Evaluation of some cyanobacterial strains as growth promoters for sweet pepper (*Capsicum annuum* var. *Annuum*)

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ABSTRACT

Three cyanobacterial strains (Spirulina, Oscillatoria and Anabaena spp.) were produced in forms of liquid culture and powder and evaluated as growth promoters for sweet pepper plants in a pot experiment. The experiment was performed in twenty four treatments including foliar application of cultures, filtrate and dried biomass (which were dissolved either in water or in culture filtrate). The negative control was water while the positive one was the recommended NPK. Spirulina-treated plants recorded high contents in both macroelements and microelements, whereas high concentrations of chlorophyll a, b and total chlorophyll were noticed in Anabaena-treated plants. Treatment with Spirulina showed increase in leaf and root parameters, while stem parameters increased by mixed culture treatment. Both Spirulina and mixed culture treatments showed earliness in flowering (110 days after transplantation). Plants gave fruits with marketable size for most treatments after 40 days of starting blooming, with protein percentages ranging from 23.9 to 16.2%. Among the examined plants, Spirulina - treated plants were the superior in growth over the other treatments. Anatomical examination revealed that Spirulina - treated plants gave the highest increment in lamina thickness than both controls, due mainly to the elevation in spongy tissue thickness. Thickness of lamina positively associated with leaf fresh weight and negatively with leaf area.

Keywords: *Cyanobacteria, Spirulina, Oscillatoria, Anabaena, Sweet pepper, Foliar application, Chemical analysis, Morphological and Anatomical parameters.*

INTRODUCTION

Increasing use of chemical fertilizers in agriculture may deteriorate environment and cause harmful impacts on living beings. In addition, they are costly and have various adverse effects on soils as depletion of water holding capacity and disparity in soil nutrients. Their residues leak into water and affect the growth of inhabiting microorganisms. It was targeted from a long time to develop some low cost effective and eco-friendly fertilizers. Now, certain species of microorganisms are widely used which have unique properties to provide natural products and serve as a good substitute of chemical fertilizers (Deepali and Gangwar, 2010). Cyanobacteria are known to excrete a great variety of secondary and biologically active metabolites such as auxins, gibberellins, cytokinins, vitamins, polypeptides and amino acids which promote plant growth and development (Arun *et al.,* 2012). Several

greenhouse and field studies carried out to evaluate the effect of inoculating different crops with cyanobacteria showed that cyanobacterial application on plants varied according to the strains used (Palaniappan *et al.,* 2010; Prasanna *et al.,* 2012 and Prasanna *et al.,* 2013). Abd El Baky *et al.* (2014) noticed increasing of total chlorophyll, chlorophyll a and b and low molecular weight antioxidant compounds, *i.e.* glutathione and carotenoids contents by foliar inoculation of the blue green algae *Spirulina*. Kumar and Kumar (2014) reported that bio-foliar spray contributed to leaf moisture. They found that the higher content in leaves of mulberry was resulted due to supply of bio-foliar nutrients and also with-standing the moisture scarcity for longer duration. They also stated that, this phenomenon is attributed to the fact that bio-foliar application increases the leaf diffusive resistance and decreases the transpiration rates. Increasing water content in plants treated with foliar spray was also reported for other crops grown under salt stress, *i.e.* barley (El-Tayeb, 2005), tomato (Tari *et al.,* 2002 and Szepesi *et al.,* 2005) and cucumber (Yildirim *et al.,* 2008).

Therefore, the present study aims at evaluating the isolated cyanobacterial strains as plant growth promoters for sweet pepper. This may lead to protect the environment and public health from the dangerous effects of chemical fertilizers.

MATERIALS AND METHODS

Isolation, purification and identification of cyanobacteria

Three cyanobacterial species from El-Khadra Lake, Wadi El-Natrun, Egypt were isolated by Selim *et al.* (2014). The isolated species were identified morphologically using light microscope, TEM and by using molecular techniques. The isolated species were *Spirulina platensis*, *Oscillatoria accuminata* and *Anabaena variabilis.*

Cultivation of cyanobacterial isolates and biomass harvest

BG-11 medium was used to cultivate both *Oscillatoria* and *Anabaena* sp. According to Pandey *et al.* (2010). *Spirulina* was inoculated into Zarrouk's medium (Zarrouk, 1966). Cultures were then transferred to larger volumes of 6-liter bottles filled with five liters of the corresponding medium and incubated for 3-4 weeks at room temperature under continuous illumination with white fluorescent lamps for 30 days and continuously aerated with air pump.

Well-grown cyanobacterial cultures were collected and 20 ml of micro-algal suspensions were centrifuged by Centurion Scientific centrifuge at 10000 rpm for 15 min. Dry weights of cyanobacterial cultures were estimated by drying the pellets overnight at 60-70˚C in Thermo Scientific Heraeus Oven Function Line UT20 and weighed.

Evaluation of cyanobacterial isolates as plant growth promoters for sweet pepper plant

Sixty-day old seedlings of sweet pepper (*Capsicum annuum*), local cultivar Omega were kindly supplied by the Nursery of General Scientific Association in Beni Suef Governorate. A pot experiment was designed and conducted, starting 1st of June 2014, to evaluate the effect of cyanobacterial isolates on sweet pepper under glasshouse conditions at Environmental Studies and Research Unit (ESRU), Faculty of Agriculture, Cairo University. The experiment consisted of 72 plastic pots (No. 30) each filled with 8 kg of soil mixture (sand to clay 1:2 v/v). Each treatment was replicated three times. The physico-chemical properties of soil and total microbial counts were determined. Sweet

pepper seedlings were transplanted into each pot (3 seedlings per pot) with equal spacing. Two controls were used in this experiment; positive control using NPK chemical fertilizer as recommended by the Ministry of Agriculture and negative one using water only. Recommended dose of NPK were equivalent to 700 kg/fed ammonium sulphate, 300 kg/fed super phosphate and 250 kg/fed potassium sulfate. Pots were irrigated when needed by tap water, maintaining 60-65% water holding capacity (WHC). Cyanobacterial foliar application was done after 2 weeks of transplantation while the NPK treatment was applied after one month of transplantation.

Treatments applied included cyanobacterial cultures, cultures filtrates, different concentrations of dried cyanobacterial biomass dissolved in either water or culture filtrates as follows: T1, positive control; T2, negative control; T3, mixed culture suspension; T4, mixed culture (1000 mg dry powder dissolved in 1 liter water); T5, *Spirulina* culture suspension; T6, *Spirulina* (500 mg dry powder dissolved in 1 liter water); T7, *Spirulina* (1000 mg dry powder dissolved in 1 liter water); T8, *Spirulina* (2000 mg dry powder dissolved in 1 liter water); T9, *Oscillatoria* culture suspension; T10, *Oscillatoria* (500 mg dry powder dissolved in 1 liter water); T11, *Oscillatoria* (1000 mg dry powder dissolved in 1 liter water); T12, *Oscillatoria* (2000 mg dry powder dissolved in 1 liter water); T13, *Anabaena* culture suspension; T14, *Anabaena* (500 mg dry powder dissolved in 1 liter water); T15, *Anabaena* (1000 mg dry powder dissolved in 1 liter water); T16, *Anabaena* (2000 mg dry powder dissolved in 1 liter water); T17, *Spirulina* culture filtrate; T18, *Oscillatoria* culture filtrate; T19, *Anabaena* filtrate; T20, Mixed filtrate; T21, *Spirulina* (1000 mg dry powder dissolved in 1 liter *Spirulina* filtrate); T22, *Oscillatoria* (1000 mg dry powder dissolved in 1 liter *Oscillatoria* filtrate); T23, *Anabaena* (1000 mg dry powder dissolved in 1 liter *Anabaena* filtrate) and T24, Mixed dry powder (1000 mg dry powder, dissolved in 1 liter mixed filtrate, 1:1:1).

At the end of the experiment (after 150 days from transplantation), the following parameters were measured;

Chemical analyses of plants

Chlorophyll a, b and total chlorophyll of plants (Holden, 1965).

Total protein of fruits was determined by Kjeldahl method (A.O.A.C., 2000).

Nitrogen (%) by micro Kjeldahel method (A.O.A.C., 2000).

Phosphorus content (%) in the digested samples was determined colorimetrically by ascorbic acid method (Jackson, 1973).

Potassium content (%) in the acid solution of the digested samples was determined using flame photometer (Jackson, 1973).

Copper , zinc, manganese and ferrous (ppm) were determined in dried plants by wet oxidation methods (Jackson, 1973).

Morphological and growth parameters of plants

Root length, root fresh weight, root dry weight, plant height, stem length, average length of internodes, stem fresh weight, stem dry weight, number of leaves per plant, leaf length, blade length, leaf area, leaves fresh weight, leaves dry weight, flowering date and fruits fresh weight were determined after 50 and 150 days from transplantation.

Anatomical studies

Samples for the anatomical study were taken from mature lamina of *Capsicum annuum* cv. Omega, at the 3rd internode, at the end of growth stage (150 days aged). All specimens were killed and fixed in formalin acetic acid solution, and dehydrated through normal butyl alcohol series before being

embedded in paraffin wax (melting point 56°C). Transverse sections (20µm-thick) were cut using a rotary microtome, then sections double-stained with Safranin/Fast green, and mounted in Canada balsam (Nassar and El-Sahhar, 1998). Selected sections were examined and measurements of different tissues were recorded. The average of 5 readings was calculated. Photographs of sections were taken using Microscope Olympus AX70 (made in Japan).

Statistical analysis

The data were subjected to ANOVA test. Randomized complete block design (RCBD) was applied. Data analysis was proceeded by Assistat software to estimate LSD values (Silva and Azevedo, 2006).

RESULTS AND DISCUSSION

Cyanobacterial biomass harvest

Each of cyanobacterial isolates was harvested and their dry weights were as follows: 3.84 g/l for *Spirulina*, 2.45 g/l for *Oscillatoria* and 2.38 g/l for *Anabaena*.

Evaluation of cyanobacteria as plant growth promoters for sweet pepper

The chemical analysis of soil used for cultivation of sweet pepper (Table 1) revealed that its pH was 7.11. In this regard, Hochmuth (1996) stated that sweet peppers grow well under a wide range of soil pH from 5.5 to 7.5. Also, the results showed its nutrients deficiency.

Table (1): Chemical properties of soil used for cultivation of sweet pepper.

Chemical parameters	pH	E.C. (dSm^{-1})	CO_3	$CaCO_3$	Macro-elements (mg/kg)			Micro-elements (mg/kg)				Cations (meq/l)						Anions (meq/l)
					N	P	K	Zn	Fe	Cu	Mn	HCO_3^-	Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	K^+	Na^+
Value	7.11	1.10	-	-	28.0	6.0	99.4	2.02	7.8	0.68	22.4	1.8	5.0	4.65	2.6	1.6	0.2	7.05

Chemical analysis of plants

Macro and microelements of plants

Data in Table (2) reveal that, at the end of growth season (after 150 days from transplantation) of sweet pepper, the highest contents of macroelements were recorded in controls and in Spirulina-treated plants (1.02%), and 0.89 and 0.74% in mix (overall average of mixes treatments; T3, T4, T20 and T24) and Oscillatoria-treated plants, respectively. On the other hand, the highest contents of microelements were observed in control plants (180 ppm) followed by Spirulina-treated plants (149.66 ppm), while the lowest content was recorded in mix treated plants (132.66 ppm). Silva and Uchida (2000) stated that Fe is essential for plants in the synthesis and maintenance of chlorophyll in plants. They also stated that copper is involved in photosynthesis and may have a role in synthesis and/or stability of chlorophyll and other plant pigments. Zinc has a role in RNA and protein synthesis and is essential component of metabolic enzymes in plants.

Chlorophyll composition of different cyanobacterial treatments

Data in Table (3) revealed that, regardless preparation type, control plants recorded the highest concentrations of chlorophyll a, b and total chlorophyll followed by *Anabaena*-treated plants. This may be related to the effect of gibrilic acid (GA_3) and

benzyladenine (BA) which have role in increasing chlorophyll a concentrations. Majidian *et al.* (2012) reported that the use of the growth regulators GA_3 and BA, increased the rate of chlorophyll in leaves of *Zantedeschia aethiopiea* plant. In this respect, Sardoei (2014) indicated that regulators of BA and GA_3 were effective on photosynthesis pigments. The author also reported that by increasing concentrations of GA_3 and BA, values of chlorophyll a increased.

Table (2): Macro- and micro-elements composition of sweet pepper plant before and after different cyanobacterial treatments (after 150 days from transplantation).

Treatments	N (%)	P (%)	K (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
0 time	1.13	0.80	1.12	112.50	128.8	87.5	47.5
T1	1.20	0.26	1.40	170.00	480.0	42.0	44.0
T2	1.60	0.23	1.30	170.00	380.0	52.0	30.0
T3	1.90	0.28	1.20	100.00	320.0	48.0	36.0
T4	1.80	0.28	0.90	150.00	320.0	44.0	16.0
T5	ND	ND	ND	ND	ND	ND	ND
T6	1.80	0.20	0.95	150.00	380.0	34.0	24.0
T7	1.60	0.22	0.94	140.00	360.0	30.0	38.0
T8	1.90	0.23	1.30	140.00	440.0	26.0	34.0
T9	1.80	0.22	0.87	170.00	360.0	48.0	40.0
T10	1.20	0.17	0.90	170.00	320.0	64.0	26.0
T11	0.90	0.22	0.90	160.00	360.0	36.0	20.0
T12	0.70	0.20	0.80	160.00	280.0	26.0	24.0
T13	1.60	0.22	0.17	170.00	260.0	42.0	20.0
T14	1.20	0.23	0.70	170.00	320.0	36.0	30.0
T15	1.40	0.16	0.80	170.00	340.0	32.0	26.0
T16	ND	ND	ND	ND	ND	ND	ND
T17	ND	ND	ND	ND	ND	ND	ND
T18	ND	ND	ND	ND	ND	ND	ND
T19	1.30	0.30	1.10	200.00	400.0	60.0	26.0
T20	0.70	0.25	0.70	150.00	320.0	28.0	60.0
T21	ND	ND	ND	ND	ND	ND	ND
T22	ND	ND	ND	ND	ND	ND	ND
T23	ND	ND	ND	ND	ND	ND	ND
T24	ND	ND	ND	ND	ND	ND	ND
$LSD_{(0.05)}$	**0.588**	**0.053**	**0.738**	**2.346**	**3.189**	**2.758**	**2.453**

ND: not determined; T1, positive control; T2, negative control; T3, mixed culture suspension; T4, mixed culture (1000 mg dry powder dissolved in 1l water); T5, *Spirulina* culture suspension; T6, *Spirulina* (500 mg dry powder dissolved in 1l water); T7, *Spirulina* (1000 mg dry powder dissolved in 1l water); T8, *Spirulina* (2000 mg dry powder dissolved in 1l water); T9, *Oscillatoria* culture suspension; T10, *Oscillatoria* (500 mg dry powder dissolved in 1l water); T11, *Oscillatoria* (1000 mg dry powder dissolved in 1l water); T12, *Oscillatoria* (2000 mg dry powder dissolved in 1l water); T13, *Anabaena* culture suspension; T14, *Anabaena* (500 mg dry powder dissolved in 1l water); T15, *Anabaena* (1000 mg dry powder dissolved in 1l water); T16, *Anabaena* (2000 mg dry powder dissolved in 1 l water); T17, *Spirulina* culture filtrate; T18, *Oscillatoria* culture filtrate; T19, *Anabaena* filtrate;T20, Mixed filtrate; T21, *Spirulina* (1000 mg dry powder dissolved in 1 l *Spirulina* filtrate); T22, *Oscillatoria* (1000 mg dry powder dissolved in 1 l *Oscillatoria* filtrate); T23, *Anabaena* (1000 mg dry powder dissolved in 1 l Anabaena filtrate); T24, Mixed dry powder (1000 mg dry powder, dissolved in 1 l mixed filtrate, 1:1:1).

Table (3): Effect of various cyanobacterial treatments on chlorophyll concentration of sweet pepper (mg/l).

Treatments	Time (days)	Chl a	Chl b	Total chlorophyll
0 time		4.18	0.19	5.95
T1	50	5.54	0.49	16.07
	150	17.13	ND	41.77
T2	50	4.55	ND	11.62
	150	17.07	0.63	37.03
T3	50	3.13	0.18	7.28
	150	14.58	0.80	30.85
T4	50	5.76	0.36	12.04
	150	14.34	0.62	30.86
T5	50	8.34	0.04	18.89
	150	ND	ND	ND
T6	50	7.29	ND	17.06
	150	12.22	0.68	25.81
T7	50	8.68	0.50	18.30
	150	8.69	0.50	18.29
T8	50	2.56	ND	6.71
	150	14.26	0.59	30.75
T9	50	6.72	0.44	14.00
	150	12.10	0.73	25.40
T10	50	5.63	0.29	11.96
	150	14.43	0.76	30.89
T11	50	4.91	ND	12.23
	150	ND	ND	ND
T12	50	7.08	ND	16.88
	150	7.9	0.65	16.05
T13	50	12.63	0.46	27.43
	150	11.82	1.67	21.90
T14	50	8.55	0.46	18.12
	150	6.75	0.10	27.37
T15	50	7.50	0.20	16.51
	150	ND	ND	ND
T16	50	3.80	0.26	7.86
	150	ND	ND	ND
T17	50	6.36	0.11	14.18
	150	ND	ND	ND

T18	50	7.76	0.20	17.09
	150	ND	ND	ND
T19	50	11.21	0.62	23.71
	150	ND	ND	ND
T20	50	6.30	0.07	14.18
	150	1.43	0.76	30.44
T21	50	9.14	0.09	20.59
	150	ND	ND	ND
T22	50	4.24	ND	10.30
	150	ND	ND	ND
T23	50	7.30	0.21	16.03
	150	12.63	0.84	27.37
T24	50	5.67	0.31	12.01
	150	ND	ND	ND
$LSD_{(0.01)}$		**2.10**	**0.27**	**6.40**

ND: not determined; T1, positive control; T2, negative control; T3, mixed culture suspension; T4, mixed culture (1000 mg dry powder dissolved in 1l water); T5, *Spirulina* culture suspension; T6, *Spirulina* (500 mg dry powder dissolved in 1l water); T7, *Spirulina* (1000 mg dry powder dissolved in 1l water); T8, *Spirulina* (2000 mg dry powder dissolved in 1l water); T9, *Oscillatoria* culture suspension; T10, *Oscillatoria* (500 mg dry powder dissolved in 1l water); T11, *Oscillatoria* (1000 mg dry powder dissolved in 1l water); T12, *Oscillatoria* (2000 mg dry powder dissolved in 1l water); T13, *Anabaena* culture suspension; T14, *Anabaena* (500 mg dry powder dissolved in 1l water); T15, *Anabaena* (1000 mg dry powder dissolved in 1l water); T16, *Anabaena* (2000 mg dry powder dissolved in 1 l water); T17, *Spirulina* culture filtrate; T18, *Oscillatoria* culture filtrate; T19, *Anabaena* filtrate;T20, Mixed filtrate; T21, *Spirulina* (1000 mg dry powder dissolved in 1 l *Spirulina* filtrate); T22, *Oscillatoria* (1000 mg dry powder dissolved in 1 l *Oscillatoria* filtrate); T23, *Anabaena* (1000 mg dry powder dissolved in 1 l Anabaena filtrate); T24, Mixed dry powder (1000 mg dry powder, dissolved in 1 l mixed filtrate, 1:1:1).

Morphological analysis and growth parameters of plants

Root morphological parameters

Regardless type of preparation, all treatments showed less enhanced root morphological parameters in comparison with controls. On the other hand, *Anabaena* recorded increase in root length over the other cyanobacterial treatments, while *Oscillatoria* treatment increased root dry weight over the other treatments. Regardless time of observation, data in Figure (1) indicated that the most enhanced root growth was in plants treated with *Spirulina* treatment (T6) and positive control (T1). In this regard, Figure (1a) shows that the maximum root length (11.2 cm) was observed in plants treated with *Spirulina* treatment (T6), while the minimum root length (2.7 cm) was recorded in plants treated with *Spirulina* treatment (T21). Figure (1b) indicates that plants treated with *Spirulina* treatment (T21) recorded the lowest root fresh weight (0.23 g), while plants treated with mixed culture treatment (T4) recorded the highest root fresh and dry weights (1.15 and 0.55 g, respectively). The improvement in root growth in T4 and T6 treatments may be due to the accumulation of abscisic acid and indole acetic acid in *Spirulina* which are known to stimulate root growth that needed to increase their ability to extract water from the soil. The reason may also be due to the accumulation of carbohydrates in T6 which are known to enhance root growth as mentioned by Koch (1996). Carbohydrates may regulate the synthesis of specific proteins (Baysdorfer and Vander Woude, 1988 and Williams *et al.,* 1992) including enzymes required for their own metabolism such as invertase and sucrose synthase (Gayler and Glasziou, 1972 and Claussen *et al.,* 1985) and metabolism of N such as nitrate reductase (Sahulka and Lisá, 1980). They may also be involved in the control of a variety of developmental processes including the initiation of lateral roots (Trewavas, 1983).

Stem morphological parameters

Results indicated that regardless of type of preparation, control plants recorded the best stem morphological parameters (Figure 2). On the other hand, regardless of time of determination, plants treated with mixed culture (T4) recorded the most enhanced stem parameters compared to control, while plants treated with *Spirulina* culture suspension (T5) recorded the lowest ones. Figure (2b) revealed that plants treated with *Spirulina* treatment (T6) recorded the highest stem fresh weight (1.79 g), while treatment of *Spirulina* culture suspension (T5) and treatment of *Spirulina* (T21) scored the lowest stem fresh weights (0.34 and 0.29 g, respectively).

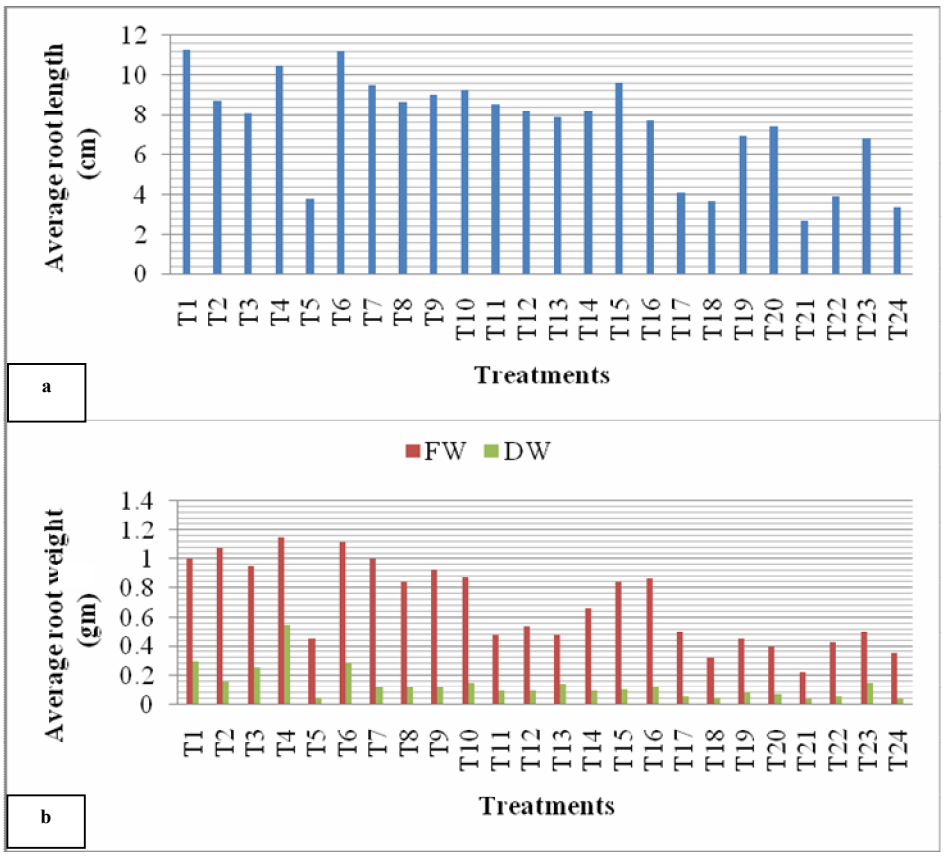

Fig.(1): Sweet pepper roots morphological and growth parameters regardless observation time. (a)Averages of root lengths (cm). (b)Average of root fresh and dry weights (g).

T1, positive control; T2, negative control; T3, mixed culture suspension; T4, mixed culture (1000 mg dry powder dissolved in 1l water); T5, Spirulina culture suspension; T6, Spirulina (500 mg dry powder dissolved in 1l water); T7, Spirulina (1000 mg dry powder dissolved in 1l water); T8, Spirulina (2000 mg dry powder dissolved in 1l water); T9, Oscillatoria culture suspension; T10, Oscillatoria (500 mg dry powder dissolved in 1l water); T11, Oscillatoria (1000 mg dry powder dissolved in 1l water); T12, Oscillatoria (2000 mg dry powder dissolved in 1l water); T13, Anabaena culture suspension; T14, Anabaena (500 mg dry powder dissolved in 1l water); T15, Anabaena (1000 mg dry powder dissolved in 1l water); T16, Anabaena (2000 mg dry powder dissolved in 1 l water); T17, Spirulina culture filtrate; T18, Oscillatoria culture filtrate; T19, Anabaena filtrate;T20, Mixed filtrate; T21, Spirulina (1000 mg dry powder dissolved in 1 l Spirulina filtrate); T22, Oscillatoria (1000 mg dry powder dissolved in 1 l Oscillatoria filtrate); T23, Anabaena (1000 mg dry powder dissolved in 1 l Anabaena filtrate); T24, Mixed dry powder (1000 mg dry powder, dissolved in 1 l mixed filtrate, 1:1:1).

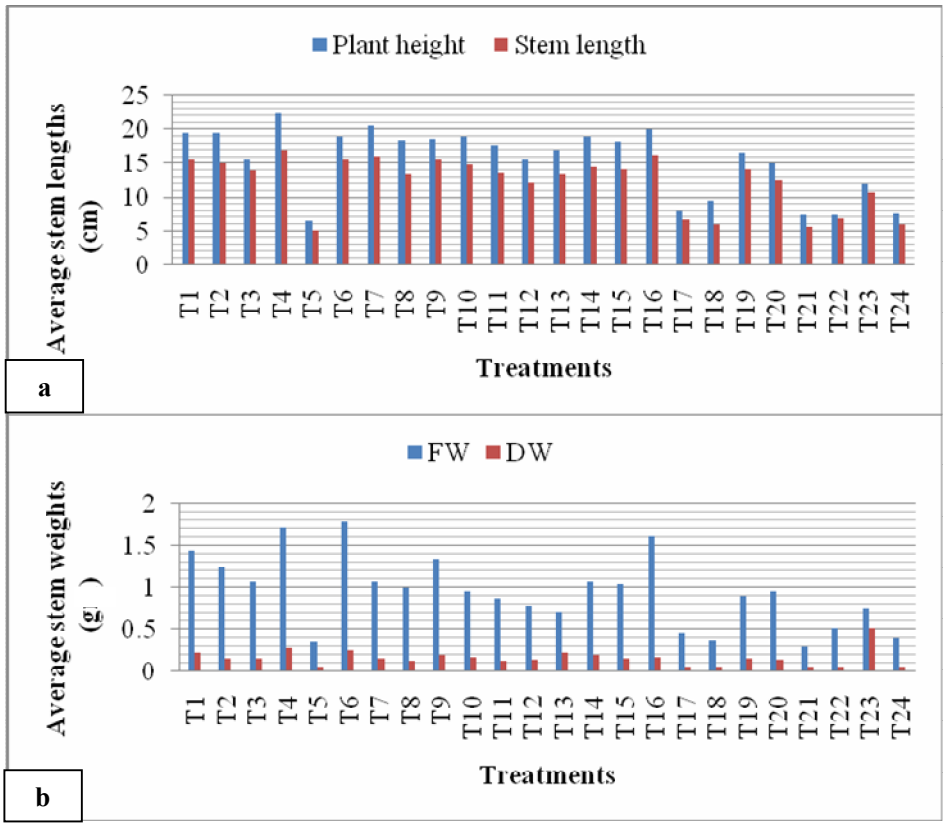

Fig.(2): Sweet pepper stem morphological and growth parameters regardless observation time. (a)Averages of plant heights and stem lengths (cm). (b) Average of stem fresh and dry weights (g).

T1, positive control; T2, negative control; T3, mixed culture suspension; T4, mixed culture (1000 mg dry powder dissolved in 1l water); T5, Spirulina culture suspension; T6, Spirulina (500 mg dry powder dissolved in 1l water); T7, Spirulina (1000 mg dry powder dissolved in 1l water); T8, Spirulina (2000 mg dry powder dissolved in 1l water); T9, Oscillatoria culture suspension; T10, Oscillatoria (500 mg dry powder dissolved in 1l water); T11, Oscillatoria (1000 mg dry powder dissolved in 1l water); T12, Oscillatoria (2000 mg dry powder dissolved in 1l water); T13, Anabaena culture suspension; T14, Anabaena (500 mg dry powder dissolved in 1l water); T15, Anabaena (1000 mg dry powder dissolved in 1l water); T16, Anabaena (2000 mg dry powder dissolved in 1 l water); T17, Spirulina culture filtrate; T18, Oscillatoria culture filtrate; T19, Anabaena filtrate;T20, Mixed filtrate; T21, Spirulina (1000 mg dry powder dissolved in 1 l Spirulina filtrate); T22, Oscillatoria (1000 mg dry powder dissolved in 1 l Oscillatoria filtrate); T23, Anabaena (1000 mg dry powder dissolved in 1 l Anabaena filtrate); T24, Mixed dry powder (1000 mg dry powder, dissolved in 1 l mixed filtrate, 1:1:1).

On the other hand, plants treated with mixed culture (T4) recorded the maximum increase in plant height (22.35 cm) and stem length (17.05 cm) (Fig.2a). The combinations of T4 may be the reason behind the improvement of stem parameters as this combination may provide different concentrations of the growth hormones required for plant growth.

They also benefit plants from their composition of different amino acids with different concentrations. They contain diverse levels of phenylalanine, glutamic, aspartic, arginine and lysine which have diverse roles in enhancing stem growth. IAA plays a key role in both root and shoot development (Cornejo *et al.,* 2009 and Shahab *et al.,* 2009).

Leaf morphological parameters

Regardless type of preparation, all treatments modified leaf morphological parameters compared to plants at the beginning of the experiment. Data revealed that control plants recorded more enhanced leaf parameters over other treatments (Fig. 3). *Anabaena* treatments showed increased number of leaves per plant over other treatments and controls. Increased leaves fresh weight was detected in control plants, while decreased fresh weight was recorded in *Anabaena*-treated plants. Mix treated plants also recorded increases in leaf length over controls and the other treatments, while the lowest dry weight was recorded in *Spirulina* treated plants. Results revealed that regardless of measurement time, the maximum leaf and blade lengths (Fig. 3a) were detected in plants treated with *Spirulina* treatment (T6; 6.55 and 4.6 cm, respectively) followed by plants treated with *Oscillatoria* (T12l; 6.4 and 4.55, respectively), while the minimum leaf length (3.3 cm) was scored in plants treated with *Anabaena* (T16).

Plants treated with *Spirulina* treatment (T6) recorded the maximum leaf fresh weight (1.62 g) but plants treated with mixed culture (T4) recorded the maximum leaf dry weight (0.46 g) (Fig. 3b), while the minimum leaf fresh (0.09 g) and dry weights (0.05 g) were observed in plants treated with *Spirulina* (T21). Table (4) showed that T6 and T10 revealed the biggest leaf areas after 50 and 150 days of transplantation, respectively, over other treatments. Generally, the most improved leaf morphological parameters were displayed by *Spirulina* (T6). This is most likely due to higher concentrations of IAA in *Spirulina* cultures which enlarged leaves and increased photothynthetic activities in plants (Awan *et al.,* 1999). In this respect, Naeem *et al.* (2004) reported that IAA increased the area of leaves and showed healthy lush green leaves with increases in the number of compound leaves in lentil.

Table (4): Sweet pepper leaves morphological parameters affected by cyanobacterial treatments after 50.and 150 days of transplantation.

Treatments	Time (days)	leaf area (cm^2)	No. of leaves/plant	Treatments	Time (days)	leaf area (cm^2)	No. of leaves/plant
0 time		**8.72 b**	**5**	**T13**	**50**	**8.39**	**7**
T1	50	9.70	6		150	ND	13
	150	14.59	15	**T14**	50	10.01	8
T2	50	9.22	6		150	7.80	17
	150	12.58	12	**T15**	50	9.63	7
T3	50	8.97	6		150	12.93	19
	150	13.86	12	**T16**	50	5.61	8
T4	50	10.50	6		150	ND	13
	150	8.85	19	**T17**	50	11.31	6
T5	50	5.26	6		150	ND	ND
	150	ND	ND	**T18**	50	6.05	8
T6	50	9.74	8		150	ND	ND
	150	14.68	14	**T19**	50	8.76	7
T7	50	8.38	6		150	ND	12
	150	8.43	7	**T20**	50	6.70	8
T8	50	9.28	6		150	10.16	17
	150	8.48	7	**T21**	50	7.51	6
T9	50	6.97	6		150	ND	ND
	150	15.59	11	**T22**	50	6.25	6
T10	50	10.77	6		150	ND	ND
	150	13.71	12	**T23**	50	5.47	5
T11	50	7.15	6		150	10.76	14
	150	9.63	12	**T24**	50	7.63	7
T12	50	9.74	7		150	ND	ND
	150	12.46	12				
LSD(0.01)		**4.21**	**3.36**			**4.21**	**3.36**

ND: not determined; *means in the same column with different superscripts are significantly different; T1, positive control; T2, negative control; T3, mixed culture suspension; T4, mixed culture (1000 mg dry powder dissolved in 1l water); T5, *Spirulina* culture suspension; T6, *Spirulina* (500 mg dry powder dissolved in 1l water); T7, *Spirulina* (1000 mg dry powder dissolved in 1l water); T8, *Spirulina* (2000 mg dry powder dissolved in 1l water); T9, *Oscillatoria* culture suspension; T10, *Oscillatoria* (500 mg dry powder dissolved in 1l water); T11, *Oscillatoria* (1000 mg dry powder dissolved in 1l water); T12, *Oscillatoria* (2000 mg dry powder dissolved in 1l water); T13, *Anabaena* culture suspension; T14, *Anabaena* (500 mg dry powder dissolved in 1l water); T15, *Anabaena* (1000 mg dry powder dissolved in 1l water); T16, *Anabaena* (2000 mg dry powder dissolved in 1 l water); T17, *Spirulina* culture filtrate; T18, *Oscillatoria* culture filtrate; T19, *Anabaena* filtrate;T20, Mixed filtrate; T21, *Spirulina* (1000 mg dry powder dissolved in 1 l *Spirulina* filtrate); T22, *Oscillatoria* (1000 mg dry powder dissolved in 1 l *Oscillatoria* filtrate); T23, *Anabaena* (1000 mg dry powder dissolved in 1 l Anabaena filtrate); T24, Mixed dry powder (1000 mg dry powder, dissolved in 1 l mixed filtrate, 1:1:1).

Morphological analysis revealed that *Spirulina* (T6) affected leaf and root morphological parameters in different extents in comparison with positive (T1) and negative (T2) controls. This may be due to the action of 6-benzylaminopurine (6-BA) and indole-3-acetic acid (IAA) that exist in *Spirulina* biomass with higher concentrations. It is reported that 6-benzylaminopurines are known to elicit plant growth and shoot development responses, setting blossoms and stimulating cell division, while IAA induces cell elongation and cell division with all subsequent results for plant growth and development. On a larger scale, IAA serves as signaling molecule necessary for development of plant organs and coordination of growth in both root and shoot development (Prusty *et al.,* 2004).

Flowering

Observations indicated that flowering started only in T1, T4, T6 and T15 after 110 days of transplantation (Fig.4). This may be due to phytohormones such as 6-BA which stimulate flowering in cyanobacteria-treated plants which has the same effect of NPK positive control. In this regard, Bonhomme *et al*. (2000) stated that cytokinins are considered as a critical physiological signal in triggering the process of flowering. The levels of cytokinins were also reported to increase in the apical meristem during floral transition and flower development in *Arabidopsis thaliana* L. (Corbesier *et al*., 2003).

Fruiting

After 130 days of transplantation, sweet pepper fruiting (Fig. 5) started in plants treated with NPK chemical fertilizer, water only, mixed culture (T4), *Spirulina* (T6), *Spirulina* (T7), *Oscillatoria* culture suspension (T9), *Anabaena* culture suspension (T13), *Anabaena* (T14) and mixed filtrate (T20). The early fruiting in plants treated with *Oscillatoria* culture suspension (T9) and plants treated with mixed filtrate (T20) may be due to higher concentrations of gibberellic acid (GA_3) in these treatments. GA_3 was effectively used to increase fruit set. Gibberellic acid (GA_3) increased the total yield in greenhouse tomato crops as a result of increased fruit set and accelerate the growth of fruit (Riley, 1987). Gibberellin-like plant hormones were identified in different families of flowering plants (Phinney *et al*., 1957), leading to the assumption that these plant hormones are also involved in the fruit developmental programme. Early fruiting in plants treated with mixed culture (T4), *Spirulina* treatment (T6)، *Spirulina* (T7) and mixed filtrate (T20) may be due to higher concentrations of abscisic acid. Previous reports suggested that the phytohormone abscisic acid (ABA) may be associated with the regulation of fruit ripening (Giovannoni, 2001; Rodrigo *et al*., 2003 and Zhang *et al.,* 2009).

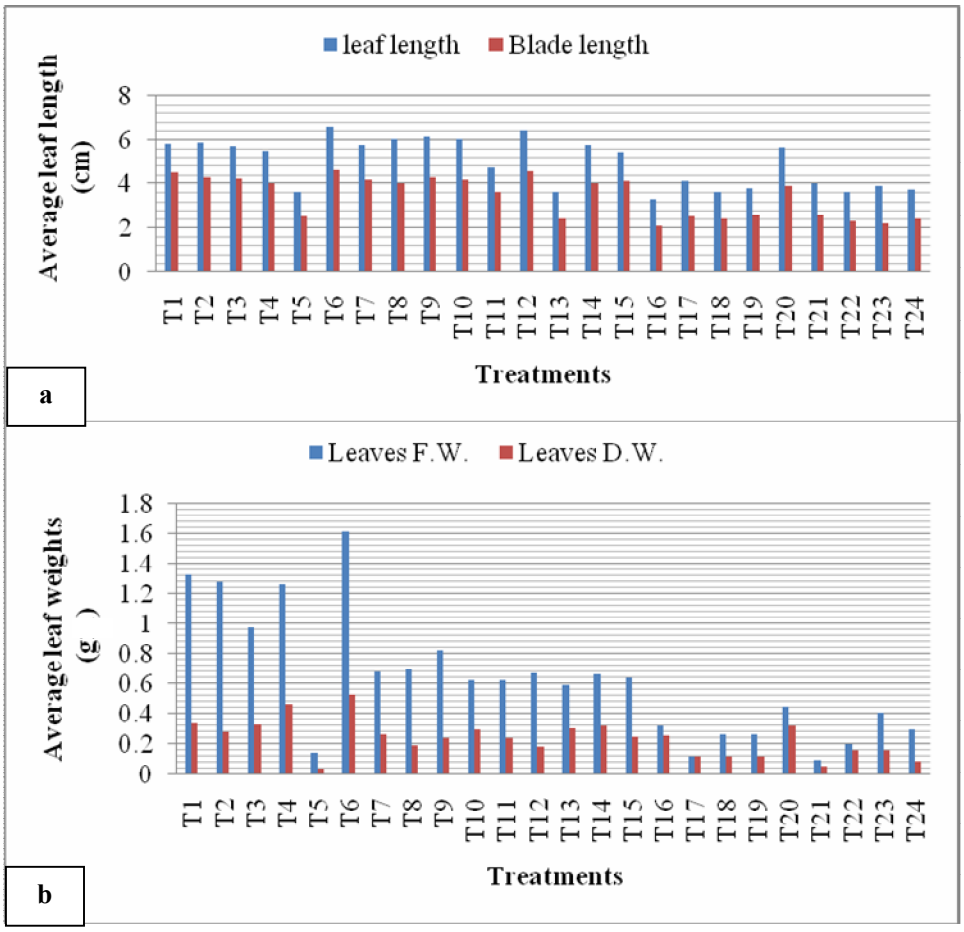

Fig.(3):Sweet pepper leaves morphological and growth parameters regardless observation time. A)Average leaves and blades lengths (cm). b)Average leaves fresh and dry weights (g).

T1, positive control; T2, negative control; T3, mixed culture suspension; T4, mixed culture (1000 mg dry powder dissolved in 1l water); T5, *Spirulina* culture suspension; T6, *Spirulina* (500 mg dry powder dissolved in 1l water); T7, *Spirulina* (1000 mg dry powder dissolved in 1l water); T8, *Spirulina* (2000 mg dry powder dissolved in 1l water); T9, *Oscillatoria* culture suspension; T10, *Oscillatoria* (500 mg dry powder dissolved in 1l water); T11, *Oscillatoria* (1000 mg dry powder dissolved in 1l water); T12, *Oscillatoria* (2000 mg dry powder dissolved in 1l water); T13, *Anabaena* culture suspension; T14, *Anabaena* (500 mg dry powder dissolved in 1l water); T15, *Anabaena* (1000 mg dry powder dissolved in 1l water); T16, *Anabaena* (2000 mg dry powder dissolved in 1 l water); T17, *Spirulina* culture filtrate; T18, *Oscillatoria* culture filtrate; T19, *Anabaena* filtrate;T20, Mixed filtrate; T21, *Spirulina* (1000 mg dry powder dissolved in 1 l *Spirulina* filtrate); T22, *Oscillatoria* (1000 mg dry powder dissolved in 1 l *Oscillatoria* filtrate); T23, *Anabaena* (1000 mg dry powder dissolved in 1 l Anabaena filtrate); T24, Mixed dry powder (1000 mg dry powder, dissolved in 1 l mixed filtrate, 1:1:1).

Fig.(4): Flowering of sweet pepper plants after 110 days of transplantation. a)Water, b) NPK, c) T4, d) T6, e) T7, f) T9.

Plants treated with mixed culture (T4), *Spirulina* (T6), *Anabaena* culture suspension (T13) and mixed filtrate (T20) gave fruits with marketable sizes after 150 days of transplantation over other treatments. This may be due to different concentrations of phytohormones present in these treatments which stimulate fruit growth. In this regard, Mariotti *et al.* (2011) stated that fruit set has traditionally been attributed to the action of three hormones, auxin and/or giberellin, and/or cytokinin. Application of any of these hormones alone can trigger fruit development to a certain extent and, in many plant species, application in combination will induce normal fruit growth indicating that interplay between these hormones is necessary for fruit set and growth (Vivian-Smith and Koltunow, 1999). Auxins play an important role during the growth phase by influencing cell enlargement together with gibberellins (Csukasi *et al.,* 2011). Fruits of these treatments were collected, freshly weighed (Fig. 6), dried and subjected to protein analysis (Fig. 7). The protein analysis of fruits revealed that protein percentages in fruits ranged from 23.9% in T4 to 16.2% in T20. Kulkarni and Aradhya (2005) stated that the increase in the total protein

content in pomegranate arils fruits might be due to an acceleration of ripening that initiates the array of enzyme activities.

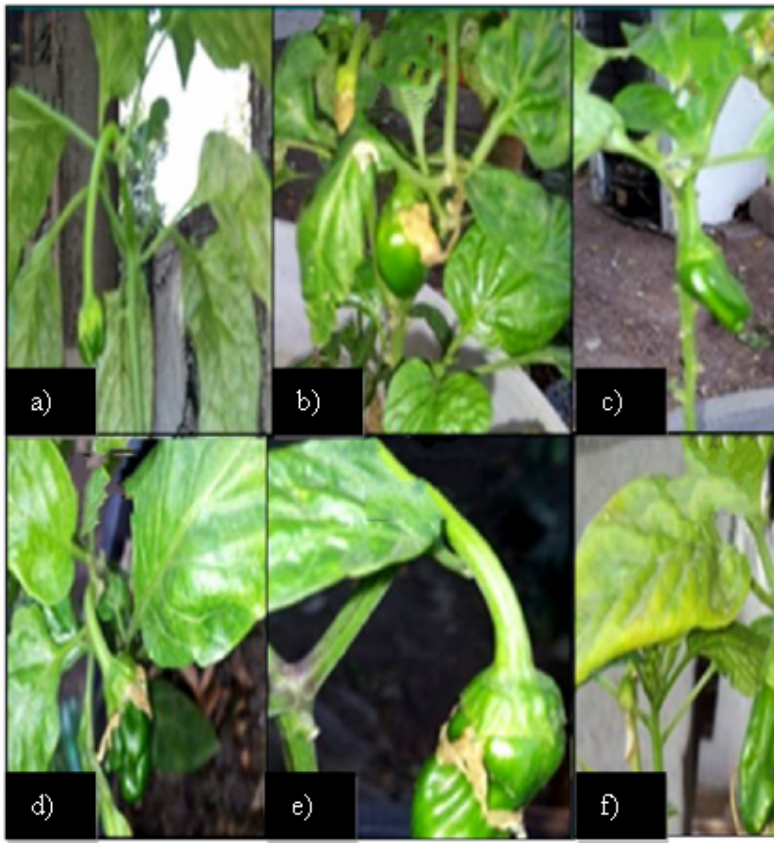

Fig. (5): Fruition of sweet pepper plants after 130 days of transplantation. a) Water, b) NPK, c) T4, d) T6, e) T7, f) T9.

Anatomical studies

In relation to aforementioned features of *Capsicum annuum* cv. Omega plants, for diverse understudied treatments, lamina inner structure has been detected. Data in Figures (8) and Table (5) for measured histological features of lamina, it was found that, for lamina thickness, that negative control (water treatment), scoring (192µm), showed elevation by 45.46% than the positive one (T1), where the narrowest, over all treatments, lamina (132 µm) exhibited in the latter. *Spirulina* (T6) showed the highest increment in lamina thickness than both controls (43.75 and 109.1% over negative and positive controls, respectively). The nearest treatment, in anatomical measurements, to controls; *Oscillatoria* (T10), differs than negative control with small reduction by 6.7%, where pass positive one by 36.36%

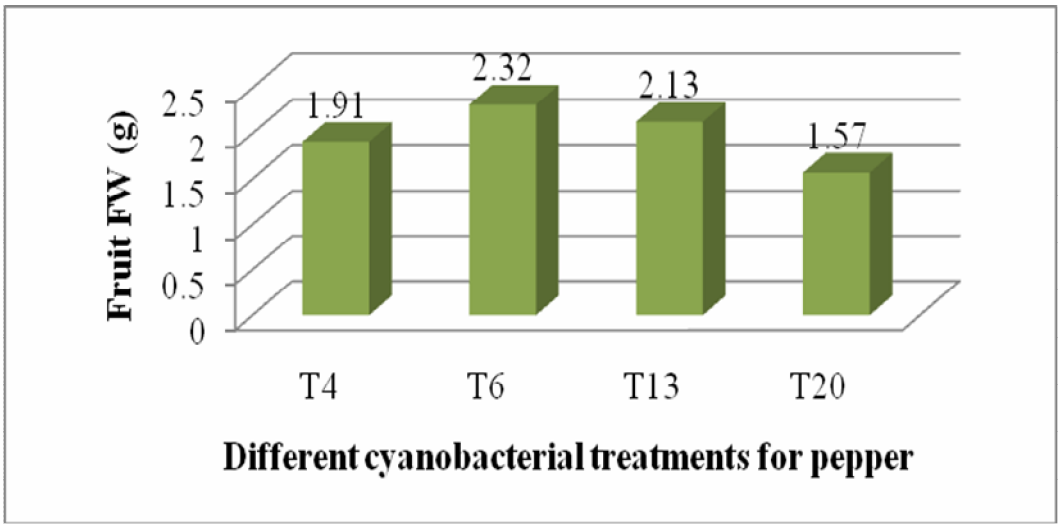

Fig. (6): Fresh weights of sweet pepper fruits treated with tested species of cyanobacteria.

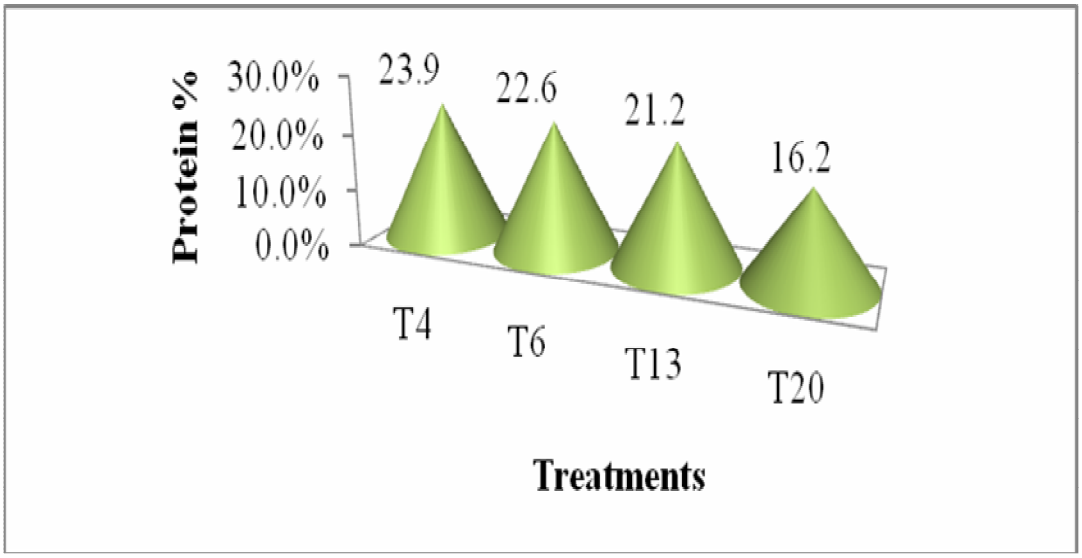

Fig. (7): Protein percentage of sweet pepper fruits after treatment with tested species of cyanobacteria.

In essence, lower epidermis has no share in former fluctuation, since it was found to be the same (12 µm) in all treatments. But upper epidermis thickness has the crucial role in small elevation of negative control than *Oscillatoria* (T10), since both have the same measurements of mesophyll contents; palisade and spongy tissues.

Highest increment of *Spirulina* (T6) than both controls (T1 and T2) is related to obvious elevation in spongy tissue (by 62.5 and 160% over negative and positive controls, respectively), and also in palisade tissue over positive control by 60%. It is worthy to mention that lamina get thicker, as the difference between palisade and spongy tissues thickness get bigger. In addition, crystals number and size increased in the same previous manner, since they increased by increasing lamina thickness. As to vascular bundle (Figure 8 and Table 5), outer (prominent) phloem showed the same thickness (36 µm) in all studied treatments (including both controls), whereas xylem thickness elevates by, at minimum, two folds the phloem thickness to nearly three folds of it.

These anatomical measurements which have been taken after 150 days from transplanting are in association, with average leaf areas and leaves average fresh weight. The latter feature is correspondence to lamina thickness, where *Spirulina* treatment showed the biggest leaves average fresh weight and then, in descending order, came negative control (T2), positive control (T1) and *Oscillatoria* treatment (T10). Although control treatments have the biggest average leaf area, but this excellence has been coincided with leaves average fresh weight, resulting in shrinked lamina in thickness than *Spirulina* (T6). The latter treatment, showed an opposite trend than the former, by exhibiting decrement in average leaf area which has been interacted with elevation of leaves average fresh weight, resulting in thicker lamina than controls.

Table (5): Measurements (µm) of different lamina tissues of 4 studied Capsicum annuum cv. Omega treated with cyanobacterial isolates.

Characters \ Treatments	Negative control (water)	Positive control (NPK)	*Spirulina* (conc. 500 ppm)	*Oscillatoria* (conc. 500 ppm)
Upper epidermis thickness	12	24	24	12
Palisade tissue thickness	60	48	84	60
Spongy tissue thickness	96	60	156	96
Lower epidermis thickness	12	12	12	12
Lamina thickness	192	132	276	180
Xylem thickness	96	84	96	72
Phloem thickness	36	36	36	36
Remarks **Vascular bundle**	bicollateral			
Crystals	frequent big	Few small	frequent big	

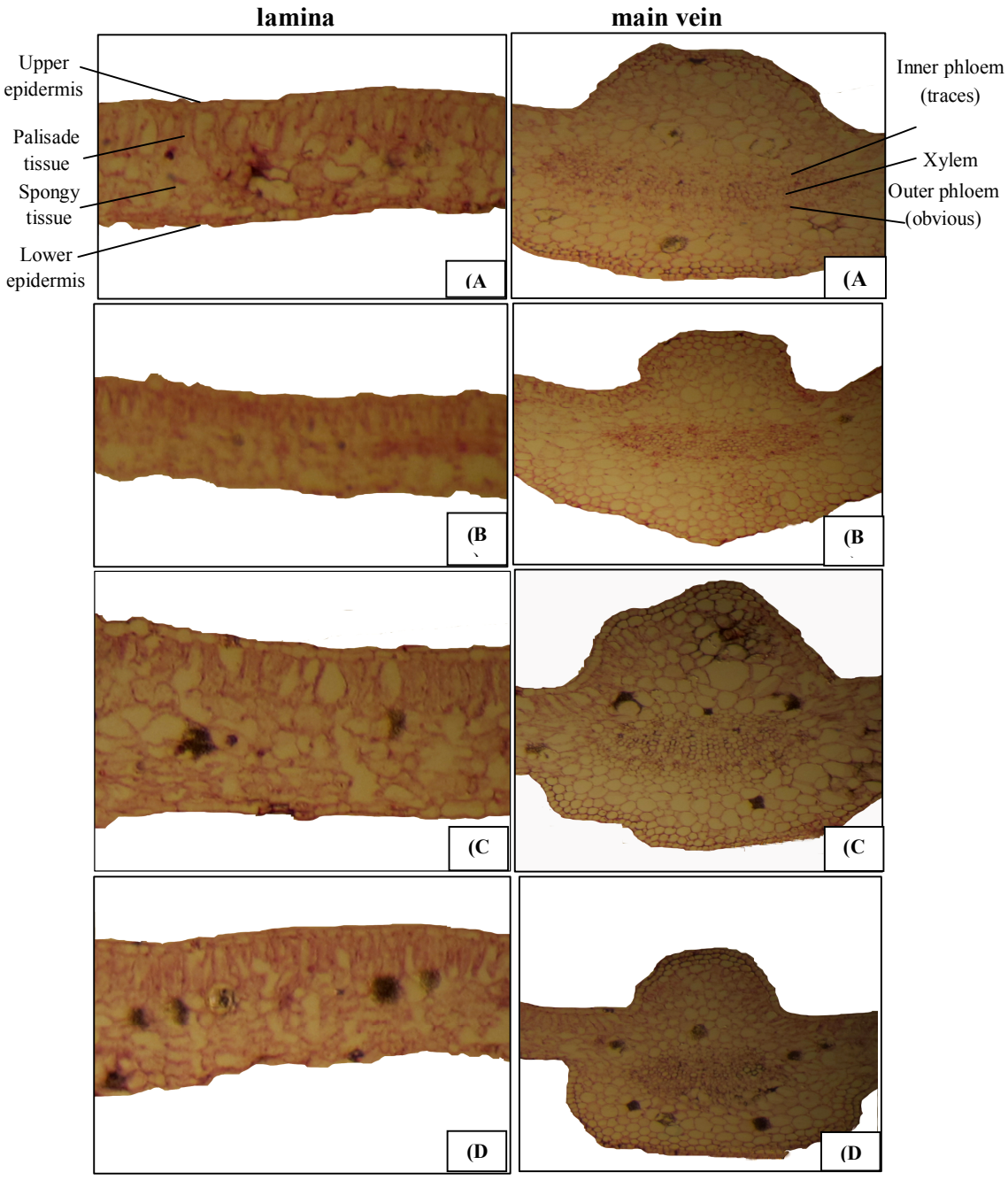

Fig. (8): Transverse sections of the lamina (X=145) and main vein (X=139) of 4 studied Capsicum annuum var. annuum treatments. A) negative control (water), B) positive control (NPK), C) Spirulina (T6), D) Oscillatoria (T10).

Decline in leaves average fresh weight for *Oscillatoria* treatment severely demolished any chance for more lamina thickening. So, it biased toward narrower lamina. The aforementioned structural anatomical features of lamina are in contrast with those found by Metcalfe and Chalk (1983), Schuerger *et al.* (1997), Diane *et al.* (2003), Dias *et al.* (2013), Wahua *et al.* (2013) and Wahua *et al.* (2014).

CONCLUSION

Cyanobacterial treatments, especially by *Spirulina* isolates, succeeded in promoting sweet pepper plant growth (as estimated by chemical, morphological, flowering, fruiting and anatomical parameters) compared with chemical fertilizers. Thus the application of cyanobacteria increase the capability to reduce the use of dangerous chemicals that cause many environmental and health problems.

REFERENCES

Abd El Baky, H. H.; Hussein, M.M. and El-Baroty G. S. (2014). Induces of antioxidant compounds and salt tolerance in wheat plant, irrigated with seawater as response to application of microalgae spray. Am. J. Agric. Biol. Sci., 9 (2): 127-137.

AOAC - Association of Official Analytical Chemists. (2000). Official Methods of Analysis of the Association of Official Analytical Chemists: method 984.13 (17th ed.). Washington, USA.

Arun, N.; Gupta, S. and Singh, D.P., (2012). Antimicrobial and antioxidant properties of commonly found microalgae *Spirulina platensis*, *Nostoc muscorum* and *Chlorella pyrenoidosa* against some pathogenic bacteria and fungi. Int. J. Pharmacy. Sci. Res., 3(12) ISSN: 0975- 8232.

Awan, I.U.; Baloch, M.S.; Sadozai, N.S. and Sulemani, M.Z. (1999). Stimulatory effect of GA3 and IAA on ripening process, kernel development and quality of rice. Pak. J. Biol. Sci., 2(2): 410-412.

Baysdorfer, C. and Van Der Woude, W.J. (1988). Carbohydrate responsive proteins in the roots of *Pennisetum americanum*. Plant Physiol. 87:566–70.

Bonhomme, F.; Kurz, B.; Melzer, S.; Bernier, G. and Jacqmard, A. (2000). Cytokinin and gibberellin activate SaMADS A, a gene apparently involved in regulation of the floral transition in *Sinapis alba*. The Plant J. 24: 103– 111.

Claussen, W.; Loveys, B.R. and Hawker, J.S. (1985). Comparative investigations on the distribution of sucrose synthase activity and invertase activity within growing, mature and old leaves of some C3 and C4 plant species. Physiol. Plant, 65: 275-280.

Corbesier, L.; Prinsen, E.; Jacqmard, A.; Lejeune, P.; Van Onckelen, H.; Pe´rilleux, C. and Bernier, G. (2003). Cytokinin levels in leaves, leaf exudate and shoot apical meristem of *Arabidopsis thaliana* during floral transition. J. Exp. Bot., 54: 2511–2517.

Cornejo, H.A.C.; Macías-Rodríguez, L.; Cortés-Penagos, C.; and López-Bucio, J. (2009). *Trichoderma virens*, a plant beneficial fungus, enhances biomass production and promotes lateral root growth through an auxindependent mechanism in *Arabidopsis*. Plant Physiol., 149(3): 1579–1592.

Csukasi, F.; Osorio, S.; Gutierrez, J. R.; Kitamura, J.; Giavalisco, P.; Nakajima M., *et al.* (2011). Gibberellin biosynthesis and signalling during development of the strawberry receptacle. *New Phytol.* 191: 376–390.

Deepali, and Gangwar, K.K. (2010). Biofertilzers: An eco-friendly way to replace

chemical fertilzers. Http:/www.krishisewa.com/cms/articles/2010 /biofert.html.

Diane, N., J. Claudia and Hilger, H. H. (2003). Leaf anatomy and foliar trichomes in *Heliotropiaceae* and their systematic relevance. Flora Morphology, Distribution, Functional Ecology of Plants. 198(6): 468–485.

Dias, G.B.; Gomes, V.M.; Moraes, T.M.S.; Zottich, U.P.; Rabelo, G.R.; Carvalho, A.O.; Moulin, M.; Gonçalves, L.S.A.; Rodrigues, R. and Da Cunha, M. (2013). Characterization of *Capsicum* species using anatomical and molecular data. Genet. Mol. Res., 12 (4): 6488-6501.

El-Tayeb, M.A. (2005). Response of barley grains to the interactive effect of salinity and salicylic acid. Plant Growth Regulat., 45: 215-224.

Gayler, K.R. and Glaziou K.T. (1972). Physiological functions of acid and neutral invertases in growth and sugar storage in sugarcane. Physiol. Plantarum, 27: 25-31.

Giovannoni J. (2001). Molecular biology of fruit maturation and ripening. Annu. Rev. Plant Physiol. Plant Mol. Biol., 52: 725–749.

Hochmuth, G. (1996). Fertilization of Pepper in Florida. Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, 10 p.

Holden, M. (1965). Chlorophylls. p. 461-488. In T. W. Goodwin (ed.) Chemistry and Biochemistry of Plant Pigments. Academic Press, N.Y.

Jackson, M.L. (1973). Soil Chemical Analysis. Pentis Hal of India, Pvt. Ltd., New Delhi.

Koch, K. (1996). Carbohydrate modulated gene expression in plants. Ann. Rev. Plant Physiol., 47: 509-540.

Kulkarni, A.P. and Aradhya, S.M. (2005). Chemicalchanges and antioxidant activity in pomegranate arils during fruit development. Food Chem. 93: 319–324.

Kumar, D. and Kumar, R.V. (2014). Efficacy of bio-foliar spray on growth and biochemical parameters of different mulberry varieties. OnLine J. Biol. Sci., 14 (1): 64-69.

Majidian, N., Nadari, A and Majidian, M. (2012). The effect of four levels of GA_3 and BA on the quantitative and qualitative characteristics of *Zantedeschia aethiopica* cv. *Childsiana* pot plant. 25(4), 361-368.

Mariotti, L.; Picciarelli, P.; Lombardi, L. and Ceccarelli, N. (2011). Fruit-set and early fruit growth in tomato are associated with increases in indoleacetic acid, cytokinin, and bioactive gibberellin contents. J. Plant Growth Regul., 30: 405–415.

Metcalfe, C.R. and Chalk, L. (1983). Anatomy of the dicotyledons. Clarendon Press, 333 pp.

Naeem, M.; Bhatti, I.; Ahmad, R.H. and Ashraf, M.Y. (2004). Effect of some growth hormones (GA3, IAA and Kinetin) on the morphology and early or delayed initiation of bud of lentil (*lens culinaris* medik). Pak. J. Bot., 36(4): 801-809.

Nassar, M.A. and El-Sahhar, K.F. (1998). Plant Microtechnique. Academic Bookshop, Egypt. 224 p. (In Arabic).

Palaniappan, P.; Malliga, P.; Manian, S.; Sivaramakrishn, S.; Madhaiyan, M. and Sa, T. (2010). Plant growth promontory effect on coe pea (*Vigna unguiculata L.*) using coir pith aqueous extract formulation of cyanobacterium *Phormidium*. Am-Euras. J. Agric. Environ. Sci., 8:178-184.

Pandey, J.P.; Tiwari, A. and Mishra, R.M. (2010). Evaluation of biomass production of *Spirulina maxima* on different reported media. J. Algal Biomass Utln., 1 (3): 70-81.

Phinney, B.O.; West, C.A.; Ritzel, M. and Neely, P.M. (1957). Evidence for 'gibberellin-like' substances from flowering

plants. Proceedings of the National Academy of Sciences, USA, 43:398-404.

Prasanna, R.; Chaudhary, V.; Gupta, V.; Babu, S.; Kumar, A.; Singh, R.; Shivay Y. S. and Nain, L. (2013). Cyanobacteria mediated plant growth promotion and bioprotection against *Fusarium* wilt in tomato. Eur. J. Plant Pathol., 136: 337–353.

Prasanna, R.; Joshi, M., Rana; A., Shivay, Y. S. and Nain, L. (2012). Influence of co-inoculation of bacteria-cyanobacteria on crop yield and C-N sequestration in soil under rice crop. World J. Microbiol. and Biotechnol.

Prusty, R.; Grisafi, P. and Fink, G.R. (2004). The plant hormone indole-acetic acid induces invasive growth in *Saccharomyces cerevisiae*. Proc. Natl. Acad. Sci. USA, 101(12): 4153–4157.

Riley, J.M. (1987). Gibberellic acid for fruit set and seed germination. CRFG J., 19: 10-12.

Rodrigo, M.J.; Marcos, J.F.; Alférez, F.; Mallent, M.D. and Zacarías, L. (2003). Characterization of Pinalate, a novel *Citrus sinensis* mutant with a fruit-specific alteration that results in yellow pigmentation and decreased ABA content. J. Exp. Bot., 54: 727–738.

Sahulka, J. and Lisá, L. (1980). Effect of some disaccharides, hexoses and pentoses on nitrate reductase, glutamine synthetase and glutamate dehydrogenase in excised pea roots. Physiol. Plant, 50 (1): 32–36.

Sardoei, A.S. (2014). Response of application of gibberellic acid (GA3) and benzyladenine (BA) to *Dizigotheeca elegantissima* plants. Int. J. Adv. Biol. and Biomed. Res., 2 (3): 615-621.

Schuerger, A.; Brown, C. S. and Stryjewski, E. C. (1997). Anatomical features of pepper plants (*Capsicum annuum L.*) grown under red light-emitting diodes supplemented with blue or far-red light. Anna. Bot.. 79: 273-282.

Selim, I. M.; Barakat, O. S.; Aly M. S. and Higazy A. M. (2014). "Ecological evaluation of marine cyanobacteria of El-Khadra Lake in Egypt". Int.J.Curr.Microbiol.App.Sci., 3(6): 468-485.

Shahab, S., Ahmed, N. and Khan, N. S. (2009). Indole acetic acid production and enhanced plant growth promotion by indigenous PSBs. Afric. J. Agric. Res., 4 (11): 1312- 1316.

Silva, F. de A.S.E. and Azevedo, C.A.V. de (2006). A new version of the Assistat-Statistical Assistance Software. In: World Congress on Computers in Agriculture, Orlando-FL-USA: Anais. Orlando: American Society of Agricultural and Biological Engineers, p. 393-396.

Silva, J.A. and Uchida, R. (2000). Essential nutrients for plant growth: Nutrient functions and deficiency symptoms In: Plant Nutrient Management in Hawaii's Soils, Approaches for Tropical and Subtropical Agriculture. (Ed., Uchida, R.). College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, pp. 31-55.

Szepesi, A.; Siszar, J.; Bajkan, S.; Gemes, K. and Horvath, F. *et al.* (2005). Role of salicylic acid pretreatment on the acclimation of tomato plants to salt and osmotic stress. Acta Biol. Szegediensis, 49: 123-125.

Tari, I.; Csiszar, J.; Gabriella, S.; Horvath, F. and Pecsvaradi, A. *et al.* (2002). Acclimation of tomato plants to salinity stress after a salicylic acid pretreatment. Acta Biol. Szegediensis, 46: 55-56.

Trewavas, A.J. (1983). Nitrate as a plant hormone. In: Jackson MB, ed. British plant growth regulator group monograph 9. Oxford: British Plant Growth Regulator Group, pp. 97–110.

Vivian-Smith, A. and Koltunow, A. M. (1999). Genetic analysis of growth-regulator-induced parthenocarpy in *Arabidopsis*. *Plant Physiol*. 121: 437–451.

Wahua, C.; Okoli, B. E. and Edwin-Wosu, N. L. (2014). Morphological, anatomical, cytological and phytochemical studies on *Capsicum annuum Linn. (Solanaceae)*. Eur. J. Exp. Biol., 4(1):464-471.

Wahua, C.; Okoli, B.E., and Sam, S.M. (2013). Comparative morphological, anatomical, cytological and phytochemical studies on *Capsicum Frutescens Linn.* and *Capsicum Annuum Linn. (Solanaceae)*. Int. J. Sci. and Eng. Res., 4(1): 1-11.

Williams, J.H.H.; Winters, A.L. and Farrar, J.F. (1992). Sucrose: a novel plant growth regulator. In The Molecular, Biochemical and Physiological Aspects of Plant Respiration, ed. H Lambers, LHW vander Plas, pp. 463–69. The Hague: Academic.

Yildirim, E.; Turan, M. and Guvenc, I. (2008). Effect of foliar salicylic acid applications on growth, chlorophyll and mineral content of cucumber (*Cucumis sativus L.)* grown under salt stress. J. Plant Nutr., 31: 593-612.

Zarrouk, C. (1966). Contribution à l´étude d´une cyanophycée influence de divers facteurs physiques et chimiques sur la croissance et la photosynthèse de *Spirulina maxima*. (Setch. *et.* Gardner) Geitler (Ph. D. thèse). Université de Paris.

Zhang, M.; Leng, P.; Zhang, G. and Li, X. (2009). Cloning and functional analysis of 9-cis-epoxycarotenoid dioxygenase (NCED) genes encoding a key enzyme during abscisic acid biosynthesis from peach and grape fruits. J. Plant Physiol., 166:1241–1252.

الملخص العربي

تقييم بعض سلالات الطحالب الخضراء المزرقة كمحفزات نمو لنبات الفلفل الحلو (*Capsicum annuum* var. *Anuum*)

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تم انتاج ثلاث سلالات من الطحالب الخضراء المزرقة (*Spirulina* و *Oscillatoria* و *Anabaena*) على صورتي بيئة سائلة ومسحوق، تقييمها كمحفزات نمو لنباتات الفلفل الحلو في تجربة أصص. تم إجراء التجربة برش ٢٤ معاملة، على صورة بيئات أو راشح أو كتلة حيوية مجففة (والتي بدورها تم إذابتها إما في الماء أو في راشح البيئة). كانت معاملات المقارنة السالبة في هذه التجربة هي المياه بينما الموجبة فكانت نتروجين: فوسفور: بوتاسيوم الموصى بها. سجلت النباتات المعاملة بواسطة *Spirulina* أعلى محتوى في كل من العناصر الكبرى (١,٠٢٪) والعناصر الصغرى (١٨٠ ppm)، بينما لوحظت المحتويات المرتفعة من الكلوروفيل أ و ب و الكلي في النباتات المعاملة بواسطة *Anabaena*. أظهرت المعاملة بواسطة *Spirulina* زيادة في قياسات الأوراق والجذور بينما زادت قياسات الساق بالمعاملة بخليط المزارع. أظهرت كلا من معاملتي *Spirulina* وخليط المزارع تبكيراً في التزهير (١١٠ يوماً بعد الشتل). أعطت النباتات ثماراً ذات حجم مناسب للتسويق في أغلب المعاملات بعد ٤٠ يوماً من بدء التزهير، ذات نسب بروتين تتراوح ما بين ٢٣,٩ – ١٦,٢٪. من بين النباتات المختبرة كانت تلك المعاملة بواسطة *Spirulina* هي المتفوقة في النمو عن المعاملات الأخرى. أظهرت الفحوصات التشريحية أن النباتات المعاملة بواسطة *Spirulina* أعطت أعلى زيادة في سمك نصل الورقة عن معاملتي المقارنة، وذلك يعود بصورة أساسية إلى الزيادة في سمك النسيج الإسفنجي. وتكون علاقة سمك النصل طردية واضحة مع متوسط الوزن الطازج للورقة، وعكسية مع متوسط مساحة الورقة.