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Optimization Coriander Production for Fruit and Essential Oil
B: Yield Improvement by Chitosan and Salicylic Acid Foliar Application

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ABSTRACT

Coriander (*Coriandrum sativum* L.), a member of the Apiaceae family, is among most widely used medicinal plant, possessing nutritional as well as medicinal properties. Thus, the present study aimed to investigate the effect of foliar application of chitosan at 20, 40, 60 and 80 ppm and salicylic acid at 15, 30, 45 and 60 ppm on improving coriander production for fruits and essential oil. The study was conducted at El- Baramoon Research Farm, Mansoura Horticulture Research Station, HRI, ARC, Egypt, during the two growing winter seasons of 2013/2014 and 2014/2015. It is clear that foliar application of either chitosan or salicylic acid at all used concentrations significantly promoted the vegetative growth characters in terms of plant height, number of branches per plant and plant fresh and dry weights. Moreover, fruit yield and its components in terms of number of umbels per plant and fruit yield per plant were also significantly higher than control treatment. Germination percentage, seed index and essential oil percentage and content were positively affected by foliar application of chitosan or salicylic acid with the superiority of chitosan. The greatest increase in the previously mentioned parameters was measured in plants (vegetative growth and yield components) sprayed with chitosan at 80 ppm followed by chitosan at 60 ppm and salicylic acid at 45 ppm. For obtaining high fruit yield and its quality as well as essential oil percentage and content of coriander plants, it could be recommended to spray plants twice with chitosan at 80 ppm.

Keywords: Coriander, chitosan, salicylic acid, germination, essential oil, fruit yield.

INTRODUCTION

Recently, cultivation of aromatic and medicinal plants has been given much attention in order to cover the increasing demands of the local industries, as well as export purposes. Several pharmaceutical studies revealed the important role of medicinal plants as a natural source for drugs.

Coriander (*Coriandrum sativum* L.) is a hardy annual member of the Apiaceae family indigenous to the Near East and Mediterranean regions. It has been cultivated since ancient times and was one of the herbs imported and cultivated in Egypt. Today, its commercial cultivation and use are nearly worldwide. Coriander is one of the important seed spices which are acclaimed throughout the globe for its enormous uses of fruits as well as leaf (Hnamte *et al.*, 2013).The plant is grown widely all over the world for fruit, as a spice or essential oil production. At one time, coriander was among the world's leading essential oil plants (Lawrence 1993). This plant is of economic importance as it has been used as flavoring agent in food products, perfumes and cosmetics. As a medicinal plant, coriander has been credited with a long list of medicinal uses. In some countries young leaves of coriander are also used to flavour salad and soups. Besides being used as spice it has several medicinal values and recently gaining momentum as an important value added export item in the global market.

Numerous studies have been made on medicinal plants to increase their productivity using different methods. Chitosan and salicylic acid are considered important to improve the vegetative and generative growth, beside their effects on plant components. Chitosan is a natural biopolymer modified from chitin, which can be transformed into chitosan by extracting the acetyl group and turn it into amino. Many investigators reported that using chitosan as foliar spray increased vegetative growth, yield and quality of different crops including Castro *et al.*, (2016) on coriander; Mahdavi, (2013) on isabgol; Yin *et al., (*2012) on Greek oregano ; Lei *et al.*, (2011) on artemisa and Kim *et al.*, (2005) on basil. Furthermore, chitosan have been recognized as a product to enhance crop production due to its bioactivities: biodegradability, growth stimulation and seed germination, increasing nutrient uptake, reducing oxidative stress, increasing chlorophyll content, photosynthetic and chloroplast enlargement in the leaves, antifungal, antiviral and antibacterial properties (Hadrami *et al*., 2010 and Hadwiger, 2013).

Salicylic acid is a plant phenol and plays roles in plant growth and development by regulating seed germination, vegetative growth. Salicylic acid has a regulatory effect on activating biochemical pathways associated with tolerance mechanisms in plants. The ameliorative effect of salicylic acid on plant growth under abiotic stress conditions have been related to its role in nutrient uptake, membrane stability, water relations, stomatal regulation, photosynthesis, growth and inhibition of ethylene biosynthesis (Khan *et al.*, 2003 and Stevens *et al.,* 2006). SA induces flowering, increase flower life, retards senescence and increases cell metabolic rate. The sustained level of SA may be a prerequisite for the synthesis of auxin and/or cytokinin (Metwally *et al*., 2003). Hesami *et al.*, 2012 and 2013 worked on coriander and reported that application of lower doses of SA increased the number of umbels and fruits per plant and fruit yield and the highest fruit yield was obtained at 0.01 mM SA. Results of Rahimi *et al.*, 2013 showed that foliar application of lowest concentrations of SA (0.01 and 0.1 mM) on cumin plants resulted in significant promotion of plant height , number of branches and umbels per plant. Fruit yield and essential oil yield significantly increased by the application of 0.1 mM SA. The essential oil percentage was increased by SA treatments. Hence, the study was undertaken with an objective to evaluate the effect of foliar spray of chitosan and salicylic acid on growth, yield, essential oil production and composition of coriander.

MATERIALS AND METHODS

Two field experiments were carried out during two successive winter seasons of 2013/2014 and 2014/2015, at El- Baramoon Research Farm, Mansoura Horticulture Research Station, HRI, ARC., Egypt. Soil sample was taken from the soil surface (0-30 cm), air dried, sieved by 2 mm sieve and analyzed for physical and chemical properties of soil according to Jackson (1967) and the analysis results are presented in Table (1).

Table 1. Physical and chemical characteristics of the soil

Mechanical analysis %				T. class	O.M%	S.P %	$CaCO_3$%	E.C $dS.m^{-1}$ 1:5	pH 1:2.5	Available ppm		
C. sand	F. sand	Silt	Clay							N	P	K
3.9	33.1	36.7	26.3	S.C.L	1.70	47.4	2.65	0.97	8.13	46.6	4.82	198

Coriander seeds were obtained from the Medicinal and Aromatic Plants Research Department, HRI, ARC. Egypt. The experimental filed was prepared and shaped to ridges 75 cm apart, each experimental plot was 3 x 5 m and contained 4 ridges. Seeds were sown on mid October in both seasons in hills at 35 cm apart then thinned for one plant/hill after 30 days from sowing.

Phosphorus (Calcium super phosphate) was added at the rate 100 kg /fed., while both nitrogen (Ammonium sulphate) and potassium (Potassium sulphate) were added individually in two equal doses at the rate of 150 kg/fed. and 50 Kg/fed, , respectively. The first dose was added after thinning and the second half at the beginning of flowering stage. Irrigation was conducted whenever required throughout the experimental period. A complete randomized block design with four replicates was followed. Each replicate included 9 treatments as follows:

1- Control (distilled water)., 2-Chitosan at 20 ppm. , 3- Chitosan at 40 ppm, 4- Chitosan at 60 ppm, 5- Chitosan at 80 ppm, 6- Salicylic acid at 15 ppm, 7- Salicylic acid at 30 ppm, 8- Salicylic acid at 45 ppm and 9- Salicylic acid at 60 ppm.

Plants were sprayed twice after 45 and 60 day from sowing with previously mentioned treatments. A hand atomizer was used for spraying plants after adding tween 20 (0.5%) as surfactant. After 85 days from sowing during each growing season 10 plants/ replicate, were randomly selected to determine plant height (cm), branches number/plant and fresh and dry weights (g/plant). In addition, Total chlorophyll (Ch) was extracted from fresh blade in the third leaf from apex (terminal leaflet) and determined according to Saric *et al.,* (1976). The shoots of10 plants in each replicate (85days after sowing) were dried at 70^{O}C for 48 hours and finally ground and nitrogen, phosphorus, and potassium were determined according to Cottenie *et al., (1982*).

At harvest stage when the secondary umbels colour was changed to green-yellow, the number of umbels per plant, fruit yield per plant and 1000 fruit weight (seed index) were recorded. In addition, fruit germination percentage was conducted using 400 fruits (four replications of 100 fruits) per each treatment (ISTA, 2011).

The volatile oil percentage was determined in the air dried fruits (were subjected to hydro-distillation for 3 hours) using a modified Clevenger apparatus according to Guenther, (1961). The GC analysis of the second season volatile oil samples were carried out using Gas chromatography instrument, Laboratory of Medicinal and Aromatic Plants Research Department, HRI., with the following specifications: DsChrom 6200 Gas Chromatograph equipped with a flame ionization detector, Column: BPX-5, 5% phenyl (equiv.) polysillphenylene-siloxane 30m x 0.25mm ID x 0.25µm film., Sample size: 1µl, Temperature program ramp increase with a rate of 10º C / min from 70º to 200º C, Detector temperature (FID): 280 °C, Carrier gas: nitrogen, Flow rate: N2 30 ml/min; H2 30 ml/min; air 300 ml/min. Main compounds of the volatile oils were identified by matching their retention times with those of the authentic samples injected under the same conditions. The relative percentage of each compound was calculated from the area of the peak corresponding to each compound.

Statistical analysis: All the collected data were tabulated and statistically analyzed by Statistical Analysis of variance using MSTAT-C version 4, 1987 software and the treatments means were compared using the LSD test according to Gomez and Gomez 1984

RESULTS AND DISCUSSION

Vegetative growth

Data presented in Table (2) reveal that chitosan or salicylic acid at all used concentrations increased significantly coriander vegetative growth in terms of plant height, number of branches per plant as well plant fresh and dry weights in the two growing seasons. It could be noticed that spraying coriander with chitosan at 60 ppm or salicylic acid at 45 ppm showed higher significant increases in all studied growth characters compared with control during both seasons. On the other hand, control plants gave the lowest values of all studied characters. Furthermore, plant fresh and dry weights had the same trend in their response to foliar application treatments and the highest values were recorded when plants treated with chitosan at 80 ppm followed by chitosan at 60 ppm, salicylic acid at 45 ppm, salicylic acid at 60 ppm, chitosan at 40 ppm, salicylic acid at 30 ppm, chitosan at 20 ppm, salicylic acid at 15 ppm, and finally non treated plants (control).

The promotive effects of chitosan on coriander vegetative growth could be attributed in part to its effect on allowed plants to produce substances such as lignin or phytoalexins (Walker-Simmons *et al.,* 1983 and Bhaskara Reddy *et al.,* 1999). The last substance plays an important role in transportation of water and nutrients as well as may be attributed to an increase in the key enzyme activities of nitrogen metabolism (nitrate reductase, glutamine synthetase and protease) and increased photosynthesis which enhanced the plant growth (Mondal *et al.,* 2012). In addition, chitosan induce to synthesize plant hormones such as gibberellins. Furthermore, it enhances growth by some signalling pathways related to auxin biosynthesis via a tryptophan independent pathway (El-Bassiony *et al.*, 2014). Also, may be attributed to an increase in the availability and uptake of water and essential nutrients through adjusting cell osmotic pressure, and reducing the accumulation of harmful free radicals by increasing antioxidants and enzyme activities (Guan *et al.,* 2009). Similar to our results, many scientists reported improvement in growth as result to chitosan application i.e. Castro *et al.* 2016 on coriander; Mahdavi 2013 on isabgol; Yin *et al.,* 2012 on Greek oregano ; Lei *et al.,* 2011 on artemisa and Kim *et al.,* 2005 on basil.

Table 2. Effect of chitosan and salicylic acid foliar application on coriander vegetative growth during 2013/2014 and 2014/2015 seasons.

Treatments	Plant height (cm)		Branches No.		Plant F. W. (g)		Plant D. W. (g)	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Control	51.5	53.9	8	10	85.2	95.2	6.95	6.82
Chitosan 20 ppm	55.7	59	10	11	105.2	108.3	8.39	8.77
Chitosan 40 ppm	64.3	70	13	14	143.5	165.3	13.11	14.87
Chitosan 60 ppm	70.7	74.3	15	17	174.5	203.3	18.92	21.27
Chitosan 80 ppm	63.5	72.7	16	17	175.4	204.6	19.23	22.36
Salicylic acid 15 ppm	57.6	61.4	11	12	91.3	103.4	7.32	8.19
Salicylic acid 30 ppm	66	74.5	14	16	137.4	155.4	12.37	13.97
Salicylic acid 45 ppm	73.4	76.5	17	18	172.5	193.1	17.37	20.34
Salicylic acid 60 ppm	70.8	75	16	16	155.3	170.5	16.27	19.47
LSD 5%	4.04	3.7	2.04	1.8	4.79	3.19	1.48	1.18

The promotive effect of salicylic acid on vegetative growth could be attributed to its bioregulator effects on physiological and biochemical processes in plants such as ion uptake, cell elongation, cell division, cell differentiation, sink/source regulation, enzymatic activities, protein synthesis and photosynthetic activity as well as increase the antioxidant capacity of plants (El-Tayeb, 2005) and its role in enhancing rooting of plants (Sandoval-Yapiz, 2004) as well as increased the length of roots which plays a key role in enhancing the growth and productivity of plants. Moreover, the increase in plant height was due to increase in number of internodes, while the increase in the fresh and dry weights of coriander might be attributed to an increase in number of branches and leaves as well as leaf area. Our results are in harmony was those of Said-Al Ahl *et al.*,(2014); Hesami *et al,*. (2012 and 2013) on coriander; Rahimi *et al.,* (2013) on cumin and Gharib, (2006) on sweet basil and marjoram. While, Pirbalouti *et al.,* (2014) mentioned that SA application had no significant effect on measured growth indices of thyme.

Fruit yield and germination behavior

Data presented in Table(3) indicated that there are significant difference between treatments on their effects on number of umbels per plant, fruit yield per plant, seed index and germination percentage. Generally, chitosan and salicylic acid treatments regardless their concentrations increased the values of the above mentioned characters over control treatment. Foliar application of chitosan at 80 ppm increased number of umbels per plant by 65% over control, while chitosan at 60 ppm increased it by 62%. Fruit yield per plant reached its maximum value when coriander plants sprayed with chitosan at 80 ppm giving 27 % over control, followed by 26% for chitosan at 60 ppm, 21% for salicylic acid at 45 ppm as average of two seasons. Seed index and germination percentage as seed quality parameters responded also positively to different foliar treatments. Regarding the seed index the differences between foliar application treatments are slight and in some cases did not reach to the significance level however, difference between the foliar application treatments and control were significant. Chitosan at 80 ppm was the superior treatment in this regard followed by chitosan at 60 ppm. Germination percentage exhibited its highest values when coriander plants sprayed with chitosan at 80 ppm followed by chitosan at 40 ppm , chitosan at 60 ppm or salicylic acid at 45 ppm, chitosan 20 ppm, salicylic 60 ppm, salicylic 30 ppm, salicylic 15 ppm and finally control plants.

Table 3. Fruit yield, seed index and germination behavior of coriander as affected by chitosan and salicylic acid foliar application during 2013/2014 and 2014/2015 seasons.

Treatments	No of umbels/ plant		Fruit yield g/plant		Seed index (g)		Germination percentage	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Control	38	39	70.65	71.86	12.51	12.63	90.00	88.75
Chitosan 20 ppm	43	45	72.38	73.81	14.12	14.21	93.25	92.50
Chitosan 40 ppm	53	55	79.07	80.39	14.57	14.72	95.00	95.00
Chitosan 60 ppm	61	64	89.31	90.82	14.93	14.98	95.25	96.00
Chitosan 80 ppm	62	65	89.43	91.01	14.78	14.89	94.75	94.50
Salicylic acid 15 ppm	40	41	71.45	72.65	13.19	13.28	91.00	90.25
Salicylic acid 30 ppm	49	51	76.63	77.92	13.67	13.78	92.00	91.00
Salicylic acid 45 ppm	58	60	85.41	86.87	14.13	14.25	94.25	95.00
Salicylic acid 60 ppm	47	48	74.67	75.93	13.32	13.36	92.00	92.50
LSD 5%	3.3	2.7	3.42	3.83	1.75	1.94	1.40	1.8

Spraying coriander plants with chitosan increased significantly all the vegetative growth traits of plant (Table 2) as well as the contents of photosynthetic pigments (Table 5) and this lead to increment in yield/plant. The increase in yield may be owed to the increment in photosynthetic pigments which led to the increment in the vigor growth and hence increase in yield. Generally, it could be said that spraying plants with chitosan increased plant product as a result of stimulation of the immunity of plants (Wanichpongpan *et al.*, (2001); Hadwiger ,(2013) and New *et al.*, (2004) to protect plants against microorganisms (Pospiesmy *et al.*, (1991) and to simulation of roots, shoots, leaves and chlorophyll content and photosynthetic rate (Chibu and Shibayama, (1999); Khan *et al.*, (2002); Gornik *et al.*, 2008). Our results are in harmony with those of Chookhongkha *et al.*, (2012), who indicated that the chili growth and seed yield are greater with chitosan application and El-Tanahy *et al.*, (2012), who reported an increase in cowpea seed yield when plants received chitosan as foliar application .In addition to salicylic acid role in improving vegetative growth which affect positively in increasing the fruit yield. There are promising results were obtained when plants of *Carica papaya* were treated with salicylic acid which showed a significantly higher fruit setting and subsequently increased the yield (Herrera-Tuz, 2004 and Martin-Mex *et al.*, 2005). Similar results were obtained by Said-Al Ahl *et al.*, 2014; Hesami *et al.* 2012 and 2013 on coriander and Rahimi *et al*,.2013 on cumin. They reported that there was an improvement in yield as result to foliar application of salicylic acid especially at low concentrations.

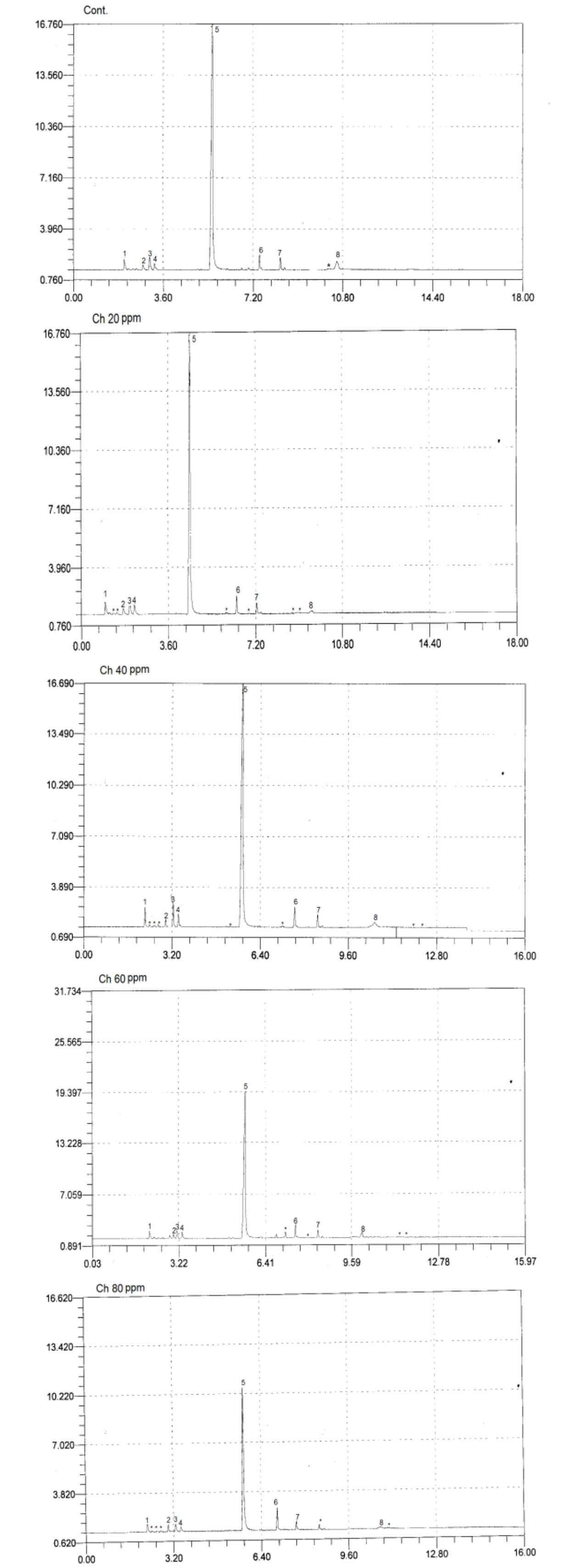
Essential oil percentage, yield and constituents

The percentage of essential oil, oil yield (ml/plant) and essential oil GC analysis to evaluate the effect of chitosan and salicylic acid on coriander active constituents are presented in table 4. Both chitosan and salicylic acid promoted the content of essential oil (as a percentage) with the superiority of chitosan but not enough to result significant differences. The highest percentages of coriander essential oil (1.43% and 1.44%) were obtained when plants treated with chitosan at 60 ppm followed by salicylic acid at 45 ppm (1.42% and 1.43%) in the first and second seasons, respectively. Essential oil yield (ml/plant) was significantly affected by chitosan and salicylic acid foliar applications while the highest essential oil yield (1.28 and 1.31 ml/plant) was of 60 ppm chitosan followed by 45 ppm salicylic acid (1.21 and 1.24 ml/plant) in both seasons, respectively. In the same table and figures (1 and 2) eight components of coriander essential oil were identified and quantified for the second season samples. Foliar application with chitosan improved the quality of coriander essential oil by increment the major component (linalool) percentage in oil with all concentrations (73.53%, 74.75% and 76.10%) except 80 ppm (66.73%) as compared with untreated plants (control, 73.08%). On the other hand the optimum concentration of salicylic acid for the high percentage of linalool over than the control was 30 ppm (75.98%), however other concentrations decreased linalool % than the control. Among major components α –Pinene (ranged from 1.81% to 6.47%), B- Pinene (ranged from 2.86% to 5.60%) and ρ̄ Cymene (ranged from 1.96% to 3.11%), were positively affected by foliar application with chitosan and salicylic acid. However, Myrcene (ranged from 0.30% to 2.71%) was negatively affected by chitosan and salicylic acid treatments. Borneol percentage (ranged from 2.41% to 8.53%) was increased with chitosan treatments; on contrary salicylic acid treatments decreased it. Moreover, Linalyl acetate (ranged from 2.32% to 3.89%) and Geranyl acetate (ranged from 2.08% to 5.58%) components were decreased by chitosan treatments and in contrast increased by salicylic acid treatments.

Table 4. Effect of chitosan and salicylic acid foliar application treatments on essential oil percentage, yield and GC of coriander during 2013/2014 and 2014/2015 seasons.

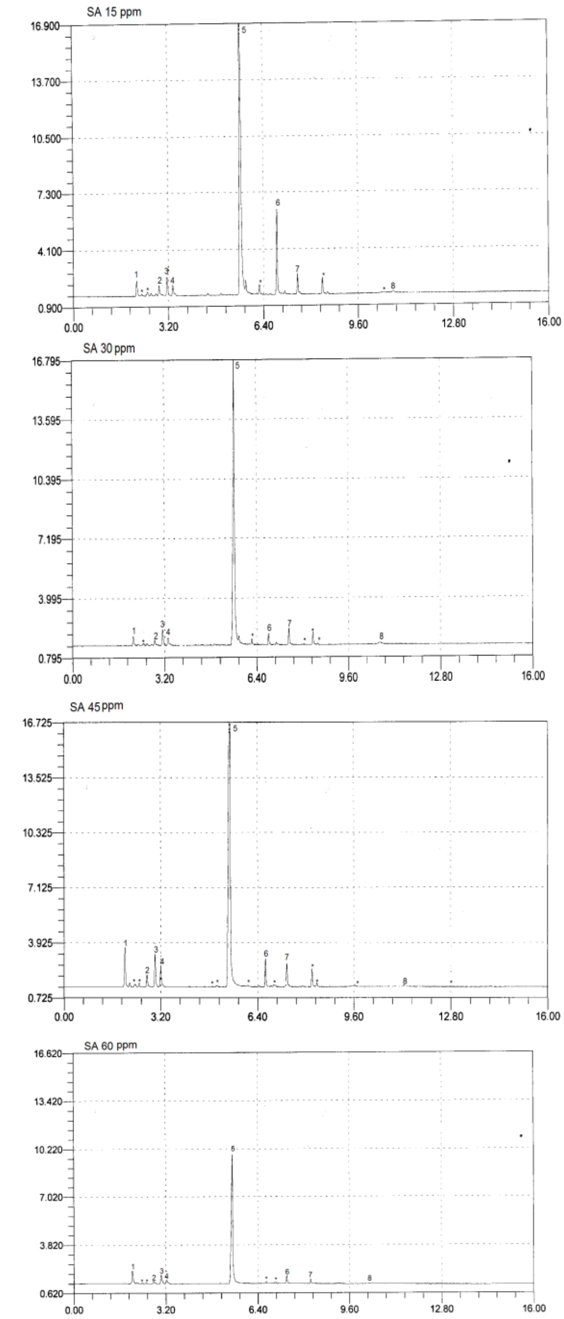
	Essential Oil % Season		Oil yield /plant (ml) Season		Essential oil constitutes							
Treatments	**1st**	**2nd**	**1st**	**2nd**	**α-pinene**	**Myrcene**	**B-pinene**	**ρ̄ Cymene**	**Linalool**	**Borneol**	**Linalyl acetate**	**Geranyl acetate**
Control	1.36	1.37	0.96	0.98	2.42	2.71	3.03	2.20	73.1	2.41	2.70	5.58
Chitosan 20 ppm	1.38	1.39	1.00	1.03	2.80	1.67	3.07	3.11	73.5	3.33	2.69	4.33
Chitosan 40 ppm	1.41	1.42	1.11	1.14	3.81	1.57	3.51	3.01	74.8	3.70	2.56	3.98
Chitosan 60 ppm	1.43	1.44	1.28	1.31	4.31	0.52	5.60	3.03	76.1	3.89	2.52	3.01
Chitosan 80 ppm	1.35	1.36	1.21	1.24	3.39	0.30	3.30	2.83	66.7	8.53	2.32	2.52
Salicylic acid 15 ppm	1.37	1.38	0.98	1.00	1.81	2.08	2.86	1.96	68.3	4.23	3.58	2.08
Salicylic acid 30 ppm	1.39	1.41	1.07	1.10	2.24	1.86	3.34	2.36	76.0	3.06	3.89	2.10
Salicylic acid 45 ppm	1.42	1.43	1.21	1.24	4.76	1.68	3.80	2.80	69.4	2.96	3.17	2.22
Salicylic acid 60 ppm	1.31	1.32	0.98	1.00	6.47	1.56	4.38	3.08	68.2	2.75	3.14	3.07
LSD 5%	0.05	0.04	0.14	0.09	--	--	--	--	--	--	--	--

The increment in essential oil content when plants treated with chitosan could be attributed to that chitosan acts as a potent inducer for biosynthesis increasing of the secondary metabolites. Also chitosan can be a significant secondary signal messenger, a key role in many activities products and an elicitor for the accumulation of phenolic and terpenoids compounds of plants (Kim *et al*.,(2005); Yin *et al.,(* 2009 and 2012) and Bistgani *et al.,* (2016).



1= α– pinene **2= Myrcene** **3= B- pinene**
4= ρ̄ Cymene **5= Linalool** **6= Borneol**
7= Linalyl acetate **8= Geranyl acetate** ***= Unknown compounds**

Figure 1. Effect of chitosan foliar application and control treatments on the essential oil components (%) of coriander during 2014 / 2015 season.



1= α– pinene **2= Myrcene** **3= B- pinene**
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7= Linalyl acetate **8= Geranyl acetate** ***= Unknown compounds**

Figure 2. Effect of salicylic acid foliar application treatments on the essential oil components (%) of coriander during 2014/2015 season.

The increment of different components of the essential oil with chitosan treatments could be attributed to that chitosan can increase the secondary metabolites by the pathways of mevalonic acid and phenylpropanoid without stress. In addition, the possibility and effectiveness of chitosan was in inducing phytochemicals in the medicinal plants without genetic modification (Kim *et al.,* 2005). These results were in harmony with those of Kim *et al.,* (2005) on *Ocimum basilicum,* , Lie *et al., (*2011) on *Artemisia annua*, Sarfaraz *et al.,* (2011) on fennel , Yin *et al.,* 2012 on *Origanum vulgare* and Bistgani *et al.,* (2016) on *Thymus daenensis.*

The positive effects of salicylic acid on essential oil yield and components may be due to the role of salicylic acid in increasing cell metabolism, affecting on plastid and pathways of secondary metabolites and enhancing the synthesis of phenolic compounds (Gorni and Pacheco 2016 and Talaat *et al.,* 2013). Idrees *et al.,* (2010) stated that improvement in essential oil content by foliar application of SA might be due to the increase in cycle growth, nutrients uptake or changes in leaf oil gland population and monoterpenes biosynthesis. Improvement of essential oil percentage and yield per plant in response to SA application has been reported in other plant species (Gharib 2006; Idrees *et al.,* 2010).Other reports indicated that the high concentrations of salicylic acid caused a reduction in essential oil and its components as those by Sadeghian *et al.,* 2013 on *Satureja khuzisanica* Jamzad and Yadegari and Shakeriaan(2014)on *Salvia officinalis.* The obtained results of salicylic acid were in the same line with those of Arzandi, (2014) and Said-Al Ahl *et al.,* (2014) on coriander, Rahimi *et al.,* (2013) on *Cuminum cyminum*, Rowshan and Bahmanzadegan ,(2013) and Gorni and Pacheco ,(2016) on *Achillea millefolium.*

Total chlorophyll content and NPK percentages

The changes in total chlorophyll content (mg/gm), nitrogen, phosphorus and potassium percentages in response to chitosan and salicylic acid treatments during both growing seasons are shown in Table (5). Chitosan and Salicylic acid caused significant increases in total chlorophyll levels in leaves. The maximum increase in total chlorophyll content is recorded in leaves treated with chitosan at 80 ppm followed by chitosan at 60 ppm in the both seasons. The increase in total chlorophyll level was attributed to the promotion in its synthesis and/or retardation of pigment degradation. These results corroborate with El-Tayeb, (2005). The enhancing effects of SA on photosynthetic capacity could be attributed to its stimulatory effects on Rubisco activity and pigment contents as well as increased CO_2 assimilation, photosynthetic rate and increased mineral uptake by the plant and increasing IAA and cytokinins therefore inhibiting their senescence. This may be due to the fact that SA protects photosynthetic apparatus through increasing the ability of cell antioxidation and new proteins synthesis.

As evident from the same table chitosan and salicylic acid treatments increased the percentage of N, P and K .The maximum mean values of N, P and K percentage were obtained as a result of chitosan at 80 ppm followed by chitosan at 60 ppm treatment, while the differences between the two concentrations treatments were non-significant. Foliar application with salicylic acid at 45 ppm came in the third level of effect on N, P and K % in both seasons, respectively. The synergistic effect of chitosan on the previous components may be due to the role chitosan in absorption the elements and their accumulation by plant (Salachna and Zawadzinska ,2014). Also the increasing in different components by salicylic acid treatments may be due to its role in increasing the nutrients uptake (Gharib ,2006).Our results were in agreement with results of Gharib,(2006) on basil and marjoram, Arzandi, (2014) on coriander, Salachna and Zawadzinska, (2014) on freesia, Salachna and Zawadzinska, (2015) on *Eucomis autumnalis*, and Bistgani *et al.,(* 2016) on *Thumus daenensis*,

Table 4. Chlorophyll content, nitrogen, phosphorus and potassium percentages of coriander in response to chitosan and salicylic acid foliar application during 2013/2014 and 2014/2015 seasons.

Treatments	Total chlorophyll (mg/g)		N %		P %		K %	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Control	9.21	9.29	3.12	3.26	0.398	0.403	4.04	4.09
Chitosan 20 ppm	10.15	10.25	3.44	3.48	0.425	0.431	4.21	4.28
Chitosan 40 ppm	11.19	11.33	3.61	3.66	0.446	0.451	4.51	4.62
Chitosan 60 ppm	14.11	14.21	3.92	3.95	0.474	0.477	4.81	4.89
Chitosan 80 ppm	14.45	15.2	4.01	4.05	0.478	0.483	4.88	4.96
Salicylic acid 15 ppm	9.81	9.92	3.31	3.37	0.411	0.414	4.15	4.26
Salicylic acid 30 ppm	10.95	11.05	3.53	3.58	0.432	0.436	4.37	4.45
Salicylic acid 45 ppm	13.21	13.62	3.86	3.91	0.471	0.474	4.72	4.81
Salicylic acid 60 ppm	10.75	10.83	3.78	3.82	0.462	0.467	4.61	4.7
LSD 5%	0.65	0.56	0.20	0.19	0.019	0.012	0.33	0.27

Finally, it was reported that chitosan may activate the responses of plants through different signaling pathways involving different second messengers. In addition, chitosan easily absorbs to epidermis of leaves and stems prolonging the time of contact and facilitates the uptake of the bioactive molecules Malerba and Cerana ,(2016).

CONCLUSION

Our study demonstrated that chitosan at 80 ppm or SA at 45 ppm had a greater promoting effect on growth, yield and essential oil yield in coriander. Thus, there are a good potential for using chitosan or salicylic acid as tools for enhancement of fruit yield and essential oil content in coriander cultivation.

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تعظيم إنتاجية الكزبرة من المحصول الثمري و الزيت الطيار
ب- تحسين المحصول بإستخدام الرش الورقي بالشيتوزان و حمض السلسيليك

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الكزبرة هى أحد نباتات العائلة الخيمية، والتى تعتبر من أهم النباتات الطبية والعطرية والتى لها استخدامات غذائية و طبية. ولذلك فقد هدفت التجربة دراسة تأثير الرش بالشيتوزان بتركيزات (٢٠ و٤٠ و٦٠ و ٨٠ جزء فى المليون) وحمض السلسيليك بتركيزات (١٥ و٣٠ و٤٥ و ٦٠ جزء فى المليون) لتعظيم إنتاجية الكزبرة من المحصول الثمري و الزيت الطيار وقد أجريت هذه الدراسة فى المزرعة البحثية بالبرامون- محطة بحوث البساتين بالمنصورة- معهد بحوث البساتين – مركز البحوث الزراعية- مصر، خلال موسمي شتاء ٢٠١٤/٢٠١٣ و شتاء ٢٠١٥/٢٠١٤. وقد اتضح من خلال نتائج موسمى الدراسة أن رش أوراق الكزبرة بالشيتوزان و حمض السلسيليك بكل التركيزات المستخدمه أدي إلي تحسن فى صفات النمو الخضري متمثلة فى إرتفاع النبات و عدد أفرعه و وزنه الطازج و الجاف و صفات المحصول الثمري متمثلة فى عدد النورات على النبات و المحصول الثمري للنبات ووزن ١٠٠٠ بذرة و نسبة الإنبات و كذا صفات الزيت الطيار كنسبته المئوية أو محتوى النبات من الزيت الطيار من خلال الرش الورقى بكل من الشيتوزان و حمض السلسيليك بأى من التركيزات المستخدمة. سجلت معاملة الرش بالشيتوزان بتركيز ٨٠ جزء فى المليون يليها الرش بتركيز ٦٠ جزء فى المليون من الشيتوزان ثم الرش بحمض السلسيليك بتركيز ٤٥ جزء فى المليون أعلى القيم فى معظم الصفات المدروسة. وعلي ذلك ومما سبق لزيادة المحصول الثمري و جودته من حيث نسبة الزيت الطيار و محتواه و كذلك نسبة الإنبات ووزن الألف بذرة لنباتات الكزبرة المنزرعة تحت ظروف التجربة و الظروف المماثلة فإنه يوصى برش النباتات مرتين خلال موسم النمو بالشيتوزان بتركيز ٨٠ جزء فى المليون.

الكلمات الرئيسية : الكزبرة ، الشيتوزان ، حمض السلسيليك ،الإنبات ، الزيت الطيار ، المحصول الثمرى .