

Seaweed Extract and Indoleacetic Acid Foliar Application in Relation to The Growth Performance of Sweet Pepper Grown Under Net House Conditions

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ABSTRACT: Sweet pepper plants (*Capsicum annuum* L.) grown worldwide in various distinct colours and shapes, and favors for consumers, especially those grown under protected houses. The attention of growers is directed toward enhancing or improving the growth, yield and quality of their fruits *via* safe agricultural practices using seaweed extract (SWE) as a biostimulant and plant growth regulators as the auxin IAA as safe alternatives for inorganic fertilization and their negative impacts. Therefore, two field experiments were carried out during two successive seasons of 2017 and 2018, to determine their influences on both vegetative and reproductive growth of sweet bell red pepper cv. 'Strick F1' grown under net house conditions. Treatments were consisted of two independent variables as foliar applicants such as seaweed extract (SWE) [Cytokan-S] at four concentrations (control, 500, 1000 and 2000 mg.l⁻¹) in combination with five concentrations of indoleacetic acid (IAA) [control, 30, 60, 90 and 120 mg.l⁻¹]. Control plants were sprayed with tap water. Pepper plants were sprayed with the assigned treatments twice, once at 15 days after transplanting, and the second one was 20 days later. Both conducted experiments were factorial experiments laid out in a randomized complete block design (RCBD), with three replicates. The obtained results showed that vegetative growth were affected significantly ($p \leq 0.05$) due to the combination of SWE at either 1000 or 2000 mg/l \times IAA at 120 mg/l; as number of leaves/plant, plant fresh and dry weights as compared to control plants. Respecting yield characters and its components, the interaction between both independent variables, exerted significant ($p \leq 0.05$) effect on the various studied traits but without clear trends, except for fruit dry weights especially, wherein the interactions between control (SWE) \times 120 mg/l (IAA), and SWE at 500 mg \times IAA at 120 mg/l, gave rise to the highest average values during both seasons, in comparison to the interaction between control treatments of both variables; recorded, mostly, the least average values of the given traits. In terms of nutrient contents of fruits; N, P and K nutrient contents, the foliar application of the combination between SWE and IAA at 2000 and 120 mg/l, each in turn, significantly ($p \leq 0.05$); brought about the highest average values of nutrient contents of fruits compare to the other tested combinations. In brief, this investigation suggests that foliar application with combination of both SWE at 2000 mg / l and IAA at 120 mg / l twice after 15 and 20 days later of transplanting, is recommended to achieve the best vegetative and yield and quality of the given cultivar.

Keywords: Sweet red pepper, Seaweed extract, Indoleacetic acid, vegetative growth, yield.

INTRODUCTION

Nowadays and worldwide, greenhouse sweet bell pepper (*Capsicum annuum* L.) grows in three different colors, and shapes. Nevertheless, the attention of both professionals and growers of greenhouse- colored grown bell peppers is directed to increase their high quality all the year-around, whereas the consumers are willing to pay more for these types of greenhouse -grown bell peppers (Smither-Kopperl and Cantliffe, 2004). Satisfying these demands require increasing the fruit set and enhancing fruit quality using natural products as seaweed extract as biostimulant and/or plant growth regulators (PGRs) as auxins for these kinds of peppers that grown under greenhouse conditions.

Yield of bell peppers has been manipulated *via* various techniques as mineral (inorganic) fertilization (Leskovar *et al.*, 1989; Qawasami *et al.*, 1999; Omar *et al.*, 2018). Nevertheless, some authors as Qawasami *et al.* (1999) reported an insignificant effect of nitrogen on total dry matter content among tested treatments, despite its high-cost, and its residues' negative impacts especially N-NO₂ within fruit tissues, its effect on soil physical and chemical properties. Therefore, yield of sweet bell peppers could be enhanced *via* natural biostimulants as seaweed extract and plant growth regulators as auxins, either solely or in combination of each other with reduction of the mineral fertilization as possible (Rouphael *et al.*, 2018).

Seaweed extracts are macroalgae classified according to their color, and widely applied for their advantages or merits as availability the coasts, plant growth promoters, ameliorating the capabilities of plants to tolerate abiotic and biotic stresses [salinity, extreme temperature, nutrient deficiencies and drought, diseases etc.] (Calvo *et al.*, 2014; Tsukanova *et al.*, 2017). Seaweed extracts contain a numerous additives of growth promoters as auxins and cytokinins, in addition to macro- and micronutrients and their positive effects on many crops and horticultural commodities have been documented (Leskovar *et al.*, 1989; Qawasami *et al.*, 1999; Omar *et al.*, 2018).

Auxins as IAA or auxin-like substances as phenyl-3-acetic acid (PAA) are well-known to produce endogenously in many marine algae (*e.g.* Sumera and Cajipe, 1981), also, has the efficacy to enhance plant growth and development for most vegetable crops. Auxins at the cellular levels affect cell elongation, cell division and the formation of adventitious roots. At the reproductive stage, foliar application of auxins or auxin-like substances can change fruit size as *Capsicum annuum* (Mahroon and Abbas, 2015).

In view of the above introduction review, the current research was carried out to determine the influence of both seaweed extract and the auxin indoleacetic acid at the tested concentrations on both vegetative and reproductive growth of sweet bell red pepper cv. 'Strick F1' grown under net house conditions ,especially yield and its components.

MATERIALS AND METHODS

Two field experiments were carried out during the summer seasons of 2017 and 2018 in a private farm, at Abou El-Matameer city, in Behiera Governorate, Egypt, under net house (shade net 25%) to study the effect of foliar application of the various levels of both seaweed extract (SWE) and indoleacetic acid (IAA) on vegetative growth, yield, and quality of 'Strick F₁ hybrid' sweet red pepper cultivar. Before planting, random soil samples of 0-30 cm depth from different places of the planting field were collected and analyzed for some important chemical and physical properties as given in Table (1).

Pepper cultivar seeds coined as 'Strick F₁ hybrid' was used for conducting the experimentation. Seeds were sown in seedling foam trays (84 eyes) filled with a mixture of Peat Moss: Vermiculite (1:1, v/v), supplemented with 300 g ammonium sulphate (20.5% N), 400 g calcium superphosphate (15% P₂O₅), 150 g potassium sulphate (48% K₂O), 50 ml micronutrient solution and 50 g of a fungicide (Thiophenate methyle) for each 50 kg of the soil mixture under plastic house conditions on Febraury 10th during both seasons of the study. Seedlings of 60 days old were transplanted in a net house at both sides of the

Table (1). Some physical and chemical properties of the experimental site during both seasons of the experimentation (2017 and 2018)

Soil properties	Season	
	2017	2018
Mechanical Analysis:		
Clay (%)	10.00	10.30
Silt (%)	4.00	3.80
Sand (%)	86.00	85.90
Textural class	Sandy loam	Sandy loam
Chemical analysis:		
pH (1:1, water suspension)	7.40	7.50
EC (1:1, water extract), dS\m	2.58	2.61
Soluble cations in (1:5, water extract), meq/l		
Ca ⁺⁺	4.14	4.20
Mg ⁺⁺	7.16	7.10
K ⁺	1.28	1.22
Na ⁺	12.17	11.80
Soluble anions in (1:5, water extract), meq/l		
HCO ₃ ⁻	3.60	3.70
Cl ⁻	8.40	8.20
SO ₄ ⁻⁻	12.75	12.42
CaCO ₃ (%)	9.10	9.30
Available N (mg/kg soil)	531.41	544.33
Available P (mg/kg soil)	25.00	26.00
Available K (mg/kg soil)	175.00	177.00

The analyses were carried out at Soil and Agricultural Chemistry Departement, The Faculty of Agricultur (Saba Basha), Alexanderia University, Egypt.

Ridge on April 13th during the both seasons at 0.3 m apart and 1.5 m width of ridge (*i. e.* the initial planting density was 4.44 transplants/m²). The experimental plot consisted of one ridge with 7.0 m long and 1.5 m width making an area of 10.50 m² using drip irrigation system. Both conducted experiments were factorial experiments laid out in a randomized complete block design (RCBD), with three replicates. Each replicate included 20 treatments. All determined treatments were distributed randomly within each block. Peppers are indeterminate plants, therefore, the plants have to be pruned and trained on a regular basis to ensure a balanced growth for the maximum fruit production.

Treatments were consisted of two factors (two independent variables) as a foliar applicants, *i.e.*; four concentrations of seaweed extract (SWE) as control, 500, 1000 and 2000 mg.l⁻¹ in combination with five concentrations of indoleacetic acid (IAA) as control, 30, 60, 90 and 120 mg.l⁻¹. Control plants were sprayed with tap water. Both conducted experiments were factorial experiments laid out in a randomized complete block design (RCBD), with three replicates. Each replicate included 20 treatments. All determined treatments were distributed randomly within each block. Seaweed extract coined as (Cytokan-S) was used in this study. It is mixed of *Ascophyllum nodosum* (25 %) and *Fhyllum phaophyta* (75%) having the following composition: organic matter 25%, inorganic matter 25%, alginic acid 9%, amino acid 10%, menthol 3%, Gibberellins 0.15%, 6-Benziladenin 0.05% and minerals (K₂O 1.5%, P₂O₅ 1.5%, N 1%, Ca 0.30%, S 1%, Se 0.03%, Mg 0.30 %, B 75 mg/l, Cu 2 mg/l, Zn 25 mg/l, Fe 75 mg/l and Mn 5 mg/l). All precautions and accuracy were followed during weighing, dissolving, spraying of both independent variables. Pepper plants were sprayed with the allocated or assigned treatments twice during the growing seasons, the first one at 15 days after transplanting and the second application was 20 days later. Harvesting was accomplished after 90 days of transplanting during both seasons.

Experimental data collection:

Four plants form each treatment, in each replications, were randomly selected and tagged for recording growth attributes after 90 days of transplanting as follows:

1. Vegetative growth:

Plant height (cm), number of leaves per plant, number of branches per plant, plant fresh and dry weights (g) were recorded.

2. Fruit number and yield parameters:

The number of fruits per plant, average fruits weight (g), and fruits dry matter according to the following formula:

Fruits dry matter (%) = $\frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$, early yield was considered as the weight of all harvested fruits during the first 40 days of harvesting per plant (g) and total fruit yield per square meter (kg).

3. Fruits N, P and K contents:

Were determined in plant tissues by using 100 g of fresh fruits which were taken from each treatment. The samples were dried at 70°C until constant weight. The obtained dry matter was ground into fine powder and 0.5 g of the ground dried material was digested with H₂O₂ according to Evenhuis and Dewaard (1980). Total nitrogen in digested samples was determined colorimetrically according to Chapman and Pratt (1961). Total P in digested samples was determined colorimetrically as described by Singh *et al.* (2005). Total K in digested samples was measured using flame photometer as described by Singh *et al.* (2005).

Statistical Analysis:

All obtained data of the present study were statistically analyzed according to the design used by the MSTAT-C computer software program (Bricker, 1991). The least significant difference test at 0.05 level of probability was used to compare the differences among the given means of the various treatment combinations as illustrated by Gomez and Gomez (1984).

RESULTS AND DISCUSSION**1. Vegetative growth:**

Average values of vegetative growth presented in Table (2) show that both independent variables (*i.e.* seaweed extract [SWE] and the auxin Indoleacetic acid [IAA]) and their combinations exerted significant ($p \leq 0.05$) effects on the dependent variable traits under the study).

The main effect of SWE exhibited a direct proportional relationship with the tested traits, in general, whereas as SWE concentration increased the vegetative growth increased significantly especially at 2000 mg/l compare to control treatment (foliar application with tap water). The increment percentages as an average of both seasons compare to control plants were 6.82%, 24.88%, 16.82%, 41.92%, and 42.16% for plant height (cm), number of leaves/plant, number of branches/plant, plant fresh weight and plant dry weight, respectively. These results are in agreement with those of Demir *et al.* (2006) on tomato, pepper and aubergine, Abdulraheem (2009) on cucumber, Prasad *et al.* (2010), Spinelli *et al.* (2010) on strawberry. Sridhar and Rengasamy (2012) reported that when chilli pepper (*Capsicum annum*) grown under filed conditions when sprayed with 1.0% of seaweed liquid fertilizer (SLF) derived from the brown seaweed *Sargassum wightii*, the plant growth characteristics enhanced total plant height, total fresh and dry weights, number of branches and leaf area. In this concern, it well-known that seaweed extracts are enriched with natural plant hormones as cytokinins and auxins, vitamins and some major nutrients (Sridhar and Rengasamy, 2012; Thirumaran *et al.*, 2009 a,b). These increments in vegetative-related characters could be taken place due to component of the used SWE from plant hormones *i.e.* cytokinins and gibberellins that practice or exert significant effects on plant growth and development through enhancing and accelerating a number of metabolic processes as cell division and enlargement (George *et al.*, 2008), and subsequently leading to increase these characters (Demir *et al.*, 2006; Prasad *et al.*, 2010; Marhoon and Abbas, 2015). Furthermore, the SWE includes unlimited amounts of micro-and macronutrients which have a crucial function in activation of many enzymes and coenzymes which participate in many biological processes; leading to cell division and enlargement (Murugalakshmikumari *et al.*, 2002; Anantharaj and Venkatesalu, 2002).

Table (2). Average values of some vegetative growth of sweet red pepper plants cv. 'Strick F₁' as affected by foliar application with seaweed extract (SWE), indoleacetic acid (IAA) and their combinations during 2017 and 2018 growing seasons

Treatments	Plant height (cm)		No. of leaves/plant		No. branches/plant		Plant fresh weight (g)		Plant dry weight (g)		
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	
SWE (main effect)											
Control	253.60 c	250.87 c	322.60 d	327.27 d	53.87 d	53.13 d	560.99 d	577.82 d	112.20 d	115.56 d	
500 mg/l	259.20 b	258.53 b	339.87 c	350.00 c	56.13 c	57.40 c	706.20 c	727.38 c	141.24 c	145.48 c	
1000 mg/l	262.53 b	267.00 a	370.00 b	381.13 b	58.53 b	61.13 b	745.16 b	767.12 b	149.02 b	153.47 b	
2000 mg/l	267.66 a	271.20 a	399.86 a	411.67 a	61.13 a	63.87 a	796.17 a	820.05 a	159.23 a	164.52 a	
IAA (main effect)											
Control	250.58 c	248.83 c	334.75 d	344.67 d	52.92 c	52.75 d	638.41 e	657.56 e	127.68 e	131.51 e	
30 mg/l	262.17 b	262.50 b	340.83 d	345.00 d	57.83 b	59.09 c	663.79 d	683.71 d	132.75 d	136.89 d	
60 mg/l	261.42 b	264.58 ab	352.58 c	363.08 c	57.67 b	59.42 bc	698.73 c	719.69 c	139.74 c	144.07 c	
90 mg/l	261.92 b	265.59 ab	371.08 b	382.33 b	58.33 b	60.92 ab	735.51 b	757.57 b	147.10 b	151.67 b	
120 mg/l	267.67 a	268.00 a	391.17 a	402.50 a	60.34 a	62.25 a	774.22 a	796.94 a	154.84 a	159.65 a	
Combinations effect											
SWE (mg/l)	IAA (mg/l)										
Control	Control	237.33 j	236.00 i	309.33 o	318.67 l	50.33 h	49.33 i	590.16 m	607.86 m	118.03 m	121.57 m
	30	253.33 hi	255.00 g	319.67 l-n	304.67 m	53.33 g	54.00 g	511.85 p	527.21 p	102.37 p	105.44 p
	60	256.33 gh	253.33 g	311.33 no	320.33 l	53.67 fg	52.00 h	538.79 o	554.95 o	107.76 o	110.99 o
	90	259.00 e-g	255.67 fg	327.33 kl	337.33 j	55.33 de	55.33 g	567.15 n	584.16 n	113.43 n	116.83 n
	120	262.00 c-e	254.33 g	345.33 hi	355.33 i	56.67 c	55.00 g	597.00 m	614.91 m	119.40 m	122.98 m
500	Control	251.67 i	247.33 h	325.67 k-m	335.33 jk	53.00 g	52.00 h	621.23 l	639.86 l	124.24 l	127.97 l
	30	261.67 d-f	260.67 de	317.33 m-o	327.00 kl	56.33 cd	57.67 f	672.46 j	692.64 j	134.49 j	138.53 j
	60	259.00 e-g	259.67 d-f	334.00 jk	344.00 j	56.33 cd	57.33 f	707.86 h	729.09 h	141.57 h	145.82 h
	90	258.00 fg	261.67 d	351.67 h	362.33 hi	56.33 cd	59.00 f	745.12 g	767.47 g	149.02 g	153.49 g
	120	265.67 bc	263.33 d	370.67 ef	381.33 ef	58.67 b	61.00 e	784.33 e	807.86 e	156.87 e	161.57 e
1000	Control	254.00 hi	254.67 g	342.67 ig	353.33 i	53.67 fg	54.33 g	653.92 k	673.54 k	130.78 k	134.71 k
	30	263.33 cd	263.00 d	348.00 hi	358.67 i	58.67 b	61.00 e	709.93 h	731.23 h	141.97 h	146.23 h
	60	261.00 d-f	271.00 bc	366.67 fg	377.67 fg	58.33 b	62.67 de	747.30 g	769.72 g	149.44 g	153.85 g
	90	261.67 d-f	269.00 c	386.00 d	397.67 d	59.33 b	62.33 de	786.63 e	810.23 e	157.31 e	162.03 e
	120	272.67 a	277.33 a	406.67 c	418.33 c	62.67 a	65.33 bc	828.03 c	850.87 c	165.59 c	170.55 c
2000	Control	259.33 e-g	257.33 e-g	361.33 g	371.33 gh	54.67 ef	55.33 g	688.33 i	708.98 i	137.67 i	141.80 i
	30	270.33 a	271.33 bc	378.33 de	389.67 de	63.00 a	63.67 cd	760.92 f	783.75 f	152.18 f	157.34 f
	60	269.33 ab	274.33 ab	398.33 c	410.33 c	62.33 a	65.67 b	800.96 d	824.99 c	160.19 d	165.62 d
	90	269.00 ab	276.00 a	419.33 b	432.00 b	62.33 a	67.00 ab	843.12 b	868.42 b	168.62 b	174.34 b
	120	270.33 a	277.00 a	442.00 a	455.00 a	63.33 a	67.67 a	887.50 a	914.12 a	177.50 a	183.50 a

- Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using L.S.D. test at 0.05 level of probability.

These results are in agreement with those of Abdulraheem (2009) on cucumber plants and with Marhoon and Abbas (2015) on sweet pepper plants (Flavio F1 and California wonder). Also, the increment percentages of number of leaves, fresh and dry weights/plant are in correlation with increasing number of branches and their leaves and their capability on photosynthesis and photosynthates in the various organs of the plant, subsequently increase organ itemed (Taiz and Zeiger, 2002).

With regard to the main effect of IAA, it is clear, also, that there is a direct proportional relationship between IAA concentrations and the dependent variable characters; whereas IAA concentration increased, such significant ($p \leq 0.05$) effect and progressive increases in the tested traits, especially upon foliar application of IAA at 120 mg/l which brought about the highest average values of tested traits compare to control plants. The increment percentages of both seasons compare to control plants were 7.00%, 16.82%, 16.00%, 21.23%, and 21.33% for plant height (cm), number of leaves/plant, number of branches/plant, plant fresh weight (g) and plant dry weight (g), each in turn. These results are in parallel with those of Van Pelt and Popham (2002); Hajheidari *et al.* (2012); Kesici *et al.* (2013). Kaur *et al.* (2017) reported that foliar spraying of IAA at 200 μ M; led to a significant increase of *Capsicum* 'Indri'cv. plant height compare to control plants, which recorded the lowest average value.

Notably, plants treated with SWE exhibit multiplied one-half number of leaves *versus* those treated with IAA (24.88 vs. 16.82), multiplied twice of both plant fresh and plant dry weights *i.e.* 41.92% vs. 21.23% and 42.15% vs. 21.33%, respectively. This finding could be attributed to the constituents versatility of SWE as plant growth stimulator contains mineral elements major and minor nutrients, trace elements, inorganic constituents etc. which improve plant growth and development, in general (Temple *et al.*, 1989).

In terms of the first order interaction between both independent variables on vegetative-growth characters, it exerted significant ($p \leq 0.05$) effect on various tested traits. Generally, it is obvious that under any concentration of SWE with IAA, more or less; the maximum average values of the studied traits compare to control plants was obvious. The interaction between SWE at either 1000 or 2000 mg/l with IAA at 120 mg/l, exhibited clear differences among tested treatments as number of leaves/plant, plant fresh and dry weights as compared to control plants.

2. Yield characters and its components:

Concerning the results of Table (3), the average values of the tested yield characters were affected significantly due to the main effects of both independent variables compare to their control treatments except fruit fresh weight, early yield/plant and early yield/m² in the second season only. In most studied traits, the foliar application of SWE at 2000 mg/l; recorded the highest percentage values.

Similar trend was noticed regarding the main effect of the auxin IAA, whereas fruit dry weight character was affected significantly and differed from the other treatments, especially at 120 mg/l which recorded the highest percentage values as 30.53 and 31.27% during both seasons, respectively, compare with control treatment (23.77 and 25.81% during both seasons).

Regarding the first order interaction between both independent variables exerted significant ($p \leq 0.05$) effect on the various studied traits but without clear trends. The combined treatment of SWE at either 1000 or 2000 mg/l with IAA at 120 mg/l, generally, recorded the highest mean values for yield characters.

Table (3). Average values of some yield characters of sweet red pepper plants cv. 'Strick F₁' as affected by foliar application with seaweed extract (SWE), indoleacetic acid (IAA) and their combinations during 2017 and 2018 growing seasons

Treatments	No. of fruits/plant		Fruit fresh weight (g)		Fruit dry weight (%)		Early yield/plant (g)		Early yield/m ² (kg)		
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	
SWE (main effect)											
Control	22.33b	22.60b	148.34b	149.33a	24.89d	26.76c	828.27b	831.60a	3.67b	3.68a	
500 mg/l	23.27 ab	23.00 ab	151.67 ab	148.67 a	26.71 c	28.93 b	881.73 a	839.94 a	3.91 a	3.73 a	
1000 mg/l	23.73 a	23.47 ab	152.00 ab	149.00 a	28.16 b	30.29 a	901.40 a	872.80 a	4.00 a	3.88 a	
2000 mg/l	23.33 ab	23.93 a	155.33 a	147.33 a	29.92 a	30.24 a	906.20 a	876.00 a	4.02 a	3.89 a	
IAA (main effect)											
Control	22.09 b	21.75 b	146.67 b	152.08 a	23.77 e	25.81 d	809.33 b	818.17 b	3.59 b	3.62 b	
30 mg/l	23.25 a	23.17 a	152.08 a	149.58 ab	26.20 d	28.17 c	883.67 a	860.09 ab	3.92 a	3.82 ab	
60 mg/l	23.50 a	23.92 a	153.75 a	145.00 b	27.57 c	29.65 b	903.17 a	860.25 ab	4.01 a	3.82 ab	
90 mg/l	23.50 a	23.33 a	152.92 a	150.00 ab	29.03 b	30.38 b	897.92 a	862.92 ab	3.98 a	3.84 ab	
120 mg/l	23.50 a	24.08 a	153.75 a	146.25 ab	30.53 a	31.27 a	902.92 a	874.00 a	4.00 a	3.88 a	
Combinations effects											
SWE (mg/l) IAA (mg/l)											
Control	Control	20.67 e	20.67 h	141.67 e	148.33 a-d	21.97 m	23.63 l	732.00 f	776.00 f	3.24 f	3.40 f
	30	22.33 d	22.33 e-g	150.00 cd	151.67 ab	23.68 l	25.46 k	837.00 e	824.00 de	3.71 e	3.66 de
	60	22.67 cd	23.67 a-d	151.67 b-d	146.67 b-e	24.92 jk	26.80 ij	858.67 c-e	867.33 a-d	3.81 c-e	3.85 a-d
	90	22.67 cd	23.00 c-f	151.67 b-d	151.67 ab	26.24 gh	28.21 gh	858.67 c-e	849.00 a-e	3.81 c-d	3.77 a-e
	120	23.33 a-d	23.33 b-e	146.67 de	148.33 a-d	27.62 e	29.70 d-f	855.00 de	841.67 b-e	3.79 de	3.74 c-e
500	Control	22.33 d	21.67 gh	146.67 de	153.33 a	23.13 l	25.88 k	815.67 e	807.67 e-f	3.62 e	3.59 ef
	30	23.00 b-d	23.33 b-e	153.33 a-c	148.33 a-d	25.52 ij	27.44 hi	882.00 b-d	864.67 a-d	3.91 b-d	3.84 a-d
	60	23.33 a-d	23.00 c-f	153.33 a-c	148.33 a-d	26.86 fg	28.89 fg	894.33 a-d	829.00 de	3.96 a-d	3.68 de
	90	23.67 a-c	22.67 d-g	151.67 b-d	151.67 ab	28.28 d	30.41 c-e	897.00 a-d	836.67 c-e	3.98 a-d	3.72 c-e
	120	24.00 ab	24.33 ab	153.33 a-c	141.67 e	29.77 c	32.01 b	919.67 ab	861.67 a-d	4.08 ab	3.83 a-d
1000	Control	22.67 cd	22.00 fg	151.67 b-d	153.33 a	24.35 k	26.18 jk	859.33 c-e	843.00 b-e	3.81 c-e	3.74 b-e
	30	24.33 a	23.33 b-e	148.33 cd	148.33 a-d	26.93 f	28.96 fg	902.00 a-c	864.67 a-d	4.00 a-c	3.84 a-d
	60	24.33 a	24.67 a	151.67 b-d	141.67 e	28.35 d	30.48 cd	922.67 ab	873.00 a-d	4.09 ab	3.88 a-d
	90	24.00 ab	23.33 b-e	151.67 b-d	151.67 ab	29.84 c	32.08 b	909.33 ab	884.33 a-c	4.03 ab	3.93 a-c
	120	23.33 a-d	24.00 a-c	156.67 ab	150.00 a-c	31.32 b	33.77 a	913.67 ab	899.00 a	4.05 ab	3.99 a
2000	Control	22.67 cd	22.67 d-g	146.67 de	153.33 a	25.63 hi	27.56 hi	830.33 e	846.00 b-e	3.68 e	3.76 b-e
	30	23.33 a-d	23.67 a-d	156.67 ab	150.00 a-c	28.65 d	30.81 c	913.67 ab	887.00 a-c	4.05 ab	3.94 a-c
	60	23.67 a-c	24.33 ab	158.33 a	143.33 de	30.16 c	32.43 b	937.00 a	871.67 a-d	4.16 a	3.87 a-d
	90	23.67 a-c	24.33 ab	156.67 ab	145.00 c-e	31.75 b	30.81 c	926.67 ab	881.67 a-c	4.11 ab	3.92 a-c
	120	23.33 a-d	24.67 a	158.33 a	145.00 c-e	33.42 a	29.60 ef	923.33 ab	893.67 ab	4.09 ab	3.97 ab

To be continued..

Continued..

Treatments	Fruit yield/plant (kg)		Fruit yield/m ² (kg)		
	2017	2018	2017	2018	
SWE (main effect)					
Control	3.32b	3.38b	14.72b	14.98b	
500 mg/l	3.53a	3.42ab	15.67a	15.16ab	
1000 mg/l	3.61a	3.49ab	16.01a	15.51ab	
2000 mg/l	3.63a	3.53a	16.09a	15.64a	
IAA (main effect)					
Control	3.25b	3.31b	14.39b	14.69b	
30 mg/l	3.54a	3.47a	15.69a	15.38a	
60 mg/l	3.62a	3.47a	16.04a	15.38a	
90 mg/l	3.60a	3.50a	15.95a	15.53a	
120 mg/l	3.61a	3.52a	16.04a	15.62a	
Combinations effect					
SWE (mg/l)	IAA (mg/l)				
Control	Control	2.93g	3.07g	13.00g	13.61g
	30	3.35ef	3.39ef	14.87ef	15.04ef
	60	3.44c-f	3.47b-e	15.25c-f	15.41b-e
	90	3.44c-f	3.49a-e	15.25c-f	15.48a-e
	120	3.42d-f	3.46b-e	15.21d-f	15.35b-e
500	Control	3.28f	3.32f	14.54f	14.75f
	30	3.53b-e	3.46b-e	15.66b-e	15.36b-e
	60	3.58a-d	3.41d-f	15.88a-d	15.13d-f
	90	3.59a-d	3.44c-f	15.93a-d	15.26c-f
	120	3.68ab	3.45c-f	16.33ab	15.30c-e
1000	Control	3.44c-f	3.37ef	15.25c-f	14.98ef
	30	3.61a-c	3.46b-e	16.02a-c	15.36b-e
	60	3.69ab	3.49a-e	16.39ab	15.51a-e
	90	3.64ab	3.54a-c	16.15ab	15.71a-c
	120	3.66ab	3.6a	16.22ab	15.97a
2000	Control	3.33f	3.48a-e	14.75f	15.43a-e
	30	3.66ab	3.55a-c	16.22ab	15.75a-c
	60	3.75a	3.49a-e	16.63a	15.48a-e
	90	3.71ab	3.53a-d	16.45ab	15.66a-d
	120	3.69ab	3.58ab	16.39ab	15.87ab

- Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using L.S.D. test at 0.05 level of probability.

3. Fruits N, P and K nutrient contents:

Results postulated in Table (4) exhibit that sweet red pepper fruits cv. 'Strick F₁' contents of N, P, and K were affected, significantly ($p \leq 0.05$), by the various tested treatments under investigation and their combinations. Concerning the main effect of SWE, foliar application effect on the N, P, and K nutrient contents of pepper fruits, generally, the given variable significantly ($p \leq 0.05$) affected the chemical constituents under study. The given chemical content percentages reflect a direct proportional relationship as the applied SWE increased; the highest content percentages increased. Whereas, the fruits of the given cultivar, derived from plants treated with the highest SWE level (2000 mg/l) have the highest significant percentages of N, P, and K fruits' content during both seasons compared to control plants which recorded the least significant average

Table (4). Percentage values of some chemical determination of sweet red pepper fruits cv. 'Strick F₁' as affected by foliar application with seaweed extract (SWE), indoleacetic acid (IAA) and their combinations during 2017 and 2018 growing seasons

Treatments	Nutrient contents of fruits (% d.w.)						
	N		P		K		
	2017	2018	2017	2018	2017	2018	
SWE (main effect)							
Control	1.52 d	1.82 d	0.32 b	0.38 d	1.99 d	2.39 d	
500 mg/l	1.61 c	1.93 c	0.38 ab	0.42 c	2.19 c	2.63 c	
1000 mg/l	1.69 b	2.03 b	0.38 ab	0.46 b	2.41 b	2.90 b	
2000 mg/l	1.80 a	2.18 a	0.45 a	0.51 a	2.66 a	3.19 a	
IAA (main effect)							
Control	1.46 e	1.77 e	0.34 b	0.35 e	1.86 e	2.22 e	
30 mg/l	1.57 d	1.89 d	0.36 ab	0.43 d	2.25 d	2.69 d	
60 mg/l	1.65 c	1.99 c	0.38 ab	0.45 c	2.36 c	2.84 c	
90 mg/l	1.74 b	2.09 b	0.40 ab	0.48 b	2.49 b	2.99 b	
120 mg/l	1.84 a	2.20 a	0.44 a	0.50 a	2.62 a	3.15 a	
Combinations effects							
SWE (mg/l)	IAA (mg/l)						
Control	Control	1.37 l	1.62 j	0.29 h	0.32 l	1.71 l	2.05 l
	30	1.44 kl	1.73 i	0.30 gh	0.36 j	1.91 j	2.28 j
	60	1.52 i-k	1.82 h	0.32 f-h	0.38 i	2.00 i	2.40 i
	90	1.60 hi	1.92 g	0.34 e-h	0.40 h	2.11 h	2.53 h
	120	1.68 fg	2.02 f	0.35 d-h	0.42 g	2.22 g	2.67 g
500	Control	1.44 kl	1.73 i	0.46 bc	0.34 k	1.81 k	2.16 k
	30	1.52 h-j	1.83 h	0.34 e-h	0.40 h	2.11 h	2.54 h
	60	1.60 gh	1.92 g	0.35 d-h	0.43 g	2.23 g	2.67 g
	90	1.69 f	2.02 f	0.37 c-h	0.45 f	2.35 f	2.81 f
	120	1.78 de	2.13 de	0.39 c-g	0.48 e	2.47 e	2.96 e
1000	Control	1.52 i-k	1.82 h	0.30 gh	0.36 j	1.90 j	2.27 j
	30	1.60 gh	1.92 g	0.37 c-h	0.45 f	2.35 f	2.82 f
	60	1.68 fg	2.02 f	0.39 c-g	0.47 e	2.47 e	2.97 e
	90	1.77 de	2.13 de	0.41 b-f	0.50 d	2.60 d	3.13 d
	120	1.87 bc	2.24 bc	0.44 b-d	0.52 c	2.74 c	3.29 c
2000	Control	1.51 jk	1.92 g	0.32 f-h	0.38 i	2.00 i	2.40 i
	30	1.73 ef	2.07 ef	0.42 b-e	0.50 d	2.61 d	3.13 d
	60	1.81 cd	2.18 cb	0.44 b-d	0.52 c	2.75 c	3.30 c
	90	1.91 b	2.29 b	0.49 ab	0.55 b	2.90 b	3.47 b
	120	2.02 a	2.42 a	0.57 a	0.58 a	3.05 a	3.66 a

- Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using L.S.D. test at 0.05 level of probability.

values, whereas intermediate levels; recorded intermediate and significant ($p \leq 0.05$) average values, too. Obviously, the increment percentages (as an average of both seasons) compare to control treatment were 19.16 for N, 37.14 for P, and 33.56 for K. this effect may be due to that seaweed extracts contain small amounts of natural auxins and indoles that help stimulate rooting formation and uptake and translocate water and minerals such as N, P and K contents. With regard to the main effect of IAA on the studied trait of nutrient content of pepper fruits, the tabulated averages disclosed similar performance as SWE was noticed

with IAA application, whereas as IAA levels increased significantly ($p \leq 0.05$) progressively fruits N, P and K increased correspondingly. Whereas, the percentage values responded positively, during both seasons. The maximum percentage values were recorded especially upon foliar application of IAA at 120 mg/l compare to control treatment (as an average values of both seasons).

The intermediate levels of IAA achieved intermediate significant ($p \leq 0.05$) percentage value, too. The increment percentages of N, P and K due to apply the maximum level of IAA (*i.e.* 120 mg/l) compare to control treatment were 25.16 for N, 36.14 for P, and 41.38 for K. Auxin are well known for their positive impact on rooting initiation and development a strong and healthy root system assists the uptake or absorb water and mineral fastly.

With respective to the interaction between both variables and their levels, the fruit chemical contents of N, P, K had affected significantly ($p \leq 0.05$). The foliar application of SWE with 2000 mg/l plus 120 mg/l IAA; recorded, in general, the highest percentages values of the tested contents compare to other combinations.

In this context, seaweed extract and IAA levels may react synergistically at different concentration; resulting in accumulation more elemental contents of N, P and K within fruit tissues. Seaweed extracts have high levels of natural plant hormones especially cytokinins, gibberellins and to some extent auxins and brassinosteroids (Stirk *et al.*, 2014) which could enhance production of gutter root mass. Greater root mass provides better uptake water and minerals and facilitates their translocation; resulting in healthier, more stress-resistant plant.

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الملخص العربي

الرش الورقي بمستخلص الطحالب البحرية وإندول حمض الخليك وعلاقتها بأداء النمو للفلفل الحلو النامي تحت ظروف البيوت الشبكية

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تزرع نباتات الفلفل الحلو (*Capsicum annuum* L.) في جميع أنحاء العالم بألوان وأشكال مختلفة، ومفضلة لدى المستهلكين خاصةً عندما تنمو تحت ظروف البيوت المظلمة التي تفي بمتطلبات المستهلكين وتتعاكس إيجابياً على كل من المحترفين والمزارعين. يتجه المزارعين نحو تعزيز أو تحسين نمو، إنتاجية وجودة ثمارهم من خلال الممارسات الزراعية الآمنة باستخدام عامل آمن بديل مثل مستخلصات الأعشاب البحرية كمنشط حيوي طبيعي ومنظمات النمو النباتية مثل أوكسين إندول حامض الخليك بدلاً من استخدام التسميد غير العضوي وتأثيراته السلبية إما للتلوث البيئي أو للنبات. لذلك، تم إجراء تجربتين حقليتين خلال الموسمين المتتاليين ٢٠١٧ و ٢٠١٨ لتحديد تأثير كلاً من مستخلص الأعشاب البحرية وأوكسين إندول حامض الخليك بتركيزات مختلفة على كلا من النمو الخضري والتكاثري لمحصول الفلفل الأحمر الحلو هجين ستريك "Strick F1" النامية تحت ظروف البيوت المظلمة. وتألفت المعاملات من عاملين (المتغيرات المستقلة) كتطبيق رش ورقي، بمعنى؛ أربعة تركيزات من مستخلص الأعشاب البحرية (SWE) وهي صفر (نباتات المقارنة)، ٥٠٠، ١٠٠٠، ٢٠٠٠ ملجم/لتر وخمسة تركيزات من أوكسين إندول حمض الخليك (IAA) وهي صفر (نباتات المقارنة)، ٣٠، ٦٠، ٩٠، ١٢٠ ملجم/لتر منفردين أو في خليط. وتم رش نباتات المقارنة بماء الصنبور. وتم رش نباتات الفلفل بالمعاملات مرتين خلال موسم النمو، الأولى بعد ١٥ يوماً من عملية الشتل، وكانت المعاملة الثانية بعد ٢٠ يوماً من الرشة الأولى. كلتا التجريبتين تم تصميمهما كتجارب عاملية في تصميم القطاعات العشوائية الكاملة (RCBD) ، في ثلاث مكررات. أظهرت النتائج المتحصل عليها أن الرش الورقي بمستخلص الأعشاب البحرية (سيتوكان- إس) بتركيز ٢٠٠٠ ملجم / لتر و أوكسين إندول حمض الخليك (IAA) بتركيز ١٢٠ ملجم / لتر واستخدام هذا المزيج كرش ورقي مرتين خلال موسم النمو بعد ١٥ يوم من الشتل و بعد ٢٠ يوماً من الرشة الأولى على نباتات الفلفل الأحمر الحلو هجين ستريك "Strick F1" المنزرع تحت ظروف البيوت المظلمة وتحت نظام الري بالتنقيط أعطت أعلى القيم لمتوسطات صفات النمو الخضري والمحصول ومكوناته ومحتوى الثمار من K, P, N .

