Salicylic acid combined with salt or alone, also increased plant vegetative parameters as compared to control. The same results were found by Khodary (2004) and Niakan *et al.,* (2010) who reported that pre-harvest spray of salicylic acid increased the shoot length and leaf area in plants. Eraslan *et al*., (2007) also reported increased in number of leaves. There is not enough literature presented which clarified the effect of salicylic acid on runner production but it could be said that it is involved in regulation of many processes in plants growth and development (Raskin, 1992). It has been reported to increased plant fresh and dry weight (Amborabe *et al.,* 2002) which concluded that it enhanced the vegetative growth in strawberry plants thus increasing canopy spread. Salicylic acid, in comparison with gibberellic acid also showed some favorable effects on accumulation of fresh weight which supported by the work of Amborabe *et al*., (2002) and Karlidag *et al*., (2009b) on fresh weight accumulation in strawberry plant shoots with further agreement with the finding of Khodary, (2004) in increasing the total weight of plants in case of *Zea mays* as compared to control. Present results also sported by Fahad & Bano (2012) who reported that exogenous foliar application of salicylic acid (10^{-5}M) was effective in ameliorating the adverse effects of salinity on nutrient status of soil. Salicylic acid (10^{-5}M) can be implicated to mitigate the adverse effects of salinity on maize plants. Calcium chloride salt when combined with growth regulators showed elevated results as compared to alone. That was may be due to the masking effect of growth regulator over salt during combined spray of salt and growth regulators. Calcium chloride alone showed less increased in plant height as compared to other treatments. Our findings agreed with that of Andriolo *et al.,* (2010) who found no significant effect of $CaCl_2$ on plant growth attributes. Calcium chloride also found to increase plant fresh weight as compared to control but it was less efficient than Gibberellic acid and Salicylic acid. Although, it was observed by Andriolo *et al*., (2010) that $CaCl_2$ spray had non-significant effect on vegetative growth of strawberry but it was also observed by White (2000) it increased the vigor of stalk and stem of plant thus, increasing fresh weight. On the other hand the dry weight observed in calcium chloride was influenced in treated plant as found by Amor and Rubio, (2009) also, Lopez & Satti (1996) observed same results in tomato.

Gibberellic acid induced flowering earlier in strawberry plant as compared to other treatments by minimizing the days required to open first flower. Similar results were showed by many researcher who found that early flowering occurred in strawberry (Paroussi *et al.,* 2002; Sharma & Singh, 2009), capsicum (Ouzounidou *et al.,* 2010), globe artichoke (Kasim *et al.,* 2007) and azaleas (Joiner *et al.,* 1982). Salicylic acid also showed decreased in number of days to flower, although not as efficient as gibberellic acid, but it was better than Calcium chloride and control. Salicylic acid treated plants also promote early flowering. Our results are in accordance with that obtained by (Hew, 1987; Tomot *et al.,* 1987; Martin-Mex *et al.,* 2005a). No significant effects of calcium chloride have been observed in stimulating early flowering. Increase in number of trusses and flowers were found in GA_3 treated plants followed by salicylic acid, $CaCl_2$ and Control. Our results agree with the findings of many researchers who revealed that gibberellic acid increased number of flowering truss and flowers in strawberry plant (Paroussi *et al.,* 2002). Karlidag *et al.,* (2009a) found that salicylic acid increased fruit yield in strawberry, which indicated towards high number of flowering trusses which ultimately produced high number of flowers and fruit. Calcium chloride also reported to increased productivity of many plants (Alcaraz *et al.,* 1994) which also confirmed increased in number of trusses and flowers. Gibberellic acid treated fruit showed more fruit set percentage than any other treatment. Our results are in accordance to that depicted by others scientists Sharma & Singh (2009), and Kappel & McDonald (2007). Salicylic acid is also responsible of increasing yield in many crops by increasing fruit set percentage (Herrera-Tuz, 2004; Karlidag *et al.,* 2009a) on the other hand, plants treated with $CaCl_2$ alone, showed reduced or non-significant effects on fruit yield (Singh *et al.,* 2009; Andriolo *et al.,* 2010; Hamayun *et al*., 2010a). Gibberellic acid showed higher number of fruits per plant when applied alone on strawberry plants, as compared to others. Same results have been shown by Sharma & Singh (2009) and Ouzounidou *et al*., (2010) who observed more number of fruits per plant. Salicylic acid also increases the number of fruits per plants by increasing yield (Ghai *et al.,* 2002; Fariduddin *et al.,* 2003). Sajid & Aftab (2012) also reported that relatively low-to-moderate concentrations of salicylic acid may be useful in improving yield of potato plants under saline conditions. Maximum fruit size was obtained in plants treated with salicylic acid combined with $CaCl_2$ spray this might be due to the activity of salicylic acid to induce resistance in plants against environmental stresses and calcium act as a messenger to these environmental stimuli that trigger defense mechanism induced by salicylic acid. Same results have been found by Wang & Li (2006) in grapes. Reduction in fruit size was observed in plants treated with gibberellic acid either alone or in combination with $CaCl_2$. Our result is accordance with that of (Sharma & Singh, 2009; Khan *et al*., 2011). This might be due to sink

of GA_3 treated plant's reserves towards early flower production and fruit setting. No more stored reserves were present that plant can use to increase its size. Calcium chloride treated plants however; produced fruits of good size with less difference to that in GA_3 treated plants. In these plants, phenomenon opposite to that occurred in GA_3 happened such as; pre-harvest application of $CaCl_2$ salt had non-significant effect on plant growth and flowering, less flower production means more stored reserves sinks towards fruit during cell enlargement stage and hence more fruit size is achieved. Karlidag *et al*., (2009a) who found an increased in fruit weight and yield in strawberry plants treated with salicylic acid. First application of GA_3 @ 100 ppm and second application of GA_3 @ 50 ppm reduced the fruit drop which resulted in higher yield of sweet orange cv. "Salustiana" (Ibrahim *et al*., 2011). In gibberellic acid treated plants fruit weight is reduced due to insufficient food reserves during cell enlargement stage as discussed earlier. Calcium chloride increases the weight per fruit due to maximum food reserves during the stage when fruit attain size and mass (Hamayun *et al*., 2011). More yields in term of weight per fruit were obtained by calcium chloride. Due to less number of fruit production (Singh *et al.,* 2009; Andriolo *et al.,* 2010) more weight attainment in these fruits occurred (Ramezanian *et al.,* 2009) which therefore, lowering the yield.

Maximum firmness was attained in fruits from plants treated with gibberellic acid (Usenik *et al.,* 2005; Cline & Trought, 2007; Ozkaya & Dundar, 2008; Canli & Orhan, 2009; Khan *et al*., 2012) as it regulate the activities of cell wall hydraulic enzymes which are responsible of fruit softening (Kondo & Danjo, 2001). Salicylic acid also increased the firmness either sprayed alone or in combination with $CaCl_2$. Such phenomena may have link with salinity & drought stress (Hamayun *et al*., 2010). Our results are in accordance with that obtained by Karlidag *et al*., (2009a) and Shafiee *et al*., (2010). Salicylic acid is effective in increasing overall quality by overcoming fungal development and ethylene production (Babalar *et al.,* 2007). Calcium chloride also increased firmness as compared to control as calcium is involved in cell wall protecting metabolism. Similar results have been found by (Naradisorn *et al.,* 2006; Cronge *et al.,* 2009; Singh *et al.,* 2009). Combined application of GA_3 + $CaCl_2$ and salicylic acid + $CaCl_2$ can improve the TSS of strawberry fruits. It is shown by Sharma & Singh, (2009) that gibberellic acid when sprayed alone on strawberry slightly decreased total soluble solids. Whereas, it was found by Kappel & McDonald, (2007) that GA_3 treated sweet cherries showed more TSS level as compared to control. On the other hand, $CaCl_2$ treated strawberries demonstrated increase in total soluble solids (^oBrix) this finding is in accordance with the work of Dunn & Able (2006) who found an increase in TSS percentage with lower calcium doses. The present study also showed better results on ascorbic acid contents in strawberries. As discussed earlier that salicylic acid increased the fruit quality by overcoming adverse effect of fungal development and ethylene production (Babalar *et al.,* 2007). It is also responsible of increasing the ascorbic acid contents in treated plants (Karlidag *et al.,* 2009a). Calcium chloride also reported to increase the ascorbic acid contents. $CaCl_2$ treatments had a significant effect on retaining ascorbic acid content in fruits. This might be because the concentrations of $CaCl_2$ delayed the rapid oxidation of ascorbic acid. Our findings were similar to that of Ramezanian *et al*., (2009) who found high ascorbic acid contents in treated pomegranate plants. Results were confirmed by Singh *et al*., (2009). The results of the present study showed an increased in ascorbic acid contents with GA_3 combined with $CaCl_2$ treatments. Similar results were found in a study done by Asrey *et al*., (2004). Combined application of growth regulators with calcium salt can produce effects on ascorbic acid contents of strawberries and that may be due to synergetic effect of both of them with each other. Our findings were in accordance with that observed by Ouzounidou *et al*., (2010) who work on effect of gibberellic acid in capsicum plant, found non-significant results regarding titratable acidity. El-Otmani & Coggins Jr. (1991) also confirms our results regarding effect of gibberellic acid. Salicylic acid treated strawberries plant also non-significantly affect titratable acidity. Similarly, Andriolo *et al*., (2010) also obtained non-significant effect of $CaCl_2$ on titratable acidity in strawberry.

Conclusion

It is concluded from the given discussion that strawberry plants respond much better with application of salicylic acid combined with calcium chloride for their growth, yield and quality features while application of gibberellic acid combined with calcium chloride proved better for maximum vegetative growth and some of the quality traits. Gibberellic acid application alone, proved to induce the early reproductive growth and more number of runners. The plants treated with single sprays of either growth regulators or salt and the plants in control did not showed satisfactory improvement in any one of the growth, yield and quality attributes of the strawberry plants. Hence, application of growth regulators combined with salt proved better for growing strawberries.

References

Alcaraz, C.F., M. Carvajal, M.J. Frutos, J.L. Gimwez, F. Martinez-Sanchez and J.J. Pastor. 1994. The physiological role of titanium in *Capsicum anuum* L. plants. In: *New Perspectives in the Research of Hardly Known Trace Elements.* (Ed.): I. Pais, University of Horticulture and Food Sciences, Budapest. p. 75-111.

Aman, S., M. Iqbal, S. Abbas, S. Banaras, M. Awais, I. Ahmad, Z.K. Shinwari and S.N. Shakeel. 2013. Molecular and comparative analysis of newly isolated beta-tubulin partial gene sequences from selected medicinal plants. *Pak. J. Bot*., 45(2): 507-512.

Amborabe, B.E., P.F. Lessard, J.F. Chollet and G. Roblin. 2002. Antifungal effects of salicylic acid and other benzoic acid derivatives towards *Eutypa lata* structure-activity relationship. *Plant Physiol. Biochem*., 40: 1051-1060.

Amor, F.M.D. and J.S. Rubio. 2009. Effects of antitranspirant spray and potassium: Calcium: magnesium ratio on photosynthesis, nutrient and water uptake, growth, and yield of sweet pepper. *J. Plant Nutr*., 32: 97-111.

Andriolo, J.L., D.I. Janisch, O.J. Schmitt, M. dal Picio, F.L. Cardoso and L. Erpen. 2010. Potassium and calcium doses on plant growth, fruit yieald and quality of strawberries in soiless cultivation. *Ciencia Rural*, 40(2): 267-272.

Asrey, R., R.K. Jain and R. Singh. 2004. Effect of pre-harvest chemical treatment on shelf life of 'Chandler' strawberry (*Fragaria ananassa*). *Indian J. Agri. Sci*., 74(9): 485-487.

Babalar, M., M. Asghari, A. Talaei and A. Khosroshahi. 2007. Effect of pre and postharvest salicylic acid treatment on ethylene production, fungal decay and overall quality of Selva strawberry fruit. *Food Chem*., 105: 449-453.

Canli, F.A. and H. Orhan. 2009. Effects of pre-harvest gibberellic acid applications on fruit quality of '0900 Ziraat' sweet cherry. *Hort. Tech*., 19(1): 127-129.

Cline, J.A. and M. Trought. 2007. Effect of gibberellic acid on fruit cracking and quality of 'Bing' and 'Sam' sweet cherries. *Canadian J. of Plant Sci*., 87(3): 545-550.

Cronge, R.B., D. Sivakumar, P.G. Mostert and L. Korsten. 2009. Effect of different preharvest treatments regimes on fruit quality of litchi cultivar ' Maritius'. *J. Plant Nutri*., 32: 19-29.

Dunn, J.L. and A.J. Able. 2006. Pre-harvest calcium effects on sensory quality and calcium mobility in strawberry fruit. *Acta Hortic*., 708: 307-312.

El-Otmani, M. and C.W. Coggins Jr. 1991. Growth regulators effect on retention of quality in stored citrus fruits. *Sci. Hortic*., 45(3-4): 261-272.

Eraslan, F., A. Inal, A. Gunes and M. Alpaslan. 2007. Impact of exogenous salicylic acid on growth, antioxidant activity and physiology of carrot plants subjected to combined salinity and boron toxicity. *Sci. Hortic*., 113:120-128.

Fahad. S. and A. Bano. 2012. Effect of salicylic acid on physiological and biochemical characterization of maize grown in saline area. *Pak. J. Bot*., 44(4): 1433-1438.

Fariduddin, Q., S. Hayat and A. Ahmad. 2003. Salicylic acid influences net photosynthetic rate, carboxylation efficiency, nitrate reductase activity and seed yield in *Brassica juncea. Photosynthetica*, 41: 281-284.

Ghai, N., R.C. Setia and N. Setia. 2002. Effects of paclobutrazol and salicylic acid on chlorophyll content, Hill activity and yield components in *Brassica napus* L. *Phytomorphology*, 52: 83-87.

Guttridge, G.G. and P.A. Thompsom. 1964. The effects of gibberellins on growth and flowering of Fragaria and Duchesnea. *J. Exp. Bot*., 115: 631-646.

Hamayun, M., S.A. Khan, A.L. Khan, Z.K. Shinwari, N. Ahmad, Y-Ha Kim and In-J Lee. 2011. Effect of foliar and soil application of nitrogen, phosphorus and potassium on yield components of lentil. *Pak. J. Bot*., 43(1): 391-396.

Hamayun, M., S.A. Khan, A.L. Khan, Z.K. Shinwari, I. Iqbal, E-Y Sohn, M.A. Khan and I-J Lee. 2010a. Effect of salt stress on growth attributes and endogenous growth hormones of soybean cultivar hwangkeumkong. *Pak. J. Bot*., 42(5): 3103-3112.

Hamayun, M., S.A. Khan, Z.K. Shinwari, A.L. Khan, N. Ahmed and I-J Lee. 2010. Effect of polyethylene glycol induced drought stress on physio-hormonal attributes of soybean. *Pak. J. Bot*., 42(2): 977-986.

Herrera-Tuz, R. 2004. Reguladores de crecimiento XXI. Efecto del acido salicilico en la productividad de papaya maradol *(Carica papaya* L.). Tesis de Licenciatura. Instituto Tecnologico Agropecuario, Conkal, Yucatan, Mexico.

Hew, C.S. 1987. The effects of 8-hydroxyquinoline sulphate, acetyl salicylic acid and sucrose on bud opening of Oncidium flowers. *J. Hort. Sci*., 62: 75-78.

Hytonen, H., P. Elomaa, T. Moritz and O. Junttila. 2009. Gibberellic mediates day length-controlled differentiation of vegetative meristem in strawberry (Fragaria × ananassa Duch.). *BMC Plant Biol*., vol. 9 art. 18.

Ibrahim, M., N.A. Abbasi, H.U. Rahman, A. Hussain and I.A. Hafiz. 2011. Phonological behavior and effect of different chemicals on pre-harvest fruit drop of sweet orange cv, "Salustina". *Pak. J. Bot*., 43(1): 453-457.

Joiner, J.N., O. Washington, C.R. Johnson and T.A. Nell. 1982. Effect of exogenous growth regulators on flowering and cytokinin levels in azaleas. *Sci. Hortic*., 18(2): 143-151.

Kappel, F. and R. MacDonald. 2007. Early gibberellic acid spray increase firmness and fruit size of 'Sweetheart' sweet cherry. *J. Am. Pomol. Soc*., 61(1): 38-43.

Karlidag, H., E. Yildirim and M. Turan 2009a. Exogenous application of salicylic acid affects quality and yield of strawberry grown under anti-frost heated greenhouse condition. *J. Plant Nutr. Soil Sci*., 172: 270-276.

Karlidag, H., E. Yildirim and M. Turan 2009b. Salicylic acid ameliorates the adverse effect of salt stress on strawberry. *Sci. Agric*., 66(2): 180-187.

Kasim, A.T.M., A.M. Abd El-Hameid and N.H.M. El-Greadly. 2007. A comparison study on the effect of some treatment on earliness, yield and quality of Globe Artichoke (*Cynare scolymus* L.). *Research J. Agri. and Bio. Sci*., 3(6): 695-700.

Khan AL, M. Hamayun, S. A. Khan, Z. K. Shinwari, M. Kamaran, Sang-Mo Kang, Jong-Guk Kim, In-Jung Lee. 2011. Pure culture of *Metarhizium anisopliae* LHL07 reporgrams soybean to higher growth and mitigates salt stress. World J. Microb Biotech. 28(4):1483-94.

Khan, AL., Z. K. Shinwari, Yoon-Ha Kim, M. Waqas, M. Hamayun, M. Kamran, In-Jung Lee . 2012. Isolation and detection of Gibberellins and indole acetic acid from Endophyte *Chaetomium globosum* LK4 growing with drought stressed plant. Pak. *J. Bot*., 44(5): 1601-1607

Khodary, S.E.A. 2004. Effect of salicylic acid on the growth, photosynthesis and carbohydrate metabolism in salt stressed maize plants. *Int. J. Agric. Biol*., 6: 5-8.

Larque-Saavedra, A. and F. Martin-Mex. 2007. Effects of salicylic acid on the bio-productivity of the plants. In: *Salicylic Acid, A Plant Hormone*. (Eds.): S. Hayat, A. Ahmad. Springer Publishers, Dordrecht, The Netherlands.

Lopez, M.V. and S.M.E. Satti. 1996. Calcium and potassium enhanced growth and yield of tomato under sodium chloride stress. *Plant Sci*., 114: 19-27.

Martin-Mex, R., A. Nexticapan-Garces and A. Larque-Saavedra. 2005b. Effect of salicylic acid in sex expression in *Carica papaya* L. In: 10th International Symposium on Plant Biorregulators in Fruit Production, June 26–30 de 2005. Saltillo, Coahuila, Mexico, p. 113.

Martin-Mex, R., E. Villanueva-Couoh, T. Herrera-Campos and A. Larque-Saavedra. 2005a. Positive effect of salicylates on the flowering of African violet. *Sci. Hortic*., 103: 499-502.

Naradisorn, M., A. Klieber, M. Sedegley, E. Scott and A.J. Able. 2006. Effect of pre-harvest calcium application on grey mould development and post-harvest quality in strawberries. *Acta Hortic*., (ISHS) 708: 147-150.

Niakan, M., A. Jahanbani and M. Ghorbanli. 2010. Spraying effect of salicylate different concentrations on growth parameters, amount of photosynthetic pigments, anthocyanin, flavonoids and solution sugars of *Coriandrum sativum* L. *J. Plant Sci. Researches*, 18(2):10-18.

Ouzounidou, G., I. Ilias, A. Giannakoula and P. Papadopoulou. 2010. Comparative study on the effects of various plant growth regulators on growth, quality and physiology of capsicum annum L. *Pak. J. Bot*., 42(2): 805-814.

Ozkaya, O. and O. Dundar. 2008. Chemical and physical determination of gibberellic acid effects on postharvest quality of sweet cherry. *Asian J. of Chem*., 20(1): 751-756.

Paroussi, G., D.G. Voyiatzis, P. Paroussis and P.D. Drogoudi. 2002. Growth, flowering and yield responces to GA_3 of strawberry grown under different environmental conditions. *Sci. Hortic*., 96: 103-114.

Ramezanian, A., M. Rahemi and M.R. Vazifehshenas. 2009. Effects of foliar application of calcium chloride and urea on quantitative and qualitative characteristics of pomegranate fruits. *Sci. Hortic*., 121(2): 171-175.

Raskin, I. 1992. Role of salicylic acid in plants. *Annu. Rev. Plant Physiol. Plant Mol. Biol*., 43: 439-463.

Sajid. Z.A and F. Aftab. 2012 Role of salicylic acid in amelioration of salt tolerance in potato (*Solanum tuberosum* L.) under *In vitro* conditions *Pak. J. Bot.*, 44: 37-42.

Shafiee, M., T.S. Taghavi and M. Babalar. 2010. Addition of salicylic acid to nutrient solution combined with postharvest treatments (hot water, salicylic acid and calcium dipping) improved postharvest fruit quality of strawberry. *Sci. Hortic*., 124: 40-45.

Sharma, R.R. and R. Singh. 2009. Gibberellic acid influences the production of malformed and button berries and fruit yield and quality in strawberry (*Fragaria Ananassa* Dutch). *Sci. Hortic*., 119: 430-433.

Siddiq, S., M. Yaseen, M. Arshad and N. Ahmed. 2012. Effect of calcium carbide on photosynthetic characteristics, growth and yield of tomato cultivars. *Pak. J. Agri. Sci*., 49: 505-510.

Singh, R., R.R. Sharma and S.K. Tyagi. 2007. Pre-harvest foliar application of calcium and boron influences physiological disorders, fruit yield and quality of strawberry (*Fragaria×Ananassa* Duch.*). Sci. Hortic*., 112(2): 215-220.

Singh, R., R.R. Sharma, C.L. Moretti, A. Kumar and R.K. Gupta. 2009. Foliar application of calcium and boron influences physiological disorders, fruit yield and quality of strawberry (F. × ananassa Duch.). *Acta Hortic*., (ISHS) 842: 835-838.

Tomot, B.K., J.P. Khurana and S.C. Maheshwari. 1987. Obligate requirement of salicylic acid for short day induction of flowering in new duck weed, *Wolffiela hyaline* 7378. *Plant Cell Physiol*., 28: 349-353.

Tsuda, K., M. Sato, J. Glazebrook, J.D. Cohen and F. Katagiri. 2008. Interply between MAMP triggered and SA-mediated defense responses. *Plant J*., 53: 763-775.

Usenik, V., D. Kastelec and F. Stampar. 2005. Physicochemical changes of sweet cherry fruits related to application of gibberellic acid. *Food Chem*., 90: 663-671.

Van Loon, L.C., M. Rep and C.M.J. Pieterse. 2006. Significance of inducible defense-related proteins in infected plants. *Annu. Rev. Phytopathol*., 44:135-162.

Wang, L.J. and S.H. Li. 2006. Salicylic acid-induced heat or cold tolerance in relation to Ca^{2+} homeostasis and antioxidant systems in young grape plants. *Plant Sci*., 170: 685-694.

White, P.J. 2000. Calcium channels in higher plants. *Biochimica et Biophysica Acta*, 1465: 171-189.

(Received for publication 22 September 2011)