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RESPONSE OF LAVENDER (*Lavandula officinalis*, Chaix) GROWTH AND YIELD COMPONENTS TO FOLIAR SPRAY WITH ASCORBIC ACID AND NANO-CHITOSAN

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ABSTRACT: For evaluating the response of growth and yield of lavender to ascorbic acid (0.0, 50, 100 and 150 ppm), nano-chitosan (0.0, 250, 500 and 750 ppm) and their interactions, an experiment was conducted at the Experimental Farm, Faculty of Agriculture, Zagazig University, Egypt, during the two consecutive summer seasons of 2018 and 2019. This experiment was arranged as split-plot experiment in the basis of completely randomized design with three replications. The main plots were occupied by four ascorbic acid concentrations, also, the sub plots were entitled to four nano-chitosan concentrations. Plant growth parameters as well as fresh and dry herb yield were recorded. Foliar spray with 150 ppm of ascorbic acid gave significantly higher values of growth and yield components compared to control and the other ones under study. Nano-chitosan at high concentrations (500 and 750 ppm) significantly increased all the investigated parameters compared to control. The best results were achieved by the interaction treatment between spraying with ascorbic acid at 100 ppm and nano-chitosan at 750 ppm. This treatment could be used by the farmers under the same conditions because it has the most profitable rate and concentration with the greatest yield advantages.

Key words: Lavender, *Lavandula officinalis*, ascorbic acid, nano-chitosan, growth, yield components.

INTRODUCTION

The Labiatae (Lamiaceae) family contains many important medicinal and aromatic plants, however, lavender (*Lavandula officinalis*, Chaix) is one of the most important plants belonging to this family. It is a native of the Mediterranean region (**Upson and Andrews, 2004**). Vegetative parts and flowers of lavender are used as aromatic and medicine purposes (**Abbaszadeh *et al.*, 2016**). Lavender oil was used for reducing the pain, healing wounds, treating rheumatism, controlling the convulsion, enhancing the health for human beings and protecting the stomach (**Oyen and Dung, 1999**). In addition, it is recommended for anxiety, restlessness and insomnia **(Najafi *et al.*, 2014)**.

Ascorbic acid is a small antioxidant molecule, vitamin C (L-ascorbic acid), accomplishes primary metabolic functions in the life of animals and plants (**Mazid *et al.*, 2011**). However, ascorbic acid (Vitamin C) is an important metabolite participated in many cellular procedures, including cell division (**Degara *et al*., 2003**), it is synthesized in higher plants and impacts plant development and growth. It is the output of D-glucose metabolism which plays an important role in electron transport regulation and influences some nutritional cycle's activities in higher plants (**El-Kobisy *et al*., 2005**).

Nanotechnology is a process to create, manipulate and prevail nano-materials into a system (**Baruah and Dutta, 2009**). This technology utilizes nano-particles having at smaller one dimension in the order of 100 nm or minimal (**Auffan *et al.*, 2009**). Chitosan is achieved of chitin which is considered as the second most abundant naturally revolving polysaccharides next to cellulose found in the plant (**Rinaudo, 2006**). Also, due to chitosan cationic attribute, chitosan submits a wide variety of physicochemical and biological

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properties, including antimicrobial, antioxidant and antihypertensive properties (**Aranaz *et al*., 2009**). It has demonstrated to be operavtive in numerous crops to keep plants against oxidative stress (**Terán and Singh, 2002**) and to encourage plant growth (**Górnik *et al*., 2008**).

In order to obtain acceptable growth and yield under summer season, this study objective to evaluate the advantageous effects of foliar spraying of ascorbic acid and nano-chitosan in terms of enhanced productivity of lavender under Sharkia Governorate, Egypt conditions.

MATERIALS AND METHODS

Two field experiments were carried out during two consecutive summer seasons of 2018 and 2019 at the Experimental Farm, Faculty of Agriculture, Zagazig University, Egypt. This study was conducted to investigate the response of growth and yield components of lavender (*Lavandula officinalis*, Chaix) plant to different concentrations of ascorbic acid (0.0, 50, 100 and 150 ppm), nano-chitosan (0.0, 250, 500 and 750 ppm) and their interaction treatments. Table 1 presents some physical and chemical analyses of the experimental soil at a depth of 0-30 cm according to **Chapman and Pratt (1978**).

The current experiments were set up in a split-plot design with three replicates. The main plots were occupied by four ascorbic acid (Asc) concentrations. The sub plots were entitled to four nano-chitosan (Nch) concentrations. The interaction treatments between main factor and sub factor were 16 treatments.

The plot area was 14.4 m^2 (3.00 ×4.80 m) included eight ridges. Each ridge was 60 cm wide and three meters length. The distance between lavender plants in the ridge was 50 cm, under surface irrigation system. The lavender seedlings were obtained from Private Nursery in Belbeis District, Sharkia Governorate, Egypt. All transplants were similar in growth and 12 cm in length. Seedlings were planted in the experimental plots on 15^{th} April and 25^{th} April during the 2018 and 2019 seasons, respectively.

Chitosan ($C_{56}H_{103}N_9O_{39}$) nano crystallite powder was synthesized by high-energy ball milling. The size of chitosan nano-particles, as evident from the TEM images found to be 50 nm. Chitosan as solution (96.40%) was obtained from Modern Agricide Company (New Cairo, Cairo, Egypt). The source of ascorbic acid ($C_6H_8O_6$) was Techno Gene Company (TGC), Dokky, Giza, Egypt. The nano-chitosan and ascorbic acid treatments were applied as foliar application at 30, 50, 70, 90 and 120 days after transplanting. Each experimental unit received 5 liters solution using spreading agent (Super Film at a rate of 1ml /l).

All recommended agricultural practices of growing lavender plants were done whenever needed. All treatments were fertilized with 200 kg calcium superphosphate (15.5% P_2O_5), 100 kg potassium sulphate (50% K_2O) and 150 kg ammonium nitrate (33% N) per faddan. Phosphorus fertilizer was applied during soil preparation. While, nitrogen and potassium fertilizers were divided into three equal doses and were added to the soil at 35, 60 and 85 days after sowing.

Data Recorded

After 150 days from transplanting, three lavender plants were randomly chosen from each plot to determine the following parameters:

Plant growth parameters

Plant height (cm), number of branches/plant, dry weight of roots/plant (g) and root length (cm) were determined.

Herb yield and its components

Fresh and dry herb yield per plant from the whole plant ridge and then the herb yields per faddan were calculated.

Statistical Analysis

Collected data were analyzed according to **Gomez and Gomez (1984)**. Least significance difference (LSD) was used to differentiate means at the at 5% level of probability. The means were compared using computer program of Statistix version 9 (**Analytical Software, 2008**).

Table 1. Some physical and chemical analyses of the experimental soil (average of the two seasons)

Physical analysis				Soil texture
Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Clay
41.39	19.26	15.62	23.73	

Chemical analysis												
pH	E C m.mohs/cm	Organic mater (%)	Soluble cations (meq./ L)				Soluble anions (meq. /L)			Available (ppm)		
			Mg^{++}	Ca^{++}	K^{+}	Na^{+}	Cl^{-}	HCO_3^{-}	SO_4^{--}	N	P	K
7.82	0.98	0.58	2.7	1.5	1.6	3.9	4.5	1.7	3.5	17	8.3	71

RESULTS AND DISCUSSION

Effect of Ascorbic Acid Concentrations

Results presented in Table 2 reveal that, using ascorbic acid (Asc) as foliar spray significantly increased lavender plant height, number of branches per plant, dry weight of roots per plant and root length compared to control (except that of branch number per plant in first season) during both seasons. The highest values in this concern were obtained from 100 and 150 ppm of Asc acid with significant difference compared to the lowest one (50 ppm) and control under study. Generally, increasing Asc acid concentration gradually increased fresh and dry herb yield per plant and per faddan in the two seasons (Table 3). Also, using the highest concentration of ascorbic acid under study recorded the highest values in lavender yield components compared to control (spraying with water) and the lowest concentration under study. The increases in herb dry yield/faddan were about 18.61 and 33.53% for 150 ppm ascorbic acid over control treatment (untreated plants) in the 1st and 2nd seasons, respectively.

However, **Blokhina *et al*. (2003)** reported that ascorbic acid is the extreme abundant antioxidant which conserve cell, ascorbic acid is actually appeared to be a regulator on plant development and growth due to its effect on cell division and differentiation. Application of Asc at different concentrations showed significant increases in all sweet basil growth parameters as well as herb fresh and dry weights (**Khalil *et al*., 2010**). Similar results were found by **Abdelkader and Hamad (2014)** who reported that foliar application of ascorbic acid increased plant growth and yield components of roselle (*Hibiscus sabdariffa*, L.) plants. The treated quinoa plants by ascorbic acid showed significant responses in the growth and yield characteristics (shoot and root lengths, number of branches per plant and plant biomass) compared to untreated plants **(Sofy *et al*., 2016).**

In addition, spraying basil plants with 300 ppm ascorbic acid evidenced to be the extreme positive functional concentration with elevating vegetative growth, increased productivity from fresh herb/plant (**Azoz *et al*., 2016**). Furthermore, the higher values of plant height ad yield of herb per faddan as well as essential oil yield per faddan of marjoram plants were obtained by spraying ascorbic acid at 300 ppm concentration (**Hashem, 2018**). Also, **Mohamed *et al*. (2020)** pointed out that vegetative growth parameters and production of *Origanum majorana* plant were enhanced by the application of ascorbic acid in both seasons.

Effect of Nano-Chitosan Concentrations

As shown in Tables 4 and 5, plant height (cm), number of branches per plant, root dry weight per plant (g) and root length (cm) as well as fresh and dry weights of herb per plant (g) and per faddan (ton) of *Lavendula officinalis* plant significantly increased with nano-chitosan (Nch) application at any concentration compared

Table 2. Effect of ascorbic acid concentrations on growth parameters of *Lavandula officinalis* plant at 150 days after transplanting during 2018 and 2019 seasons

Ascorbic acid concentration (ppm)	Plant height (cm)	Number of branches/plant	Dry weight of roots/plant (g)	Root length (cm)
		2018 season		
Control (water)	37.67	38.86	7.31	15.03
50	40.31	38.50	7.83	16.69
100	42.97	46.28	9.73	21.08
150	43.08	48.14	10.25	22.49
LSD at 5%	**2.01**	**0.69**	**0.20**	**0.60**
		2019 season		
Control (water)	37.25	38.89	7.18	15.56
50	41.78	41.56	8.55	17.06
100	44.19	48.78	9.74	22.00
150	43.64	49.14	10.02	22.17
LSD at 5%	**0.79**	**1.22**	**0.30**	**0.46**

Table 3. Effect of ascorbic acid concentrations on yield components of *Lavandula officinalis* plant at 150 days after transplanting during 2018 and 2019 seasons

Ascorbic acid concentration (ppm)	Fresh herb yield/plant (g)	Dry herb yield/plant (g)	Fresh herb yield/faddan (ton)	Dry herb yield/faddan (ton)
		2018 season		
Control (water)	150.25	53.99	2.003	0.720
50	152.52	56.67	2.034	0.756
100	162.82	60.52	2.171	0.807
150	163.27	64.07	2.176	0.854
LSD at 5%	**2.66**	**1.34**	**0.035**	**0.018**
		2019 season		
Control (water)	148.75	51.71	1.983	0.689
50	153.71	56.55	2.049	0.754
100	172.71	70.48	2.303	0.940
150	172.46	68.98	2.299	0.920
LSD at 5%	**3.38**	**1.68**	**0.045**	**0.022**

Table 4. Effect of nano-chitosan concentrations on growth parameters of *Lavandula officinalis* plant at 150 days after transplanting during 2018 and 2019 seasons

Nano-chitosan concentration (ppm)	Plant height (cm)	Number of branches/plant	Dry weight of roots/plant (g)	Root length (cm)
		2018 season		
Control (water)	34.25	35.28	7.09	16.36
250	40.31	41.78	7.78	18.02
500	43.25	45.89	9.39	20.20
750	46.22	48.83	10.77	22.49
LSD at 5%	**0.66**	**0.66**	**0.20**	**0.48**
		2019 season		
Control (water)	35.70	37.44	7.05	15.61
250	41.06	44.19	8.11	18.48
500	43.92	47.11	9.51	20.69
750	46.19	49.61	10.82	22.00
LSD at 5%	**0.55**	**0.53**	**0.24**	**0.29**

Table 5. Effect of nano-chitosan concentrations on yield components of *Lavandula officinalis* plant at 150 days after transplanting during 2018 and 2019 seasons

Nano-chitosan concentration (ppm)	Fresh herb yield/plant (g)	Dry herb yield/plant (g)	Fresh herb yield/faddan (ton)	Dry herb yield/faddan (ton)
		2018 season		
Control (water)	129.87	43.54	1.732	0.581
250	156.63	57.89	2.088	0.772
500	165.57	61.80	2.208	0.824
750	176.80	72.02	2.357	0.960
LSD at 5%	**2.06**	**1.22**	**0.027**	**0.016**
		2019 season		
Control (water)	138.03	48.17	1.840	0.642
250	158.10	58.44	2.108	0.779
500	166.10	63.23	2.215	0.843
750	185.41	77.88	2.472	1.028
LSD at 5%	**2.15**	**1.61**	**0.029**	**0.021**

to control (unsprayed plants) in both seasons. However, increasing Nch concentration gradually increased plant growth and yield components in 2018 and 2019 seasons. The best treatment in this connection was that 750 ppm of nano-chitosan with significant differences with the other Nch concentrations under study.

Many researchers indicated that chitosan enhanced key enzymes activities of nitrogen metabolism and enhanced the transportation of nitrogen in the functional leaves which enhance plant development and growth (**Chibu *et al*., 2000; Khan *et al*., 2002**). In addition, **Shams and Morsy (2014)** reported that chitosan nano-particles (0.5 or 1%) increased plant height, fresh and dry weights of leaves per tomato plant as well as early and total yield per plant than all other treatments. **Dzung *et al*. (2017**) suggested that among treatment, chitosan proved to be the best, which increased chilli fresh weight of shoots by 71.5%, dry weight of shoots by 184%, and fruit fresh weight by 49.8% for the control. Moreover, **Dehghani *et al*. (2019**) demonstrated that foliar application of chitosan at 125 mg/l increased number of branches per plant and flower dry yield of German chamomile plant.

Effect of Interaction Between Ascorbic Acid and Nano-Chitosan Concentrations

Results of both seasons in Tables 6 and 7 indicate that, all interactions between Asc acid and Nch concentration treatments significantly increased lavender growth parameters in both seasons, in most cases. The plants which sprayed with ascorbic acid at 150 ppm + nano-chitosan at 750 ppm resulted in the highest value for each of fresh and dry herb yield/plant and total yield/faddan in both seasons, followed by the interaction treatment between plants which sprayed with ascorbic acid at 100 ppm + nano-chitosan at 750 ppm. The increases in dry herb yield/faddan were about 98.69 and 110.88% for the interaction between ascorbic acid at 150 ppm + nano-chitosan at 750 ppm; 96.08 and 112.44% for the interaction between 100 ppm ascorbic acid + 750 ppm nano-chitosan over control treatment (sprayed plants with tap water) in the first and second seasons, respectively.

The simulative effect of ascorbic acid and nano-chitosan on fresh and dry yields of herb may be attributed to that they involved as antioxidant defense as well as regulation of photosynthesis and growth (**Blokhina *et al*., 2003**). Moreover, as mentioned above, both ascorbic acid and nano-chitosan (each alone) increased growth parameters and tield components of lavender plant, in turn; they together might maximize their effects leading to taller plants, more branches and heavier yield per plant and per faddan. However, spraying ascorbic acid on the fenugreek plant, an increase was noticed in vegetative growth (**Alizadeh *et al*., 2013**). Also, **Soltani *et al*. (2014)** indicated that ascorbic acid significantly affected fresh and dry weights of *Calendula officinalis* plants compared to control. **Elbohy *et al*. (2018)** stated that the maximum value for each of plant height, dry weight of roots/plant, root length/plant and dry weight of flower heads/plant were detected in plants treated with 300 ppm ascorbic acid. Ascorbic acid at 200 ppm significantly increased each of plant height, number of branches, total dry weight per plant and per faddan of dragonhead plants compared to control **(Mostafa, 2018)**. Regarding nano-chitosan effect, **Choudhary *et al*. (2017)** reported that plant height, ear length, ear weight/plot and grain yield/plot of maize plant were improved in chitosan nano-particles treatments compared to control. **Shabana and Farroh (2018)** found that all foliar spraying treatments with increased vegetative traits and fruit yield of tomato plants compared to control.

Conclusion

It can be concluded that using 100 ppm ascorbic acid and 750 ppm from nano-chitosan as foliar application five times/season enhancing plant growth and yield components of lavender (*Lavandula officinalis*) under Sharkia Governorate condition.

Table 6. Effect of interaction treatments between ascorbic acid and nano-chitosan concentrations on growth parameters of *Lavandula officinalis* plant at 150 days after transplanting during 2018 and 2019 seasons

Interaction treatments		Plant growth parameters							
Ascorbic acid concentration (ppm)	Nano-chitosan concentrations (ppm)	Plant height (cm)		Number of branches/plant		Dry weight of roots/plant (g)		Root length (cm)	
		2018 season	2019 season	2018 season	2019 season	2018 season	2019 season	2018 season	2019 season
Control (water)	Control (water)	31.44	33.22	30.89	32.89	6.20	5.31	13.78	14.44
	250	37.33	36.56	36.22	38.33	7.13	6.95	14.55	14.45
	500	40.78	38.78	42.44	40.89	7.80	7.77	14.89	15.78
	750	41.11	40.44	45.89	43.44	8.11	9.69	16.89	17.55
50	Control (water)	33.45	35.78	31.78	34.33	6.90	7.12	15.22	14.78
	250	40.44	41.11	36.78	40.78	6.84	7.54	15.44	16.22
	500	42.22	43.44	40.56	44.22	8.36	9.33	18.22	17.56
	750	45.11	46.78	44.89	46.89	9.22	10.21	17.89	19.67
100	Control (water)	35.89	37.89	37.89	40.11	7.16	7.60	17.89	16.45
	250	41.67	43.78	45.11	47.89	8.61	9.23	19.78	21.67
	500	45.11	46.67	49.78	51.89	10.29	9.92	23.22	24.56
	750	49.22	48.44	52.33	55.22	12.86	12.21	23.44	25.33
150	Control (water)	36.22	35.89	40.55	42.44	8.09	8.17	18.55	16.78
	250	41.78	42.78	49.00	49.78	8.89	8.72	22.32	21.60
	500	44.89	46.78	50.78	51.44	11.12	11.02	24.46	24.87
	750	49.44	49.11	52.22	52.89	12.90	12.16	24.63	25.43
LSD at 5%		**2.30**	**1.24**	**1.33**	**1.52**	**0.40**	**0.51**	**1.03**	**0.69**

Table 7. Effect of interaction treatments between ascorbic acid and nano-chitosan concentrations on yield components of *Lavandula officinalis* plant at 150 days after transplanting during 2018 and 2019 seasons

Interaction treatments		Yield components							
Ascorbic acid concentration (ppm)	Nano-chitosan concentrations (ppm)	Fresh herb yield/plant (g)		Dry herb yield/plant (g)		Fresh herb yield/faddan (ton)		Dry herb yield/faddan (ton)	
		2018 season	2019 season	2018 season	2019 season	2018 season	2019 season	2018 season	2019 season
Control (water)	Control (water)	119.98	129.25	40.16	43.43	1.600	1.723	0.536	0.579
	250	150.50	145.11	55.24	50.11	2.007	1.935	0.737	0.668
	500	163.20	158.05	58.85	43.79	2.176	2.107	0.785	0.717
	750	167.34	162.60	61.70	59.52	2.231	2.168	0.823	0.794
50	Control (water)	123.66	128.50	43.51	46.21	1.649	1.713	0.581	0.616
	250	153.44	155.88	55.76	56.97	2.046	2.078	0.743	0.760
	500	162.83	158.11	59.74	54.85	2.171	2.108	0.797	0.731
	750	170.17	172.36	67.68	68.18	2.269	2.298	0.902	0.909
100	Control (water)	136.23	143.63	44.58	49.15	1.816	1.915	0.594	0.655
	250	160.32	164.86	57.87	62.75	2.138	2.198	0.772	0.837
	500	167.83	178.89	60.84	77.76	2.238	2.385	0.811	1.037
	750	186.89	203.48	78.81	92.26	2.492	2.713	1.051	1.230
150	Control (water)	139.63	150.74	45.91	53.90	1.862	2.010	0.612	0.719
	250	162.27	166.54	62.67	63.93	2.164	2.221	0.836	0.852
	500	168.41	169.34	67.78	66.52	2.245	2.258	0.904	0.887
	750	182.79	203.22	79.89	91.57	2.437	2.710	1.065	1.221
LSD at 5%		**4.43**	**5.01**	**2.50**	**3.24**	**0.059**	**0.067**	**0.033**	**0.043**

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استجابة النمو، والمساهمات المحصولية لنبات اللافندر للرش الورقي بحامض الأسكوربيك والشيتوزان متناهي الصغر

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أجريت تجربة في المزرعة التجريبية كلية الزراعة، جامعة الزقازيق، مصر خلال الموسمين الصيفيين المتتاليين لعامي ٢٠١٨ و٢٠١٩، لتقييم استجابة نمو ومحصول اللافندر للرش الورقي لحامض الاسكوربيك (صفر، ٥٠ ، ١٠٠ و ١٥٠ جزء في المليون)، والنانو شيتوزان (صفر، ٢٥٠، ٥٠٠ و٧٥٠ جزء في المليون) والتفاعل بينهما، كان تصميم التجربة قطع منشقة مرة واحدة في قطاعات كاملة العشوائية في ثلاث مكررات، وزعت الأربع تركيزات من حامض الأسكوربيك في القطع الرئيسية، كما وزعت تركيزات النانوشيتوزان الأربع في القطع الفرعية، أعطى الرش الورقي بتركيز ١٥٠ جزءًا في المليون من حمض الأسكوربيك قيمًا عالية بمعنوية لكل من النمو والمساهمات المحصولية مقارنة بالكنترول والمعاملات الأخرى قيد الدراسة، أدى استخدام التركيزات العالية من النانو الشيتوزان (٥٠٠ و٧٥٠ جزء في المليون) إلى زيادة معنوية لجميع الصفات التي تم فحصها مقارنة بالكنترول، تم تحقيق أفضل النتائج عن طريق معاملة التفاعل بين حمض الأسكوربيك بتركيز ١٠٠ جزء في المليون والرش بالنانوشيتوزان بتركيز ٧٥٠ جزء في المليون، يمكن أن يستخدم المزارعون هذه المعاملة تحت نفس الظروف للحصول على أعلى معدل فائدة مع أفضل مزايا محصولية لنبات اللافندر تحت الظروف المصرية.

المحكمـــــــون:

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