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ORIGINAL ARTICLE

Foliar Application of Salicylic Acid and Calcium on Yield, Yield Component and Chemical properties of Strawberry

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ABSTRACT
In order to study effect of salicylic acid and calcium foliar application on growth, yield and yield components of strawberry plants as a factorial in completely randomized experimental design with four replications. This factors included of salicylic acid in 3 levels (0.25, 0.5 and 0.75 mM) and calcium in 2 levels (2.5 and 5 mM) spray on strawberry. Results showed that salicylic acid (0.25 mM) and calcium chloride (2.5 mM) spray either alone or in combination (0.25 mM SA+2.5 mM Ca) affected on vegetative and reproductive growth, significantly. Mean comparisons indicated yield, and quality of strawberry plants was improved in low salicylic acid and calcium chloride concentration. In Finally, salicylic acid and calcium chloride application can be helpful for yield improvement and prevent of decreasing yield.
Keywords: *Strawberry, Salicylic acid, Calcium chloride, Yield, Quality*

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INTRODUCTION

Foliar feeding of vegetable plants can effectively supplement soil fertilization. It has been found that elements foliar application is in a same level and even more influential compared to soil application. It was suggested that foliar feeding could be applied successfully to compensate shortage of those elements [1]. Salicylic acid, a naturally occurring plant hormone acting as an important signaling molecule adds to tolerance against abiotic stresses. It plays a vital role in plant growth, ion uptake and transport. Salicylic acid can also play a significant role in plant water relations, photosynthesis and growth in plants [2]. In cucumber and tomato, the fruit yield enhanced significantly when the plants were sprayed with lower concentrations of salicylic acid [3]. Khodary [4] and El-Tayeb [5] found that SA treatment increased the chlorophyll, dry weights and carotenoid contents in maize and barley plants. Calcium (Ca^{2+}) is a universal second messenger and it has long been considered as the second messenger in many signaling cascades; including defense signaling [6]. The preharvest nutritional status of fruit, especially with respect to calcium, is an important factor affecting potential storage life [7]. Direct application of calcium to the fruit is the most effective method for increasing fruit calcium content [8]. Preharvest and postharvest treatments with calcium salts have been effective in controll of several physiological disorders, reducing the incidence of fungal pathogens and maintaining fruit firmness [9]. Foliar applications of calcium chloride have been reported to delay ripening and retard fungal growth on strawberries [10]. SA and Ca treatments have the potential for commercial control of quality properties and increase shelf life of harvested fruit. Therefore, the aim of this research is to determine the effects of pre-harvest application of SA and Ca in strawberry cultivar 'Selva', specially the change in quality properties.

MATERIALS AND METHODS

Plant material and growth conditions

The experiment was conducted during 2013 and 2014 on strawberry plants at a hydroponic greenhouse located in Iran. Strawberry plants (*Fragaria × ananassa* Duch. cv. Selva) were grown under natural light conditions. The temperature conditions were 25 ± 2°C and 16 ± 4°C, during days and nights respectively; with mean relative humidity of 70 ± 5%. Runner plants were rooted in plastic pots filled with leca and perlite. They were irrigated three times a day. Rooted plants were transplanted into 3 liter pots. The pots were filled with lica, perlite and peatmoss (1: 3: 1 v/v/v). The plants were fertilized with the following complete nutrient solution containing: N, P_2O_5, K_2O, Ca, Mg, S, Fe, Mn, Mo and Cu.

Treatments

SA at the rate of 0.25, 0.5 and 0.75 mM, Ca at the rate of 2.5 and 5 mM as $CaCl_2$ were applied as foliar. The surface of pot was covered with aluminium foil to prevent the adding of SA and $CaCl_2$ solution into root medium. Untreated plants were left as a control and sprayed with distilled water.

Measurements

Total leaf areas of each plant were recorded with portable leaf area meter. Petiole length was measured using a ruler. The change in petiole diameter was determined for each plant using vernier caliper. To attain a constant weight for biomass estimation (dry weight), plant components were oven dried at 70°C. Total fruit weight of each plant was separately measured and considered as yield. To evaluate fruit quality, total soluble solid (TSS), titratable acidity (TA) and ascorbic acid (vitamin C) were measured. TSS of fruits was determined using a refractometer. Total titrable acid and vitamine C was measured by NaOH (0.1 M) titration and indophenol's method according to Horvitz *et al.,* [11]. The experiment was a factorial in completely randomized design with 6 replications. Data were analyzed by SPSS 16 software and and comparing averages was done by Duncan-s test and a probability value of %5.

RESULTS AND DISCUSSIONS

The results indicated that 0.25 mM SA and 2.5 mM Ca both caused a significant increase in vegetative and reproductive growth compared to other levels ($p \leq 0.05$). The combination between SA and Ca (0.25 mM SA + 2.5 mM Ca) on vegetative and reproductive growth was significant, as well (Table 1). The dry weight increased to its maximum (15.13 g) with 0.25 mM SA + 2.5 mM Ca application (Table 1). The maximum number of runners (6.12), leaf area (30.12 cm), length of roots number (27.12), number of flowers (14.51), length of flowering period (35.12), weight of primary fruit (18.9 g), weight of secondary fruit (17 g), number of achenes of primary fruit (215.12) and number of achenes of secondary fruit (195) was recorded with 0.25 mM SA + 2.5 mM Ca (Table 1-2). Salicylic Acid (SA) is a growth regulator which participates in the regulation of physiological processes in plants. It stimulates flowering in a range of plants, increases flower life, controls ion uptake by roots and stomatal conductivity [12]. Previous studies have demonstrated that a wide range of responses might appear after exogenous SA application as follows: height plant increases, fruit weight and fruits per plant [13-14]. Application of SA also significantly increased dry weights of root and top part of barley and soybeans[15]. The mechanism of salicylic acid was reported by Oata [16] and Pieterse and Muller [17] who concluded that salicylic acid induced flowering by acting as a chelating agent. This view was supported by Raskin *et al.,* [18] who confirmed that salicylic acid functioned as endogenous growth regulators of flowering and florigenic effects. Deficiency of Ca decreases plant height by decreasing mitotic activity in the terminal meristem [19]. Thus, the application of calcium increases plant height [20]. Application of Calcium carbide also stimulates root growth and early onset of flowering in agronomic and vegetable crops [21]. The highest percentage of TSS and TA and ascorbic acid content was attained in fruits treated with 0.25 mM SA + 2.5 mM Ca and the lowest was achieved in control (Table 4). Also highest of pH (2.21 %) content was attained in fruits treated with 0.25 mM of foliar SA concentration. Table 3, indicates the effect of SA and Ca on total phenolics (TP), flavonoids (TF), and non-flavonoids (TNF) and lipid peroxidation (MDA). 0.25 mM SA + 2.5 mM Ca of increased total phenolics (TP), flavonoids (TF), and non-flavonoids (TNF) of strawberry. In general, application of SA and Ca produced significantly decreased lipid peroxidation (MDA) of fruits compared to control. It was reported that the foliar application of salicylic acid on soybean also enhanced the flowering and pod formation [22]. Sayyari *et al.,* [23] has shown that the amount of acidity and TSS was influenced by SA treatment in pomegranate. Chandra *et al.,* [24] reported that application of salicylic acid increased total soluble sugar and soluble protein of cowpea plants. Vitamin C, pH, TSS and titratable acidity (TA) of fruits treated with higher 5-SSA concentrations was higher than those of control fruits. It has been suggested that TA decreases in fruits in result of breakup of acids to sugars during respiration [25]. Han and Li [26] have also reported that apple fruits treated with SA had increased TA content at the end of storage. Our results showed that SA had significant effect on maintaining higher content of vitamin C in peach fruits. Kazemi *et al*., [27] have also reported that fruits treated with SA were observed with maximum vitamin C content. Ghasemnezhad *et al*., [28] reported that the decrease of total phenolic levels might be due to breakdown of cell structure in order to senescence phenomena during the storage period. The effect of salicylic acid treatments on maintain of total phenolics content plausibly may be attributed to delay in senescence process. Our results are in agreement with those of kazemi et al., [27], who reported treatment with salicylic acid significantly reduced the membrane permeability and MDA content. In conclusion, foliar application of SA and Ca treatments were generally effective on vegetative growth, photosynthetic pigments, minerals, yield and quality of strawberry fruit.

Table 1) Effect of pre-harvest application of SA and Ca on dry weight, number of runners, leaf area, number of flowers and length of the roots of strawberry

Treatment		dry weight(g)	Number of runners	Leaf area (cm)	Length of roots (cm)	Number of flowers
Control	0	6c	3c	20.67c	16.03c	9.78c
SA	0.25	13ab	5.98a	28ab	26.67a	13.6ab
	0.5	10.11b	4.43b	28b	23.34ab	12.07b
	0.75	10b	4.4b	27.45b	20.12b	12.01b
Ca	2.5	13.12ab	6a	28.67ab	26.78a	13.67qb
	5	9.97b	4.47b	27.78b	19.89b	11.87b
Combination	0.25*2.5	15.13a	6.12a	30.12a	27.12a	14.51a
	0.25*5	10b	4.49b	27b	20.12b	12.11b
	0.5*2.5	9.78b	4.35b	26.45b	18.12bc	12b
	0.5*5	9bc	4.3b	23.56bc	18.43bc	10.12bc
	0.75*2.5	9bc	3.45bc	23.34bc	18.08bc	10.08bc
	0.75*5	8.89bc	3.39bc	23.12bc	18bc	10bc

Means followed by same letter are not significantly different at 5% probability using Duncan's test.

Table 2) Effect of pre-harvest application of SA and Ca on Length of flowering period, weight of primary fruit, weight of secondary fruit, number of achenes of primary fruit and Number of achenes of secondary fruit

Treatment		Length of flowering period (day)	Weight of primary fruit (g)	Weight of secondary fruit (g)	Number of achenes of primary fruit	Number of achenes of secondary fruit
Control	0	12.12c	10c	7.88c	110c	98c
SA	0.25	19.12ab	17.98ab	16.01ab	200ab	191.12ab
	0.5	15.14b	15.11b	12bc	189.12b	160b
	0.75	15b	15b	12.7b	167.12bc	145.21bc
Ca	2.5	18.98b	18ab	16.21ab	199.23ab	187.12ab
	5	16b	15.65b	13.13b	187.12b	167.12b
Combination	0.25*2.5	21.12a	18.97a	17a	215.12a	195a
	0.25*5	16.09b	16.01b	12.12b	170.12bc	167.12b
	0.5*2.5	16b	15.34b	13b	168.12bc	160.09b
	0.5*5	15.34bc	15b	12.34b	165.32bc	150.09bc
	0.75*2.5	15bc	13.14bc	11.12bc	163.09bc	148.12bc
	0.75*5	15.01bc	13bc	11bc	161.23bc	146bc

Means followed by same letter are not significantly different at 5% probability using Duncan's test.

Table 3) Effect of pre-harvest application of SA and Ca on TP, TF, TNF and MDA

Treatment		TP w(gallic acid)/(mg/kg)	TF w(gallic acid)/(mg/kg)	TNF w(gallic acid)/(mg/kg)	MDA (nmol gfw-1)
Control		67.41c	20.11c	21.12c	28.12a
SA	0.25	119.23a	40.12ab	45.32a	11c
	0.5	151.23b	33.11b	30.12b	20bc
	0.75	149.21b	32.32b	29.34b	20.12bc
Ca	2.5	119a	41.14ab	44.54a	12.12c
	5	142.12b	33b	31.12b	19.12bc
Combination	0.25*2.5	121.12a	44.12a	46.12a	10.11c
	0.25*5	150.12b	40.12ab	40.12ab	12.12c
	0.5*2.5	147.21b	31.12b	32.12b	19.67bc
	0.5*5	149.21b	28.23bc	30.12b	19.56bc
	0.75*2.5	145.12b	27.56bc	30b	19.34bc
	0.75*5	144.54b	26.34bc	28.12bc	19bc

Means followed by same letter are not significantly different at 5% probability using Duncan's test.

Table 4) Effect of pre-harvest application of SA and Ca on pH, TSS, TA and Vit.C

Treatment		pH	TSS	TA g(citric acid)/(g/L)	Vitamin C (mg/100 g)
Control		1c	5c	1.43c	20.12c
SA	0.25	2.21a	7.8ab	3a	30.12ab
	0.5	1.67b	6.45b	2.45b	25.12b
	0.75	16b	6.35b	2.4b	25b
Ca	2.5	1.98a	7.67ab	2.98a	31.12ab
	5	1.6b	6.3b	2.32b	26.12b
Combination	0.25*2.5	2.11a	8a	3.12a	33.11a
	0.25*5	1.6b	6.45b	2.32b	25b
	0.5*2.5	1.56b	6.4b	2.3b	24.98b
	0.5*5	1.52b	5.31bc	1.67bc	22.11bc
	0.75*2.5	1.5b	5.3bc	1.6bc	22bc
	0.75*5	1.5b	3.13bc	1.54bc	21.12bc

Means followed by same letter are not significantly different at 5% probability using Duncan's test.

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