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ENHANCING GROWTH AND PRODUCTIVITY OF DILL (*Anethum graveolens*, L.) PLANT BY USING SALICYLIC ACID AND BIO-FERTILIZATION APPLICATIONS

Walid S. Nosir*

Dept. Hort. (Ornamental, Medicinal and Aromatic Plants), Fac. Agric., Zagazig Univ., Egypt.

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ABSTRACT

Two field experiments were carried out at the Experimental Farm, Fac. Agric., Zagazig Univ., Sharkia Governorate, Egypt during the two consecutive seasons of 2018/2019 and 2019/2020. Aiming to study the influence of different salicylic acid rates (0, 50, 100 and 150 ppm), biofertilization types (without inoculation, nitrobein or/and phosphorein at 1 kg/feddan of each type) and their interaction treatments on vegetative growth, yield characters and volatile oil as well as total chlorophyll content and total carbohydrates percentage of dill plant. In the two consecutive seasons, dill plants treated with salicylic acid at 100 or 150 ppm rates showed a significant increase in vegetative growth (plant height, number of branches per plant and total herb dry weight) compared to the other rates under study. The highest rate of salicylic acid as foliar spray recorded the highest value in each yield character (umbel number per plant as well as fruit weight per plant and per feddan) as well as volatile oil production (volatile oil percentage and yield per plant) compared to the other ones under study. In most cases, adding bio-fertilization (nitrobein + phosphorein) produced the highest values of each studied parameter compared to the other types under study. Generally, application of 150 ppm salicylic acid combined with 1 kg/feddan nitrobein + phophorein recorded an increase in vegetative growth, yield characters, volatile oil production and total chlorophyll content compared to either of salicylic acid or/and biological fertilizers rates under study in both seasons.

INTRODUCTION

Dill (*Anethum graveolens*, L.) plant is an aromatic and medicinal annual herbal plant belonging to the Apiaceous family that primarily brings from Eastern Mediterranean (**Sokhangoy *et al*., 2012**). Leaves of dill plant are one of the extreme widespread green herbs. It has an altitude nutrient's content and has a reasonable taste blends other flavors together as well as utilized in fragrance, household cosmetic and medicinal (**Rashed, 2002**). Dill leaves could be utilized as food such as the popular food in Egypt salads, soups and sea foods. Dill fruits could be utilized in flavoring pickles and bread (**Elsayed *et al*., 2020**).

Moreover, influences which are proposed by over application of inorganic fertilizers and expenses of their production are the purposes for international tendency across application of bio-fertilizers (**Kannayan, 2002**). Free living nitrogen fixing bacteria like *Azospirillum lipoferum* (called nitrobien), can not only fix nitrogen of atmospheric but can as well relief plant hormones such as indole acetic acid and gibberellins to encourage development and growth of plant (**Fayez *et al*., 1985**). In addition, phosphorein which contains live cells of efficient bacteria strains (*Bacillus megaterium*) as phosphate solubilizing bacteria (PSB), which have an capability to switch nutritionally serious elements from unavailable to available form out of biological procedures **(Vessey, 2003)**.

* **Corresponding author: E-mail address:** w.nosir@gmail.com
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Growth stimulator such as salicylic acid (SA) is as a rule utilized to stimulate growth and yield of aromatic and medicinal plants. The influence of SA as an endogenous stimulator of growth and flowering was reported in different plant species belonging to various families (**Hayat *et al*., 2007**). In addition, plant pigments (chlorophyll a + b and carotenoids) were enhanced at supplying 300 ppm SA concentration (**Gad *et al*., 2016**). Also, the efficiency of salicylic acid in improving rosemary height and branch number per plant (**Morsi *et al*., 2018**), umbel numbers of Ajowan plant, seed yield per plant and essential oil percentage and yield (**Fathi and Najafian, 2020**) were reported.

The most important aim of this study was to investigate the influence of different salicylic acid concentrations and bio-fertilizers types as well as their interactions on growth, fruit yield components, volatile oil and total chlorophyll content and carbohydrates percentage of *Anethum graveolens* plant under Sharkia Governorate conditions.

MATERIALS AND METHODS

In order to enhance growth and productivity of dill plant, two field experiments were conducted at Experimental Farm, Fac. Agric., Zagazig Univ., Sharkia Governorate, Egypt during the two winter consecutive seasons of 2018/2019 and 2019/2020. The experiment included two factors, the first was the different types of bio-fertilizer (without inoculation, nitrobein or/and phophorein at 1 kg/feddan of each) and the second was the different concentrations of salicylic acid (0, 50, 100 and 150 ppm) as well as the interaction between them.

Experimental Design

The statistical layout of this experiment were split-plot design experiment between bio-fertilization types (four types) as main plot and salicylic concentrations (four concentrations) as sub-plot in randomized complete blocks design (RCBD) with three replicates. The interaction treatments between bio-fertilization types and salicylic concentrations were consisted of 16 treatments.

Plant Material and Cultivation

The source of dill fruits were Agriculture Research Centre of Medicinal and Aromatic Plants Department, Dokky, Giza, Egypt. Fruits were sown immediately in soil on 9th October through the two seasons. The experimental unit area was 4 × 3.6 m. Every experimental unit contained five ridges with 4 m long. The distance between ridges was 60 cm and distance between plants in the same ridge was 30 cm. About 5-6 fruits were sown per hill, and then thinned after 3 weeks to 2 plants/hill (84 plants/plot unit). The other agricultural practices were carried out as recommended. The physical and chemical properties of the experimental farm soil (average of the two seasons) are tabulated in Table 1 as reported by **Chapman and Pratt (1978)**.

Bio-fertilizers and Salicylic Acid Application

The inoculation, with nitrobein (*Azospirillum lipofrum*) and phosphorein (*Bacillus megatherium phosphaticum*) was performed by coating dill fruits with each product individually utilizing a sticking substance (5% Arabic gum) just before sowing. Salicylic acid (SA) acid ($C_7H_6O_3$) was obtained from TECHNO GENE Company, Dokky, Giza, Egypt. Furthermore, salicylic concentrations were added as foliar application. The first application began thirty days after planting and repeated every two weeks until 90 days (3 times/season) from dill sowing. The untreated plants (control) were sprayed with tap water.

Fertilization Rate and its Time

The recommended rate of NPK was 150 : 200:100 kg/feddan of ammonium sulphate (20.5% N), calcium superphosphate (15.5%

Table 1. Physical and chemical properties of the experimental farm soil (average of the two seasons)

Physical analysis				Soil texture
Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Clayey
56.36	9.26	17.62	16.76	

Chemical analysis												
pH	E.C. m.mohs/ cm	Organic matter (%)	Soluble cations (meq./L)			Soluble anions (meq./L)			Available (ppm)			
			Mg^{++}	Ca^{++}	Na^{+}	Cl^{-}	HCO_3^{-}	SO_4^{--}	N	P	K	
7.82	0.98	0.58	3.1	2.3	4.3	4.5	1.7	3.5	18	20	71	

P_2O_5) and potassium sulphate (48.5% K_2O) respectively. All amount of phosphorus fertilizer was added during soil preparation. While, nitrogen and potassium fertilizers were divided into 3 equal doses and were applied at 30, 60 and 90 days after sowing date.

Sampling and Collecting Data

Vegetative growth parameters

After 100 days from dill sowing, 3 plants were randomly chosen from each plot to determine the following parameters: Plant height (cm), number of branches/plant, and total dry weight/ plant (g).

Yield characters

At harvest (135 days from sowing), number of umbels per plant and fruit weight per plant (g) were recorded then fruit yield per feddan was calculated (Kg) as multiplying fruit weight per plant (g) × number of plants per feddan/1000.

Volatile oil production

The volatile oil from air-dried dill fruits, at the end of experiment, was isolated by hydro distillation for 3 hours in order to extract the essential oils according to **Guenther (1961)**. Also, volatile oil yield per plant was calculated by multiplying volatile oil percentage by fruit yield per plant (ml). Volatile oil per feddan was calculated by multiplying the volatile oil yield per dill plant by weight of fruits per feddan (l) for each treatment.

Chemical constituents

Total chlorophyll (a+ b) content (mg/ 100g fresh weight) was determined in dill fresh leaves (after 90 days from sowing date) according to the method reported by **Cherry (1973)**. Also, total carbohydrates percentage of dill fruits was determined (after 135 days from sowing) according to the methods described by **AOAC (1990)**.

Statistical Analysis

The statistical layout of this study was split-plot in completely randomized block design. Data were analyzed as pointed out by **Gomez and Gomez (1984)**. The collected means were compared utilizing computer program of Statistix version 9 (**Analytical Software, 2008**).

RESULTS AND DISCUSSION

Vegetative Growth Parameters

Results recorded in Tables 2, 3 and 4 indicate that, in most cases, inoculation with nitrobein and/or phosphorein significantly increased plant height, number of branches

Table 2. Effect of bio-fertilizers type (B) and salicylic acid (S) concentrations as well as their combinations (B×S) on plant height (cm) of *Anethum graveolens* plant during 2018/2019 and 2019/2020 seasons

Bio-fertilizers type	Salicylic acid concentration (ppm)				Mean (B)
	Control	50	100	150	
			2018/2019 season		
Control	63.89	64.55	66.55	71.33	**66.58**
Nitro*	65.44	66.33	70.11	77.44	**69.83**
Phosph**	70.56	70.89	75.89	81.11	**74.61**
Nitro+Phosph	73.67	76.22	79.89	83.00	**78.20**
Mean (S)	**68.39**	**69.50**	**73.11**	**78.22**	
LSD at 5 %	**For (B)= 1.09**		**For (S)= 0.74**	**For (B×S)= 1.67**	
			2019/2020 season		
Control	62.89	66.11	70.22	73.89	**68.28**
Nitro*	74.00	73.34	74.78	78.89	**75.25**
Phosph**	73.44	74.45	78.33	83.44	**77.42**
Nitro+Phosph	76.44	78.89	82.78	87.11	**81.31**
Mean (S)	**71.69**	**73.20**	**76.53**	**80.83**	
LSD at 5 %	**For (B)= 0.63**		**For (S)= 0.34**	**For (B×S)= 1.08**	

* Nitro = Nitrobein, ** Phosph = Phosphorein

Table 3. Effect of bio-fertilizers type (B) and salicylic acid (S) concentrations as well as their combinations (B×S) on number of branches per plant of *Anethum graveolens* plant during 2018/2019 and 2019/2020 seasons

Bio-fertilizers type	Salicylic acid concentration (ppm)				Mean (B)
	Control	50	100	150	
			2018/2019 season		
Control	6.44	7.00	7.44	7.66	**7.14**
Nitro*	6.22	7.66	8.45	8.67	**7.75**
Phosph**	6.78	7.89	9.11	9.78	**8.39**
Nitro+Phosph	7.45	8.45	9.45	11.00	**9.09**
Mean (S)	**6.72**	**7.75**	**8.61**	**9.28**	
LSD at 5 %	**For (B)= 0.57**		**For (S)= 0.34**	**For (B×S)= 0.82**	
			2019/2020 season		
Control	6.33	7.11	8.00	8.56	**7.53**
Nitro*	7.11	8.11	10.33	9.78	**8.83**
Phosph**	7.11	8.45	9.22	9.78	**8.64**
Nitro+Phosph	7.33	9.22	10.56	11.22	**9.58**
Mean (S)	**7.00**	**8.22**	**9.53**	**9.83**	
LSD at 5 %	**For (B)= 0.37**		**For (S)= 0.30**	**For (B×S)= 0.64**	

* Nitro = Nitrobein, ** Phosph = Phosphorein

Table 4. Effect of bio-fertilizers type (B) and salicylic acid (S) concentrations as well as their combinations (B×S) on total dry weight of plant (g) of *Anethum graveolens* plant during 2018/2019 and 2019/2020 seasons

Bio-fertilizers type	Salicylic acid concentration (ppm)				Mean (B)
	Control	50	100	150	
			2018/2019 season		
Control	14.32	15.90	16.83	20.27	**16.83**
Nitro*	16.79	18.47	20.27	24.87	**21.00**
Phosph**	16.40	20.17	20.73	23.80	**20.28**
Nitro+Phosph	18.73	23.17	24.87	27.50	**23.57**
Mean (S)	**16.56**	**19.43**	**20.68**	**24.11**	
LSD at 5 %	**For (B)= 0.65**		**For (S)= 0.43**	**For (B×S)= 0.99**	
			2019/2020 season		
Control	15.70	16.40	18.20	19.30	**17.40**
Nitro*	17.47	18.40	20.50	22.57	**19.73**
Phosph**	17.27	18.80	22.53	21.80	**20.10**
Nitro+Phosph	19.93	21.30	24.00	25.17	**22.60**
Mean (S)	**17.59**	**18.73**	**21.31**	**22.21**	
LSD at 5 %	**For (B)= 0.87**		**For (S)= 0.46**	**For (B×S)= 1.17**	

* Nitro = Nitrobein, ** Phosph = Phosphorein

per plant and total dry weight of plant compared to the control in both seasons. The best treatment in this regard was that inoculation dill fruit with nitrobein + phosphorein at 1 kg/feddan. The using of microorganisms as bio-fertilizers is counted a hopeful alternative to chemical fertilizers and it was reflected to enhance plant growth (**El-Sayed *et al*., 2018**). Furthermore, **Shehata (2019)** found that microbein + phosphorein, significantly, affected vegetative growth of parsley plant compared to control.

In addition, all salicylic acid concentrations significantly increased dill growth parameters compared to control in both seasons. Increasing SA concentration gradually increased plant height, branch number per plant and total plant dry weight in the first and second seasons. The highest value in each trait was obtained by the treatment of 150 ppm concentration compared to the other ones under study. Moreover, the increases in total dill dry weight were about 45.59 and 26.26% for 150 ppm salicylic acid over control treatment in the 1st and 2nd seasons, respectively. These results are in agreement with those stated by **Gad *et al*. (2016)** on *Ixora coccinea*, **Ali *et al*. (2017)** on fennel and **Fathi and Najafian (2020)** on *Carum copticum* plants.

Furthermore, results cleared that dill plants inoculated with nitrobein + phosphorein and sprayed with 150 ppm salicylic acid recorded the highest value for each of plant height, number of branches per plant as well as total dry weight with significant difference than the other interaction treatments in the two tested seasons (Tables 2, 3 and 4). In general, increasing SA concentration under any bio-fertilizer type gradually increased dill height (cm), number of branches per plant and total plant dry weight (g) in both seasons. Moreover, as mentioned just before, both bio-fertilization and salicylic acid concentration (each alone) increased plant height, number of branches per plant and total dry weight of *Anethum graveolens* plant, in turn, they together might maximize their influences leading to the highly vegetative growth parameters.

Yield Characters

Results under discussion in Tables 5, 6 and 7 indicate that using mixture of bio-fertilizers (nitrobein + phosphorein) significantly increased number of umbels per plant as well as fruit yield per plant and per feddan compared to control and nitrobein or phosphorein individually in both seasons. Furthermore, the increases in fruit yield per feddan of dill reached to 27.35 and 25.98% for nitrobein + phosphorein over control treatment in the 1st and 2nd seasons, respectively. The most remarkable advantages of growth enhancing bacteria may be due to production of growth inducing and development of root system as well as improving water and nutrients uptake and regulating hormones which reflected on increasing yield component of plant (**Kravchenko *et al*., 1994**). Likewise, bio-fertilizers treatments enhanced parsley seed yield compared to control (**Massoud *et al*., 2019**).

Generally, number of umbels per plant, fruit yield per plant (g) and fruit yield per feddan (kg) significantly increased by using SA at any concentration compared to the control in both seasons (Tables 5, 6 and 7). The highest concentration of SA (150ppm) gave the highest value in each dill yield component compared to unsprayed plants in the two seasons. In other words, the increases in dill fruit yield per feddan were about 32.10 and 43.66% for 150 ppm salicylic acid over control treatment in the 1st and 2nd seasons, respectively. Moreover, dill plants sprayed with salicylic acid gave a significant enhance in number of inflorescences per plant and seed yield per plant compared to the control (**Al-Japer, 2016)**.

The interaction treatment between bio-fertilizers (as mixture type) and salicylic acid at 150 ppm significantly increased dill yield components compared to the control and the other interactions under study in both seasons (Tables 5, 6 and 7). The increases in fruit yield per plant were about 66.79 and 69.50 % for the combination between nitrobein + phosphorein of bio-fertilization and 150 ppm salicylic acid over control treatment in the 1st and 2nd seasons, respectively. In general, increasing SA concentration under each bio-fertilization type gradually increased dill number of umbels per plant as well as fruit yield per plant and per feddan. Furthermore, **Sharaf El-Din *et al*. (2013)** pointed out that bio-fertilizers microbein (nitrogen fixing bacteria) and phosphorein (phosphate dissolving bacteria) increased significantly celery and dill yield components than control (the untreated plants). Also, **Abdelkader and Hamad (2014)** demonstrated that high yield (number of fruits per plant as well as sepals and seeds yield per plant and per feddan) could be obtained by spraying roselle plant with SA at 200 ppm.

Volatile Oil Production

It is quite clear from the results in Tables 8 and 9 that volatile oil percentage and volatile oil yield per plant (ml) of dill significantly increased as influence to bio-fertilizers types compared to control. In the same trend, volatile oil yield per feddan (l) gave the highest values when dill plants were fertilized by bio-fertilizers compared to untreated plants (Table 10). However, fruit yield characters of dill were significantly increased with nitrobein + phosphorein type over control and the other types under study in both seasons. In other words, the increases in volatile oil yield per feddan were about 32.95 and 29.53% for the nitrobein + phosphorein mixture type compared to control (un inoculated plants) in the first and second seasons, respectively. These results are in full agreement with those obtained by **Nejatzadeh-Barandozi (2014)** who suggested that the highest essential oil content of dill detected in biological fertilizer compared to the control.

Table 5. Effect of bio-fertilizers type (B) and salicylic acid (S) concentrations as well as their combinations (B×S) on number of umbels per plant of *Anethum graveolens* plant during 2018/2019 and 2019/2020 seasons

Bio-fertilizers type	Salicylic acid concentration (ppm)				Mean (B)
	Control	50	100	150	
			2018/2019 season		
Control	15.44	17.56	18.33	20.78	**18.03**
Nitro*	17.22	19.78	21.56	23.78	**20.58**
Phosph**	17.22	19.11	23.11	25.89	**21.33**
Nitro+Phosph	19.33	23.67	27.22	29.89	**25.03**
Mean (S)	**17.31**	**20.03**	**22.56**	**25.08**	
LSD at 5 %	**For (B)= 0.72**		**For (S)= 0.56**	**For (B×S)= 1.20**	
			2019/2020 season		
Control	16.22	18.11	19.67	23.55	**19.39**
Nitro*	18.33	19.33	20.56	26.11	**21.08**
Phosph**	17.89	19.89	22.45	28.22	**22.11**
Nitro+Phosph	20.45	22.45	26.55	31.55	**25.25**
Mean (S)	**18.88**	**19.95**	**22.31**	**27.36**	
LSD at 5 %	**For (B)= 0.93**		**For (S)= 0.57**	**For (B×S)= 1.35**	

* Nitro = Nitrobein, ** Phosph = Phosphorein

Table 6. Effect of bio-fertilizers type (B) and salicylic acid (S) concentrations as well as their combinations (B×S) on fruit yield per plant (g) of *Anethum graveolens* plant during 2018/2019 and 2019/2020 seasons

Bio-fertilizers type	Salicylic acid concentration (ppm)				Mean (B)
	Control	50	100	150	
			2018/2019 season		
Control	13.43	14.57	15.10	16.37	**14.87**
Nitro*	14.83	15.40	17.07	18.20	**16.38**
Phosph**	14.73	15.63	18.47	19.30	**17.03**
Nitro+Phosph	14.73	18.20	20.40	22.40	**18.93**
Mean (S)	**14.43**	**15.95**	**17.76**	**19.07**	
LSD at 5 %	**For (B)=0.34**		**For (S)= 0.40**	**For (B×S)= 0.76**	
			2019/2020 season		
Control	13.67	13.90	16.13	18.40	**15.53**
Nitro*	14.93	15.50	19.77	21.40	**17.90**
Phosph**	14.60	16.20	20.07	20.83	**17.93**
Nitro+Phosph	15.13	17.77	22.17	23.17	**19.56**
Mean (S)	**14.58**	**15.84**	**19.53**	**20.95**	
LSD at 5 %	**For (B)= 0.38**		**For (S)= 0.44**	**For (B×S)= 0.85**	

* Nitro = Nitrobein, ** Phosph = Phosphorein

Table 7. Effect of bio-fertilizers type (B) and salicylic acid (S) concentrations as well as their combinations (B×S) on fruit yield per feddan (kg) of *Anethum graveolens* plant during 2018/2019 and 2019/2020 seasons

Bio-fertilizers type	Salicylic acid concentration (ppm)				Mean (B)
	Control	50	100	150	
			2018/2019 season		
Control	626.90	679.80	704.70	763.80	**693.78**
Nitro*	692.20	718.70	796.50	849.30	**764.17**
Phosph**	687.60	729.60	861.80	900.70	**794.89**
Nitro+Phosph	687.60	849.30	952.00	1045.30	**883.56**
Mean (S)	**673.56**	**744.34**	**828.73**	**889.78**	
LSD at 5 %	**For (B)= 15.69**		**For (S)=18.41**	**For (B×S)= 35.46**	
			2019/2020 season		
Control	637.80	648.70	752.90	858.70	**724.51**
Nitro*	696.90	723.30	922.50	998.70	**835.34**
Phosph**	618.30	756.00	936.50	972.20	**836.51**
Nitro+Phosph	706.20	829.10	1034.50	1081.10	**912.73**
Mean (S)	**680.56**	**739.28**	**911.56**	**977.67**	
LSD at 5 %	**For (B)= 17.48**		**For (S)= 20.60**	**For (B×S)= 39.65**	

* Nitro = Nitrobein, ** Phosph = Phosphorein

Table 8. Effect of bio-fertilizers type (B) and salicylic acid (S) concentrations as well as their combinations (B×S) on volatile oil percentage of *Anethum graveolens* plant during 2018/2019 and 2019/2020 seasons

Bio-fertilizers type	Salicylic acid concentration (ppm)				Mean (B)
	Control	50	100	150	
			2018/2019 season		
Control	2.123	2.143	2.173	2.267	**2.177**
Nitro*	2.167	2.207	2.243	2.310	**2.232**
Phosph**	2.187	2.207	2.237	2.323	**2.238**
Nitro+Phosph	2.217	2.250	2.277	2.337	**2.270**
Mean (S)	**2.173**	**2.202**	**2.233**	**2.309**	
LSD at 5 %	**For (B)= 0.010**		**For (S)= 0.006**	**For (B×S)=0.015**	
			2019/2020 season		
Control	2.150	2.170	2.193	2.233	**2.187**
Nitro*	2.183	2.193	2.220	2.273	**2.218**
Phosph**	2.193	2.243	2.240	2.283	**2.240**
Nitro+Phosph	2.210	2.223	2.243	2.310	**2.247**
Mean (S)	**2.184**	**2.208**	**2.224**	**2.275**	
LSD at 5 %	**For (B)=0.005**		**For (S)=0.008**	**For (B×S)=0.014**	

* Nitro = Nitrobein, ** Phosph = Phosphorein

Table 9. Effect of bio-fertilizers type (B) and salicylic acid (S) concentrations as well as their combinations (B×S) on volatile oil yield per plant (ml) of *Anethum graveolens* plant during 2018/2019 and 2019/2020 seasons

Bio-fertilizers type	Salicylic acid concentration (ppm)				Mean (B)
	Control	50	100	150	
			2018/2019 season		
Control	0.285	0.312	0.328	0.371	**0.324**
Nitro*	0.321	0.340	0.383	0.420	**0.366**
Phosph**	0.322	0.345	0.413	0.449	**0.382**
Nitro+Phosph	0.327	0.409	0.464	0.523	**0.431**
Mean (S)	**0.314**	**0.352**	**0.397**	**0.441**	
LSD at 5 %	**For (B)= 0.008**		**For (S)=0.009**	**For (B×S)=0.018**	
			2019/2020 season		
Control	0.294	0.302	0.354	0.411	**0.340**
Nitro*	0.326	0.340	0.439	0.487	**0.398**
Phosph**	0.321	0.364	0.450	0.476	**0.402**
Nitro+Phosph	0.335	0.395	0.497	0.535	**0.441**
Mean (S)	**0.319**	**0.350**	**0.435**	**0.477**	
LSD at 5 %	**For (B)=0.009**		**For (S)=0.010**	**For (B×S)= 0.020**	

* Nitro = Nitrobein, ** Phosph = Phosphorein

Table 10. Effect of bio-fertilizers type (B) and salicylic acid (S) concentrations as well as their combinations (B×S) on volatile oil yield per feddan (l) of *Anethum graveolens* plant during 2018/2019 and 2019/2020 seasons

Bio-fertilizers type	Salicylic acid concentration (ppm)				Mean (B)
	Control	50	100	150	
			2018/2019 season		
Control	13.313	14.570	15.315	17.314	**15.128**
Nitro*	15.000	15.86	17.87	19.62	**17.087**
Phosph**	15.035	16.099	19.276	20.926	**17.834**
Nitro+Phosph	15.243	19.109	21.674	24.426	**20.113**
Mean (S)	**14.647**	**16.409**	**18.533**	**20.572**	
LSD at 5 %	**For (B)=0.389**		**For (S)=0.428**	**For (B×S)=0.835**	
			2019/2020 season		
Control	13.712	14.077	16.514	19.177	**15.870**
Nitro*	15.216	15.863	20.477	22.703	**18.565**
Phosph**	14.944	16.961	20.978	22.201	**18.771**
Nitro+Phosph	15.609	18.434	23.207	24.972	**20.556**
Mean (S)	**14.870**	**16.334**	**20.294**	**22.263**	
LSD at 5 %	**For (B)= 0.420**		**For (S)= 0.466**	**For (B×S)= 0.908**	

* Nitro = Nitrobein, ** Phosph = Phosphorein

The maximum increase in volatile oil percentage and volatile oil yield per plant and per feddan of dill were observed with salicylic acid at 150 ppm concentration compared to the other SA concentrations under study during the two tested seasons. In the meantime, there was gradual increase in the abovementioned parameters with increasing salicylic acid concentrations (Tables 8, 9 and 10). Moreover, **Es-sbihi *et al*. (2020)** found that the essential oil yield enhanced under treatment with salicylic acid, especially at 0.5 mM concentration, with 116.66% enhancement as compared to control (untreated with SA).

Generally, the best interaction treatment for increasing volatile oil production of dill was that of the treatment of nitrobein + phosphorein interacted with salicylic acid at 150 ppm concentration compared to the other interaction treatments in both seasons. Moreover, under each treatment of bio-fertilizers type volatile oil percentage and volatile oil yield per plant and per feddan of dill were increased with increasing SA concentrations. In the same time, **Sharaf El-Din *et al*. (2013)** reported that the highest increasing in oil percentage was achieved by *Rosmarinus officinalis* plants inoculated with (phosphorein + microbein) for two cuts in both two seasons, whenever, the same treatment achieved the most increases of essential oil content /plant in the two cuts for both seasons compared to control plants. However, **Hanfy *et al*. (2019)** cleared that the highest values of volatile oil yield of *Origanum syriacum* was gained with the 750 or 1000 mg.l^{-1} acetyl salicylic acid compared to control.

Chemical Constituents

Results of both seasons in Tables 11 and 12 show that using bio-fertilization types as nitrobein and/or phosphorein significantly increased total chlorophyll (a+ b) content and total carbohydrate percentage of dill plant compared with control in both seasons. However, the highest values of total chlorophyll content (2.18 and 2.17 mg/ 100g fresh weight) and total carbohydrate percentage (17.43 and 17.65%) were obtained with nitrobein + phosphorein mixture application treatment in the 1st and 2nd seasons, respectively. Likewise, the increase in this connection was also found by **Abbasniayzare *et al*. (2012)** on *Spathiphyllum illusion* plants.

Different salicylic acid concentrations (50, 100 or 150 ppm) significantly increased chemical constituents' contents of dill plant compared to control in both seasons (Tables 11 and 12). Moreover, the increases in total chlorophyll content were about 14.84 and 14.05% for the SA at 150 ppm during the first and second seasons, respectively. In contrast, the lowest values in this connection (1.82 and 1.85 mg/100 g fresh weight) were produced without foliar spray with salicylic acid (control). **Gad *et al*. (2016)** pointed out that *Ixora coccinea* pigments (chlorophyll a, b and a+b) were enhanced at 300 ppm concentration compared to the lowest ones and control.

In general, total chlorophyll content and total carbohydrate percentage of dill were increased by increasing all salicylic acid concentrations under any bio-fertilization type treatments up to nitrobein+ phosphorein mixture type if compared with control during 2018/2019 and 2019/2020 seasons (Tables 11 and 12). Generally, the best values of chemical constituents were determined under study of dill were obtained with nitrobein+ phosphorein each at 1 kg/ feddan interacted with 150 ppm concentration compared to the other interaction treatments in both seasons. The positive effect of bio-fertilization in this respect may be due to increase nutrients in the soil solution. This increase can encourage the plant growth, which increased the photosynthetic rates leading to an increase in the assimilation rates and hence the total chlorophyll content and carbohydrates percentage were increased. These results are in line with those reported by **Ahmad *et al*. (2018)** on the peppermint plant regard salicylic effect and **Massoud *et al*. (2019)** on the parsley plant concern bio-fertilizers effect.

Table 11. Effect of bio-fertilizers type (B) and salicylic acid (S) concentrations as well as their combinations (B×S) on total chlorophyll content (mg/100g fresh weight) of *Anethum graveolens* plant during 2018/2019 and 2019/2020 seasons

Bio-fertilizers type	Salicylic acid concentration (ppm)				Mean (B)
	Control	50	100	150	
			2018/2019 season		
Control	1.77	1.83	1.91	1.85	**1.84**
Nitro*	1.80	2.06	2.27	2.02	**2.04**
Phosph**	1.84	2.03	2.29	2.11	**2.07**
Nitro+Phosph	1.86	2.18	2.31	2.36	**2.18**
Mean (S)	**1.82**	**2.03**	**2.19**	**2.09**	
LSD at 5 %	**For (B)= 0.04**		**For (S)= 0.04**	**For (B×S)= 0.08**	
			2019/2020 season		
Control	1.82	1.86	1.92	1.87	**1.87**
Nitro*	1.83	2.05	1.97	2.03	**1.97**
Phosph**	1.86	1.99	2.05	2.20	**2.03**
Nitro+Phosph	1.88	2.13	2.32	2.33	**2.17**
Mean (S)	**1.85**	**2.01**	**2.07**	**2.11**	
LSD at 5 %	**For (B)= 0.05**		**For (S)= 0.04**	**For (B×S)= 0.09**	

* Nitro = Nitrobein, ** Phosph = Phosphorein

Table 12. Effect of bio-fertilizers type (B) and salicylic acid (S) concentrations as well as their combinations (B×S) on total carbohydrates percentage of *Anethum graveolens* plant during 2018/2019 and 2019/2020 seasons

Bio-fertilizers type	Salicylic acid concentration (ppm)				Mean (B)
	Control	50	100	150	
			2018/2019 season		
Control	15.03	15.30	16.23	16.83	**15.85**
Nitro*	15.73	16.43	16.87	17.73	**16.69**
Phosph**	16.10	16.67	16.87	17.40	**16.76**
Nitro+Phosph	16.54	17.17	17.60	18.43	**17.43**
Mean (S)	**15.85**	**16.39**	**16.89**	**17.60**	
LSD at 5 %	**For (B)= 0.31**		**For (S)= 0.29**	**For (B×S)= 0.59**	
			2019/2020 season		
Control	15.33	15.87	16.47	16.87	**16.13**
Nitro*	15.63	16.27	17.30	17.30	**16.63**
Phosph**	15.87	16.77	17.50	17.37	**16.88**
Nitro+Phosph	17.00	17.30	17.87	18.43	**17.65**
Mean (S)	**15.96**	**16.55**	**17.28**	**17.49**	
LSD at 5 %	**For (B)= 0.27**		**For (S)= 0.29**	**For (B×S)= 0.57**	

* Nitro = Nitrobein, ** Phosph = Phosphorein

Conclusion

It can be concluded that inoculating dill fruits by nitrobein + phosphorein mixture each at 1 kg/feddan interacted with 150 ppm salicylic acid as foliar application five times/season enhanced plant growth and yield components and volatile oil production of dill (*Anethum graveolens*, L.) under Sharkia Governorate conditions.

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الملخص العربي

تحسين نمو وإنتاجية نبات الشبت باستخدام حمض الساليسيليك وتطبيقات التسميد الحيوي

وليد صبري نصير

قسم البساتين (نباتات الزينة والطبية والعطرية)، كلية الزراعة، جامعة الزقازيق، مصر

اجريت تجربتين حقليتين في المزرعة التجريبية، بكلية الزراعة، جامعة الزقازيق، محافظة الشرقية، مصر خلال الموسمين المتتاليين لأعوام 2019/2018 و2020/2019. وذلك، بهدف دراسة تأثير معدلات حمض الساليسيليك المختلفة (صفر، 50، 100 و150 جزء في المليون) وأنواع التسميد الحيوي (بدون تلقيح، النيتروبين و/أو الفسفورين بمعدل 1 كجم/فدان من كل نوع) ومعاملات التفاعل بينهما على النمو الخضري، صفات المحصول والزيت العطري وكذلك المحتوى الكلي من الكلوروفيل والنسبة المئوية للكربوهيدرات في نبات الشبت. أظهرت نباتات الشبت المعاملة بحمض الساليسيليك بمعدلات 100 أو 150 جزء في المليون زيادة معنوية في النمو الخضري (طول النبات، عدد الأفرع لكل نبات والوزن الجاف الكلي للعشب) في كلا الموسمين مقارنة بالمعدلات الأخرى قيد الدراسة. سجل أعلى معدل لحمض الساليسيليك رشاً ورقياً أعلى قيم في مكونات المحصول (عدد النورات لكل نبات وكذلك محصول الثمار للنبات وللفدان) وكذلك إنتاج الزيت العطري (نسبة الزيت العطري المئوية والمحصول لكل نبات) مقارنة مع المعاملات الأخرى قيد الدراسة، في معظم الحالات. علاوة على ذلك، فإن إضافة التسميد الحيوي (نتروبين + فسفورين) أنتج أعلى قيم لجميع صفات النمو تحت الدراسة مقارنة بالأنواع الأخرى قيد الدراسة. عموماً، حققت معاملة التفاعل بين 150 جزء في المليون من حمض الساليسيليك مع 1 كجم/ فدان نتروبين + فسفورين زيادة في النمو الخضري وصفات المحصول وإنتاج الزيت العطري ومحتوى الكلوروفيل الكلي مقارنة بأي من حمض الساليسيليك و/ أو معدلات الأسمدة الحيوية قيد الدراسة منفرداً في كلا الموسمين.

الكلمات الاسترشادية: نبات الشبت، حمض الساليسيليك والأسمدة الحيوية، نمو النبات، المحصول، الزيت الطيار.

المحكمـــــون:

1- أ.د. محمود عبدالهادي حسن أستاذ النباتات الطبية والعطرية، كلية الزراعة، جامعة المنيا، مصر.

2- أ.د. ناهـد مصطفي رشـــاد أستاذ النباتات الطبية والعطرية، كلية الزراعة، جامعة دمياط، مصر.