

RESULTS

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4. Results

Many recent researches concluded that the bioremoval of heavy metals can be affected significantly by physiochemical parameters of the aqueous solutions, such as pH, ion strength and concentration, contact time and by other characteristics of the biomass as biomass dosage.

4.1 Optimum pH for metal ions bioremoval:

The effect of different pH values on metal ions (Cd^{+2} , Pb^{+2} , Ni^{+2} , Zn^{+2} and Cu^{+2} , respectively) bioremoval efficiency of different algal biomass are given in Tables (2- 6) and Figures (1- 5).

It is obvious that the removal efficiency decreased at low acidic and high alkaline pH and the optimum pH value for high metals adsorption by algae ranged from pH 5 to pH 7.

The data presented in Table (2) and Figure (1) show that the maximum removal percent of Cd^{+2} ion by *C. mediterranea* and *U. lactuca* at pH 5.0 were 71.6 and 64.1%, respectively, 58.8% by *J. rubens* at pH 6, and 55.8% by *P. capillacea* at pH 7.0.

In respect of biosorption of Pb^{+2} , the data in Table (3) and Figure (2) revealed that the biosorption of Pb^{+2} was more efficient at pH 5.0 by *U. lactuca*, *C. mediterranea* and *J. rubens* (95.9, 79.5 and 79.2%, respectively). Also, *P. capillacea* reached a plateau at pH 6.0 and remove 83.6% of pb^{+2} from the solution.

Data of Table (4) and Figure (3) indicated that at pH 5 the maximum Ni^{+2} uptake by *U. lactuca* were 83.4% and *J. rubens*

81.1% at pH 7. While the maximum removal of Ni^{+2} by *C. mediterranea* and *P. capillacea* at pH 6 reached 75.98 and 74.9%, respectively.

It is clear from Table (5) and Figure (4) that Zi^{+2} absorption percentage reached maximum by *P. capillacea*, *U. lactuca* and *J. rubens* 98, 93 and 81.3%, respectively, at pH 6.0, and 76.7% by *C. mediterranea* at pH 5.0.

As can be seen from Table (6) and Figure (5) that the maximum removal efficiency of Cu^{+2} at pH 6.0 was detected by *J. rubens* and *C. mediterranea*, 91.7 and 78.1%, respectively. Whereas, *P. capillacea* remove 77.1% at pH 4, and *U. lactuca* remove 75% at pH 6.

Table (2): Effect of pH on Cd⁺² removal percentage by different algal powder.

Algal species \ pH		pH									
		2	3	4	5	6	7	8	9	10	
<i>Chlorophyta</i>	<i>U. lactuca</i>	5.9	27.4	38.4	64.1	50	49.6	45.5	42.4	25.9	
<i>Rhodophyta</i>	<i>C. mediterranea</i>	5.9	18.6	55.3	71.6	54.9	65.2	45.13	21.3	2.5	
	<i>J. rubens</i>	37.8	42.8	43	57.33	58.8	50.7	46.9	44.6	12.7	
	<i>P. capillacea</i>	6.7	20.9	34.9	42.9	46	55.8	27.9	18.4	13	

Table (3): Effect of pH on Pb⁺² removal percentage by different algal powders.

Algal species \ pH		pH									
		2	3	4	5	6	7	8	9	10	
<i>Chlorophyta</i>	<i>U. lactuca</i>	19.7	12.7	29.6	95.9	69.6	79.3	62.7	50	41.5	
<i>Rhodophyta</i>	<i>C. mediterranea</i>	3.7	13.4	28.16	79.5	61.03	58.4	32.4	28.7	18.6	
	<i>J. rubens</i>	13.4	44.1	28.2	79.2	65.7	70.9	20.6	27.03	8.5	
	<i>P. capillacea</i>	23.2	29.6	59.5	69.7	83.6	82.9	13.4	25.3	2.7	

Table (4): Effect of pH on Ni⁺² removal percentage by different algal powders.

Algal species \ pH		pH									
		2	3	4	5	6	7	8	9	10	
<i>Chlorophyta</i>	<i>U. lactuca</i>	13.4	23.5	48.5	83.4	66.6	60.8	73.2	61	66.5	
<i>Rhodophyta</i>	<i>C. mediterranea</i>	9.1	25.6	49.28	64.08	75.98	52.05	29.3	15	6.3	
	<i>J. rubens</i>	12.6	31.9	52.89	70.24	78.9	81.06	20.85	3.8	1.5	
	<i>P. capillacea</i>	34	37.9	33.9	64.4	74.9	29.38	31.7	17	6.5	

Table (5): Effect of pH on Zn⁺² removal percentage by different algal powders.

Algal species		pH								
		2	3	4	5	6	7	8	9	10
<i>Chlorophyta</i>	<i>U. lactuca</i>	20.5	39	59.4	85.2	93	66.7	50.4	52.7	41.5
<i>Rhodophyta</i>	<i>C. mediterranea</i>	12	36.9	52.13	76.7	62	48.9	20.6	9.1	5.8
	<i>J. rubens</i>	30.2	58.5	76.6	77.9	81.3	61.4	55.9	43.9	22.7
	<i>P. capillacea</i>	59	78.1	86.7	91.5	98	73.7	61.8	44.2	25.3

Table (6): Effect of pH on Cu⁺² removal percentage by different algal powders.

Algal species		pH								
		2	3	4	5	6	7	8	9	10
<i>Chlorophyta</i>	<i>U. lactuca</i>	10.7	25.9	33.9	74.5	75	42.8	42.7	58.4	38
<i>Rhodophyta</i>	<i>C. mediterranea</i>	4.1	9.3	36.5	48.1	78.1	51.5	38.4	15.4	3.
	<i>J. rubens</i>	19.8	33.2	43.9	87.1	91.7	50.5	31.4	11.8	6.
	<i>P. capillacea</i>	36.5	55.8	77.1	76	48.8	52.33	30.7	16	12

Fig. (1): Effect of pH on Cd⁺² removal percentage by different algal powders.

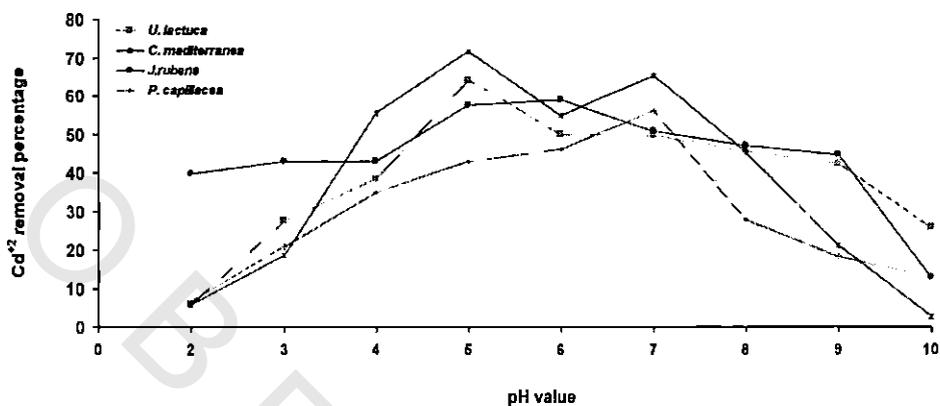


Fig. (2): Effect of pH on Pb⁺² removal percentage by different algal powders.

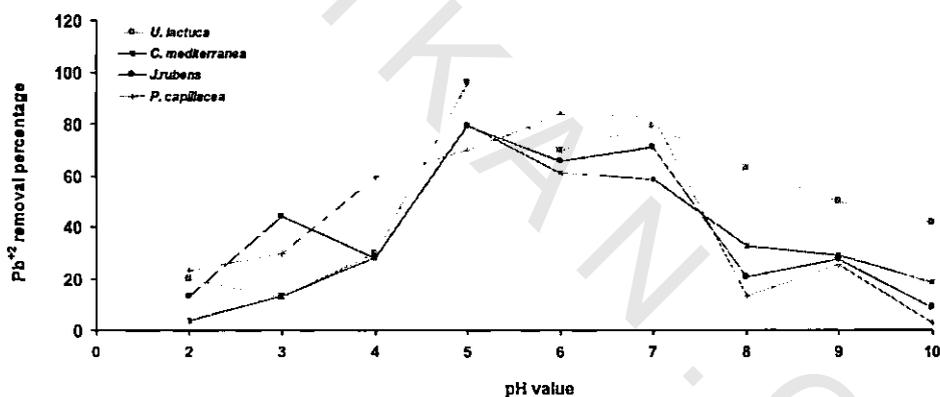


Fig. (3): Effect of pH on Ni⁺² removal percentage by different algal powders.

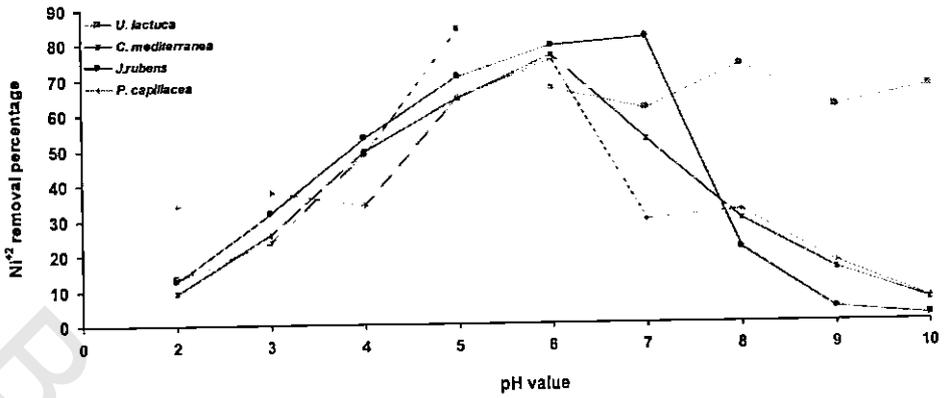


Fig. (4): Effect of pH on Zn⁺² removal percentage by different algal powders.

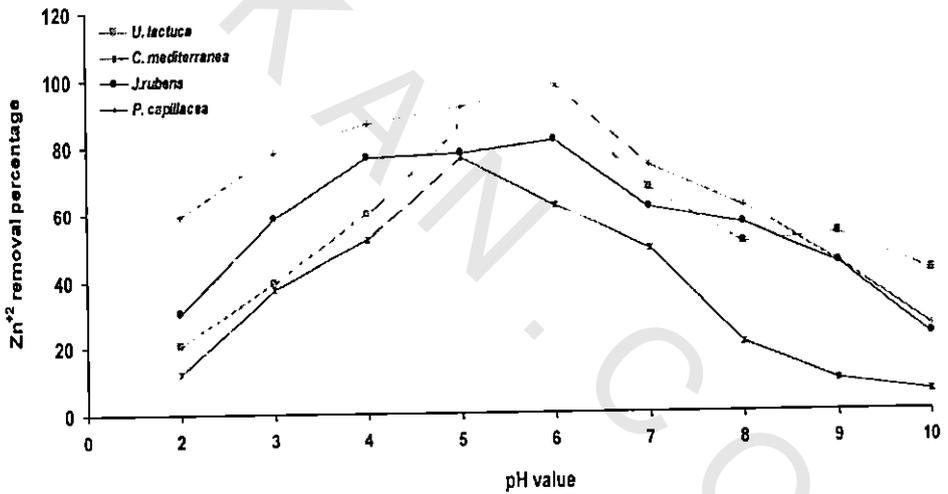
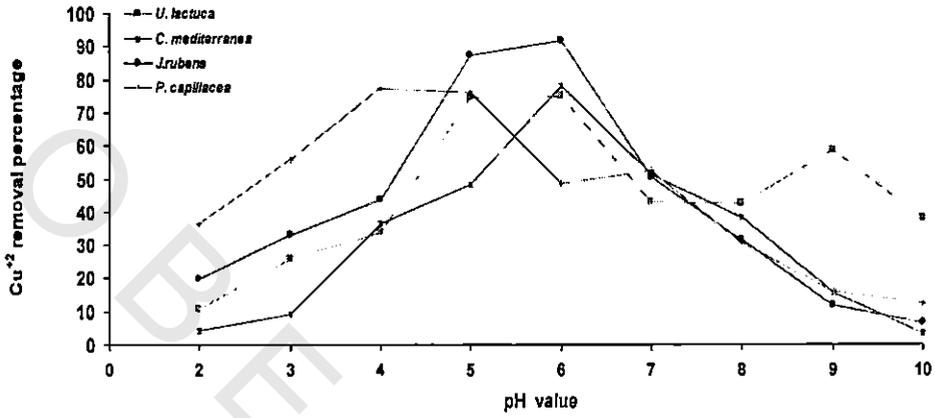


Fig. (5): Effect of pH on Cu⁺² removal percentage by different algal powders.



4.2 Optimum contact time for metal ions bioremoval:

The effect of different contact periods (5 min., 10 min., 20 min., 60 min. and 120 min.) on metal ion bioremoval efficiency of different algal biomass, are given in Tables (7- 11) and Figures (6- 10) for the metal ions (Cd^{+2} , Pb^{+2} , Ni^{+2} , Zn^{+2} and Cu^{+2} respectively).

It is clear from the obtained results that the efficiency of metal ion bioremoval increased as contact time increased. For almost all cases, the highest metal ion concentrations removed by different test algae was achieved at 60 minutes and above that it was more or less constant. The maximum efficiency of metal ion bioremoval at 60 min ranged between 38.2% and 90.3% for different algal sp. powders.

Table (7): Effect of contact time on Cd⁺² removal percentage by different algal powders.

Algal species		Time				
		5 min	10mi n	20 min	60 min	120mi n
Chlorophyt <i>a</i>	<i>U. lactuca</i>	21.2	33	43.7	64.3	61.5
Rhodophyt <i>a</i>	<i>C. mediterranea</i>	11.7	29.2	43.2	52.6	89.23
	<i>J. rubens</i>	10	14.48	28.6	65.6	38.16
	<i>P. capillacea</i>	6.95	13.8	24.8	38.16	39.5

Table (8): Effect of contact time on Pb⁺² removal percentage by different algal powders.

Algal species		Time				
		5 min	10mi n	20 min	60 min	120min
Chlorophyt <i>a</i>	<i>U. lactuca</i>	2.59	12.34	15.6	48.8	59.6
Rhodophyt <i>a</i>	<i>C. mediterranea</i>	8.2	24.6	56	83.4	87.7
	<i>J. rubens</i>	17.4	15.6	38.31	74.02	77.27
	<i>P. capillacea</i>	2.59	31.8	63.7	75.12	63.2

Table (9): Effect of contact time on Ni⁺² removal percentage by different algal powders.

Algal species		Time				
		5 min	10min	20 min	60 min	120mi n
<i>Chlorophyt a</i>	<i>U. lactuca</i>	10.8	25.5	35.4	43.5	47.39
<i>Rhodophyta</i>	<i>C. mediterranea</i>	16.4	33.1	49.5	68.9	76
	<i>J. rubens</i>	12.8	20.5	45.6	61.1	56.45
	<i>P. capillacea</i>	4.12	6.2	11.4	59.5	61.2

Table (10): Effect of contact time on Zn⁺² removal percentage by different algal powders.

Algal species		Time				
		5 min	10mi n	20 min	60 min	120mi n
<i>Chlorophyt a</i>	<i>U. lactuca</i>	15.36	48.26	79.80	80.4	81.6
<i>Rhodophyt a</i>	<i>C. mediterranea</i>	13.2	42.2	62.5	74.9	93.5
	<i>J. rubens</i>	25.8	45.5	54.68	69.9	67.5
	<i>P. capillacea</i>	12.5	35.9	77.47	90.26	88.2

Table (11): Effect of contact time on Cu^{+2} removal percentage by different algal powders.

Algal species		Time				
		5 min	10mi n	20 min	60 min	120mi n
<i>Chlorophyt</i> <i>a</i>	<i>U. lactuca</i>	19	42.8	72.3	79.95	80.43
<i>Rhodophyt</i> <i>a</i>	<i>C. mediterranea</i>	21.5	35	48.13	52.6	89.2
	<i>J. rubens</i>	24.8	50.6	68.5	89	95.4
	<i>P. capillacea</i>	17.75	34.8	62.6	77.8	74.01

Fig. (6): Effect of contact time on Cd^{+2} removal percentage by different algal powders.

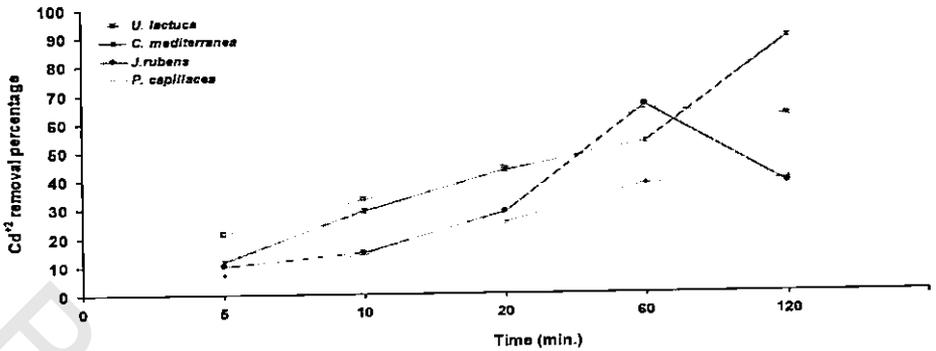


Fig. (7): Effect of contact time on Pb^{+2} removal percentage by different algal powders.

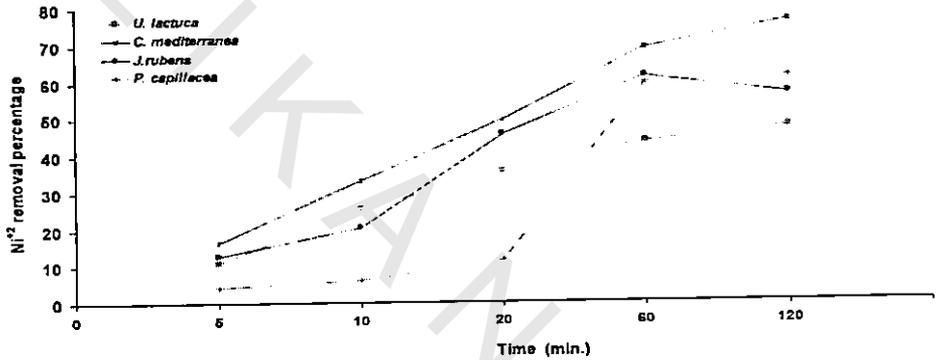


Fig. (8): Effect of contact time on Ni^{+2} removal percentage by different algal powders.

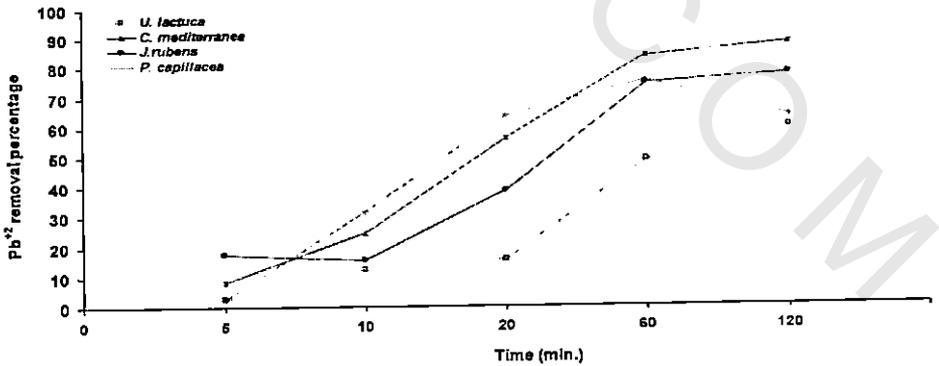


Fig. (9): Effect of contact time on Zn^{+2} removal percentage by different algal powders.

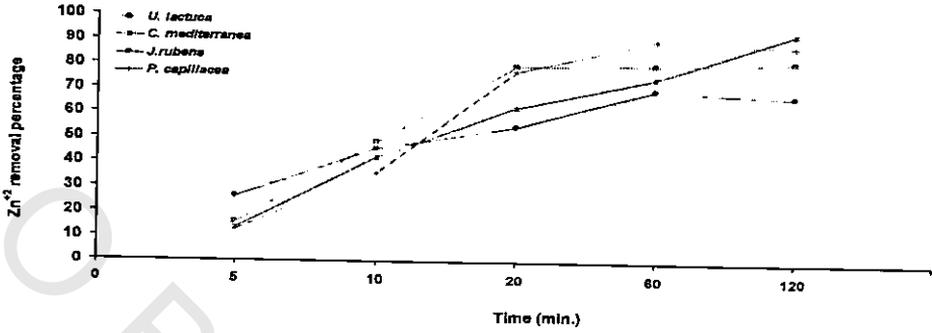
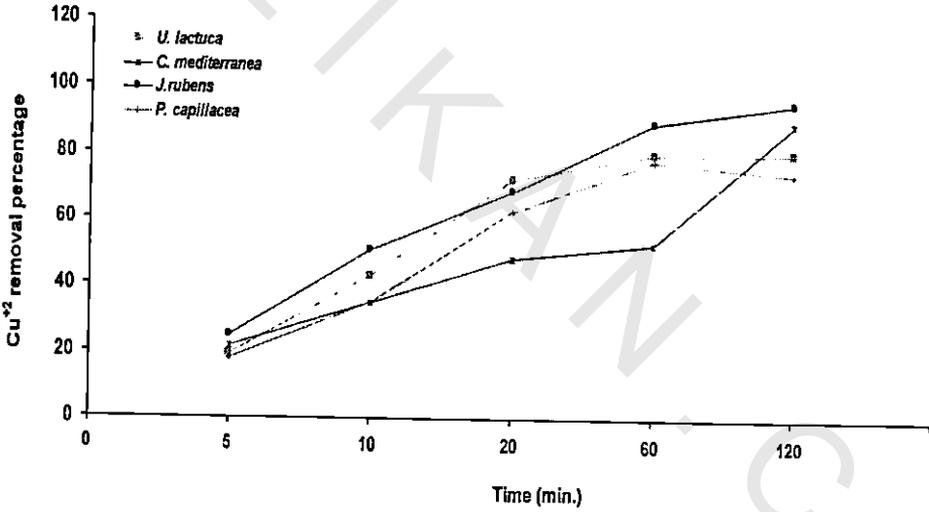


Fig. (10): Effect of contact time on Cu^{+2} removal percentage by different algal powders.



4.3 Optimum algal biomass for metal ions bioremoval:

Data in Tables (12- 16) and Figures (11- 15) show the effect of algal biomass on metal ion bioremoval efficiency. The results clearly reveal that the efficiency of metal ion bioremoval increases as algal biomasses increases from 1 g/L to 2 g/L to 5 g/L to 10 g/L to 20 g/L and 40 g/L. With all algae, the highest value of metal ions removal percentage was observed at 40 g/L and the maximum efficiency for removal of metal ions ranged between 86.7% by *U. lactuca* and 68.1% by *P. capillacea* for Cd, 92.7% by *C. mediterranea* and 79.7% by *P. capillacea* for Pb, 94.52% by *P. capillacea* and 65.34% by *J. rubens* for Ni, 92.7% by *J. rubens* and 89.3% by *C. mediterranea* for Zn, 92.6% by *J. rubens* and 71.2% *C. mediterranea* by for Cu.

Table (12): Effect of algal biomass on Cd⁺² removal percentage by different algal powders.

Biomass dosage		Algal species					
		1g/L	2 g/L	5 g/L	10 g/L	20 g/L	40 g/L
<i>Chlorophyta</i>	<i>U. lactuca</i>	2.9	12.9	27.9	59.9	87.1	86.7
<i>Rhodophyta</i>	<i>C. mediterranea</i>	7.2	36.8	56.1	73	81.9	83.4
	<i>J. rubens</i>	5.6	24.7	50.6	57.5	49.3	74.9
	<i>P. capillacea</i>	3.8	8.01	16.7	36.4	56.4	68.1

Table (13): Effect of algal biomass on Pb⁺² removal percentage by different algal powders.

Biomass dosage		Algal species					
		1g/L	2 g/L	5 g/L	10 g/L	20 g/L	40 g/L
<i>Chlorophyta</i>	<i>U. lactuca</i>	6.7	20.5	53.9 7	59.3	85.93	80.12
<i>Rhodophyta</i>	<i>C. mediterranea</i>	9.4	23.7	63.5	84	95.2	92.7
	<i>J. rubens</i>	2.48	32.8 6	43.6	76.1	83.5	89.3
	<i>P. capillacea</i>	7.9	18.2	45.7	69.35	47.98	79.7

Table (14): Effect of algal biomass on Ni⁺² removal percentage by different algal powders.

Algal species \ Biomass dosage		1g/L	2	5	10	20	40
		g/L	g/L	g/L	g/L	g/L	g/L
<i>Chlorophyta</i>	<i>U. lactuca</i>	3.7	8.5	28.9	47.7	97	91.78
<i>Rhodophyta</i>	<i>C. mediterranea</i>	17.3	45.3	59.2	61.8	73.7	79.9
	<i>J. rubens</i>	1.5	5.8	36.2	66.5	67.2	65.34
	<i>P. capillacea</i>	1.2	7.3	22.4	62.32	93.5	94.52

Table (15): Effect of algal biomass on Zn⁺² removal percentage by different algal powders.

Algal species \ Biomass dosage		1g/L	2	5 g/L	10	20	40
		g/L	g/L	g/L	g/L	g/L	g/L
<i>Chlorophyta</i>	<i>U. lactuca</i>	4.55	17.4	35.62	78.62	67.6	90.9
<i>Rhodophyta</i>	<i>C. mediterranea</i>	20	35.7	57.4	78.1	85.7	89.3
	<i>J. rubens</i>	5.89	13.8	24.3	74.5	88.9	92.7
	<i>P. capillacea</i>	1.43	22.5	46.9	86.9	79.32	89.9

Table (16): Effect of algal biomass on Cu^{+2} removal percentage by different algal powders.

Algal species \ Biomass dosage		1g/L	2 g/L	5 g/L	10 g/L	20 g/L	40 g/L
		<i>Chlorophyta</i>	<i>U. lactuca</i>	10.4	35.9	64.24	71.3
<i>Rhodophyta</i>	<i>C. mediterranea</i>	12.6	29.1	48.9	56.5	66.3	71.2
	<i>J. rubens</i>	4.6	16.9	48.2	75.5	79.4	92.6
	<i>P. capillacea</i>	5.1	15.4	42.16	82.16	83.53	82.95

Fig. (11): Effect of algal biomass on Cd⁺² removal percentage by different algal powders.

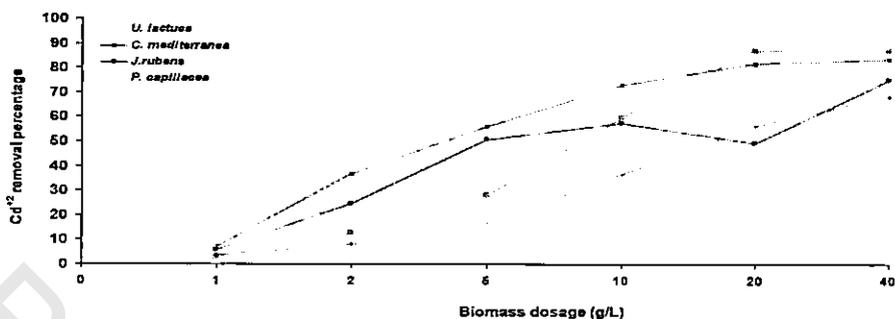


Fig. (12): Effect of algal biomass on Pb⁺² removal percentage by different algal powders.

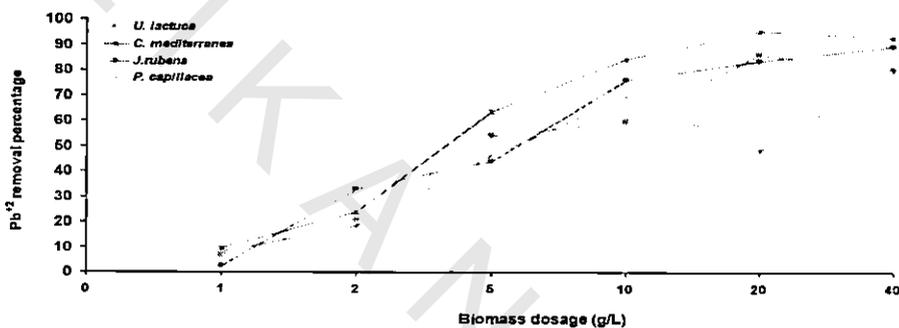


Fig. (13): Effect of algal biomass on Ni⁺² removal percentage by different algal powders.

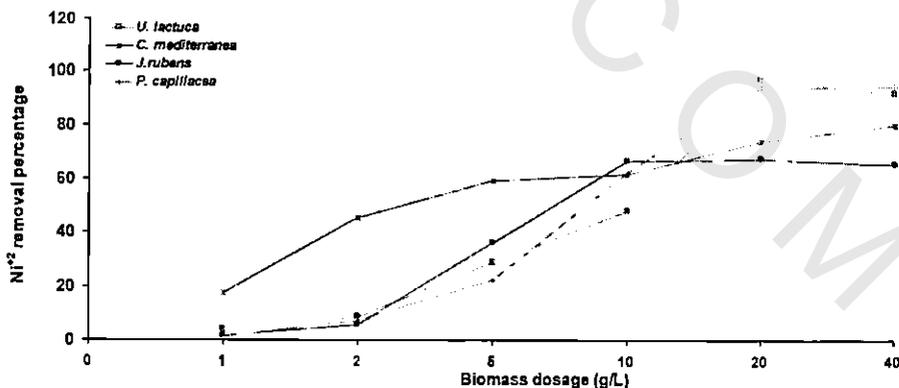


Fig. (14): Effect of algal biomass on Zn⁺² removal percentage by different algal power powers

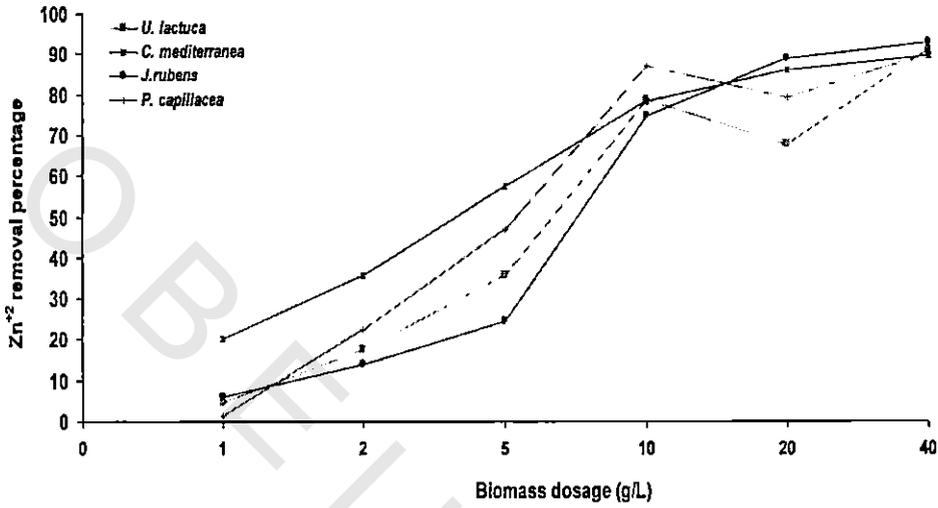
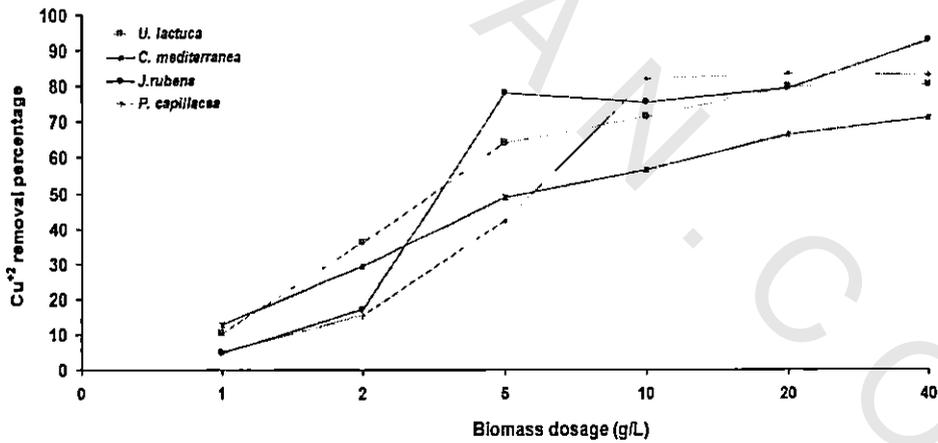


Fig. (15): Effect of algal biomass on Cu⁺² removal percentage by different algal Powders.



4.4 Effect of irrigation with low quality water before and after algal treatment.

This part of study show the effect of irrigation with low quality water contained different concentrations of heavy metals (Cd^{+2} , Pb^{+2} , Ni^{+2} , Cu^{+2} and Zn^{+2}) before and after marine algal treatment on the final germination percentage, seedling enzymes, some vegetative growth parameters, photosynthetic pigments and some chemical components of wheat grains and faba bean seeds.

4.4.1 The final percentage germination of seeds:

The final percentage germination values of wheat grains and faba bean seeds at 7 days from planting as influenced by low quality water irrigation before and after algal treatment are presented in Table (17) and graphically in Figure (16).

4.4.1.1 Wheat:

The data revealed that using El- Batts drainage water in irrigation significantly inhibited wheat grains germination by 23.33%, than irrigation with Nile fresh water (control). However, the reduction in the final percentage germination was only 13.33% than the control when El- Batts drainage water was treated by algae. On the other hand, it was clear that increasing heavy metal concentration in synthetic solutions from 20 to 60 or 100 ppm caused more and remarkable inhibition in wheat grains germination by 33.33, 36.67 and 43.34%, respectively, when compared with corresponding control. Irrigation with synthetic solutions contained 20, 60 and 100 heavy metals after algal treatment raised wheat germination percentage at 7- days when compared to non-algal treated ones by 15.0, 21.05 and 33.54%, respectively.

4.4.1.2 Faba bean:

The final percentage germination of faba bean seeds irrigated with El- Batts drainage water before algal treatment was significantly decreased by 16.67%, than irrigation with Nile fresh water. However, irrigation with algal treated water of El- Batts drainage gave an increase in seed germination percentage to reach about 96.66%. Irrigating seeds with synthetic solutions contained 20 or 60 ppm heavy metals before algal treatment inhibited the germination percentage significantly by 40%, as compared with the Nile fresh water (control) and without any differences between the two synthetic concentrations. However, a sharp inhibition in the germination percentage was occurred by using synthetic solution of 100 ppm concentration of heavy metals, and the germination percentage reached 46.66% only.

It is obvious that treating synthetic solutions contained 20, 60 and 100 ppm with algae and used it in irrigation, increased the germination percentage of faba bean seeds than non-treated solutions by 13.33% for these statements.

4.4.2 Seedling enzyme activities:

4.4.2.1 Peroxidase (U/gm F.W.):

4.4.2.1.1 Wheat:

Data in Table (17) and Figure (17) indicate that irrigation with El. Batts drainage water and synthetic solution contained 20, 60 and 100 ppm of heavy metals before algal treatment caused very highly significant reductions in seedling peroxidase activity by 13.76, 25.38, 58.46 and 64.32%, respectively, when compared with Nile fresh water irrigation.

Using algal treated water in irrigation gave fluctuated effect on seedling peroxidase activity. Irrigation with El- Batts drainage water or synthetic solution of 20 ppm heavy metals after algal treatment significantly reduced the seedling peroxidase enzyme by 11.92 and 28.9% when compared with corresponding untreated with algae. However, irrigation by synthetic solution contained 60 or 100 ppm heavy metals concentration decreased peroxidase activity. Treatment of these two synthetic solutions (60 and 100 ppm) by algae leads to increase in seedlings peroxidase activity by 48.96 and 46.84%, respectively.

4.4.2.1.2 Faba bean:

It is clear from Table (17) and Figure (17) that irrigation with El Batts drainage water or synthetic solutions contained 20, 60 and 100 ppm of heavy metals before algal treatment gave very highly significant increases in seedling peroxidase activity by 24.60, 22.75, 26.11 and 23.63%, respectively, when compared with the Nile fresh water irrigation.

On the other hand, irrigation with algal treated water caused decrease in seedling peroxidase activity than the non- algal treated water by 24.57, 23.78, 2.07 and 11.34% for El- Batts drainage water and synthetic solutions 20, 60 and 100 ppm heavy metals, respectively.

4.4.2.2 Catalase (U/gm F.W.):

4.4.2.2.1 Wheat:

The results in Table (17) and Figure (18) demonstrated that the maximum catalase activity in wheat seedlings was detected from irrigation with Nile fresh water (control).

Irrigation with El- Batts drainage water or synthetic solutions contained 20, 60 and 100 ppm of heavy metal without algal treatment gave very highly significant decrease in catalase activity than the control by 60.6, 81.7, 81.82 and 75.75%, respectively.

The irrigation with algal treated El- Batts drainage water significantly reduce catalase activity in seedlings compared with non- treated drainage water by 57.7%.

Treatment synthetic solutions of 20, 60 and 100 ppm heavy metals with algae gave significant increases in catalase activity in seedlings than non-algal treated water.

4.4.2.2.2 Faba bean:

As can be seen from Table (17) and Figure (18) that irrigation with El- Batts drainage water exhibit a very highly significant decrease in catalase activity of faba been seedlings by 53.33% than the control. However, in the case of non-treated synthetic solutions, the catalase activity of seedlings detected from irrigation with 20 or 60 ppm heavy metals solution significantly reduced by 70.91 and 33.33% than irrigation with the Nile fresh water, respectively.

Regarding, irrigation with synthetic solution contained 100 ppm heavy metals , the catalase activity of seedlings significantly increased than the control (Nile fresh water) by 10.6%.

It can be noticed that irrigation with algal treated water caused very highly significant increases in the catalase activity, comparing with irrigation by non-algal treated water, except at 100 ppm heavy metals of algal treated, the catalase activity reduced.

Table (17): Effect of low quality and algal treated irrigation water on final percentage germination (%) of seeds and seedling enzymes of wheat and faba bean.

Water treatments	Wheat			Faba bean			
	Final germination(%)	Seedling Peroxidase (U/gm. F.W)	Seedling Catalase (U/gm. F.W)	Final germination (%)	Seedling Peroxidase (U/gm. F.W)	Seedling Catalase (U/gm. F.W)	
Nile fresh water (control)	100.00 ±0.58	59.51 ±0.08	6.00 ±0.01	100.0 ±0.58	24.179 ±0.02	30.000 ±0.43	
El-Barts drainage water	76.67*** ±3.3	51.32*** ±0.09	2.36*** ±0.02	83.33* ±4.4	30.127*** ±0.04	14.000*** ±0.07	
	S.S.20	66.67*** ±3.3	44.40*** ±0.17	1.10*** ±0.04	60.00*** ±2.9	29.679*** ±0.03	8.727*** ±0.06
Non-algal treated water	S.S.60	63.33*** ±3.3	24.72*** ±0.05	1.09*** ±0.04	60.00*** ±5.8	30.492*** ±0.69	20.000*** ±0.10
	S.S.100	56.67*** ±3.3	21.23*** ±0.01	1.46*** ±0.01	46.67*** ±4.4	29.892*** ±0.03	33.161** ±0.08
Water treated with mixture of algal powder	El-Barts	86.67n.s. ±3.3	45.21*** ±0.07	1.00*** ±0.01	96.67n.s. ±3.3	22.725*** ±0.14	18.180*** ±0.02
	S.S.20	76.67 n.s. ±3.3	31.57*** ±0.11	2.91*** ±0.09	73.33n.s. ±3.3	22.620*** ±0.47	14.000*** ±0.10
	S.S.60	76.67* ±3.3	36.67*** ±0.66	3.09*** ±0.01	73.33n.s. ±3.3	29.861n.s. ±0.08	34.910*** ±0.04
	S.S.100	70.00n.s. ±5.8	31.18*** ±0.09	4.09*** ±0.02	60.00n.s. ±2.9	26.502*** ±0.05	21.818*** ±0.02

Non significant n.s. at P > 0.05

Significant (*) at P ≤ 0.05

Highly significant (**) at P ≤ 0.01

Very highly significant (***) at P ≤ 0.001

S.S.20 = Synthetic solution of heavy metals (4 ppm of Cd, 4 ppm of Pb, 4 ppm of Ni, 4 ppm of Zn and 4 ppm of Cu)

S.S.60 = Synthetic solution of heavy metals (12 ppm of Cd, 12 ppm of Pb, 12 ppm of Ni, 12 ppm of Zn and 12 ppm of Cu)

S.S.100 = Synthetic solution of heavy metals (20 ppm of Cd, 20 ppm of Pb, 20 ppm of Ni, 20 ppm of Zn and 20 ppm of Cu)

Mixture of algal powder (10 gm of powder of *U. lactuca*, *C. mediterranea* and *J. ribensis*)

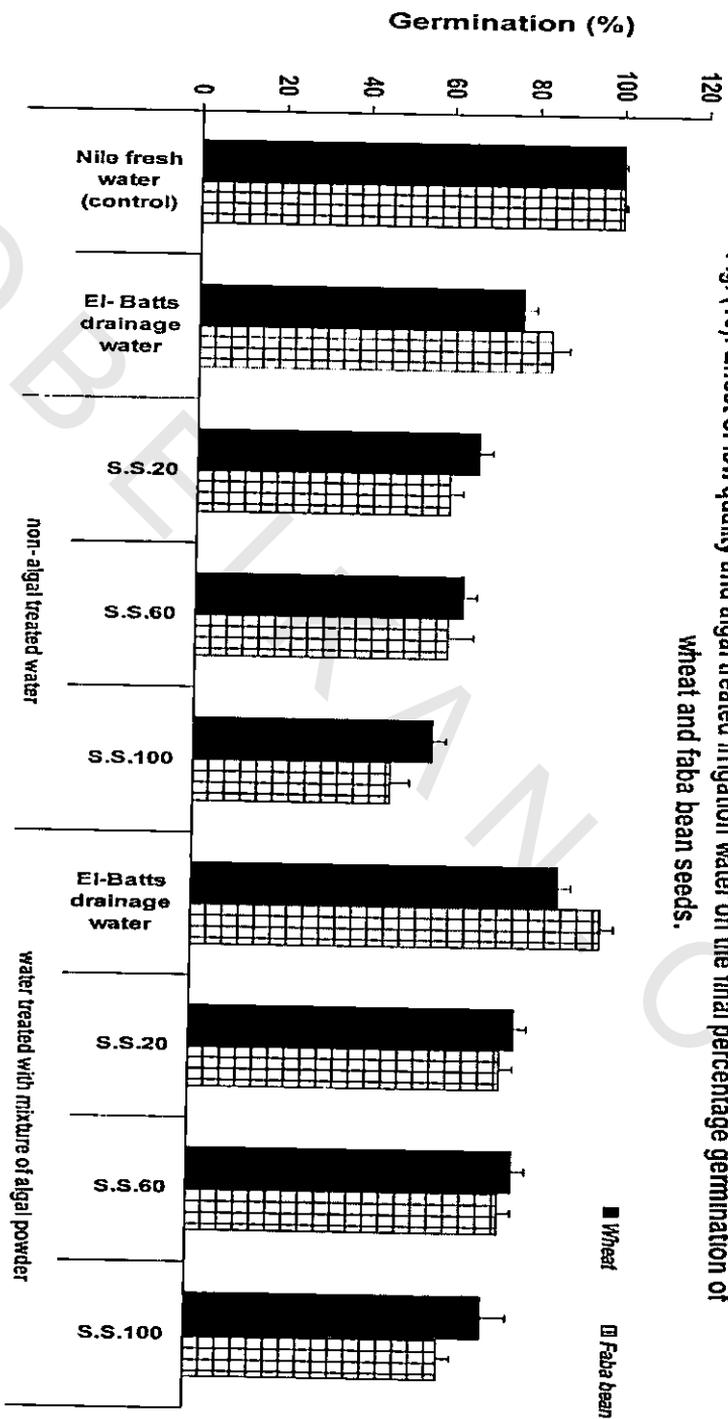


Fig. (16): Effect of low quality and algal treated irrigation water on the final percentage germination of wheat and faba bean seeds.

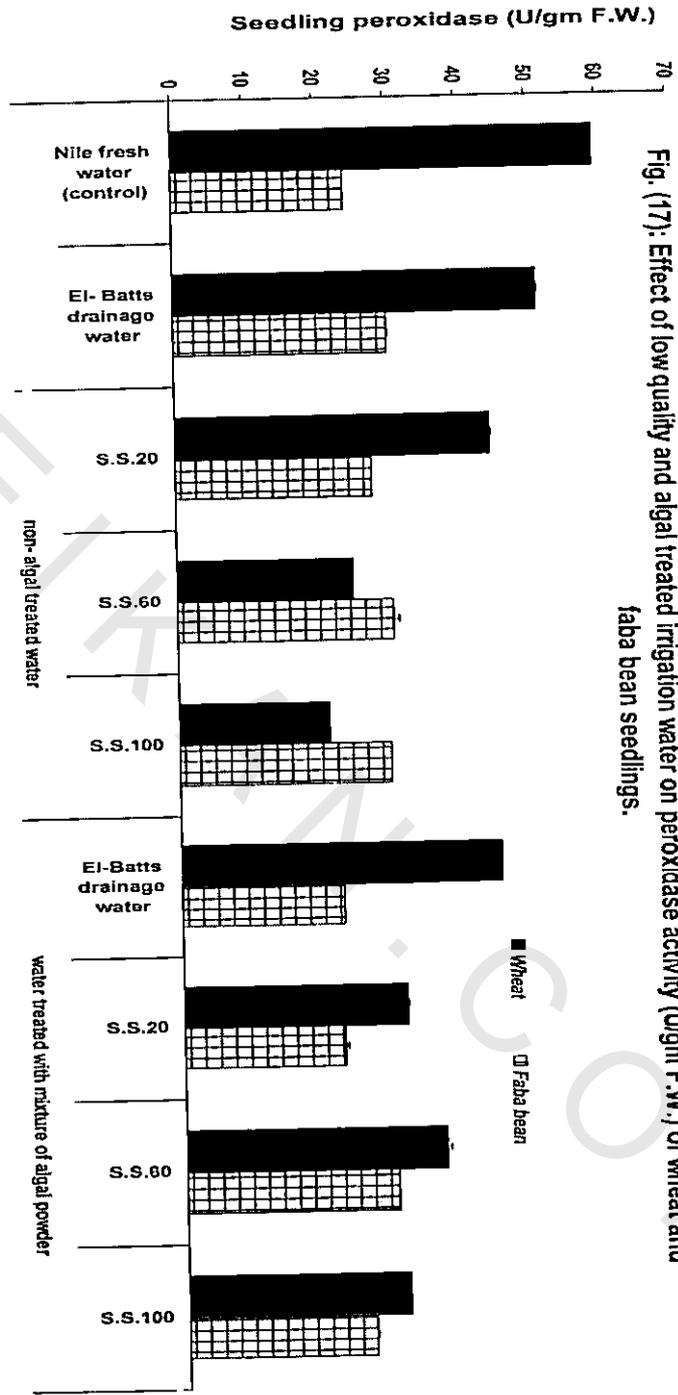


Fig. (17): Effect of low quality and algal treated irrigation water on peroxidase activity (U/gm F.W.) of wheat and faba bean seedlings.

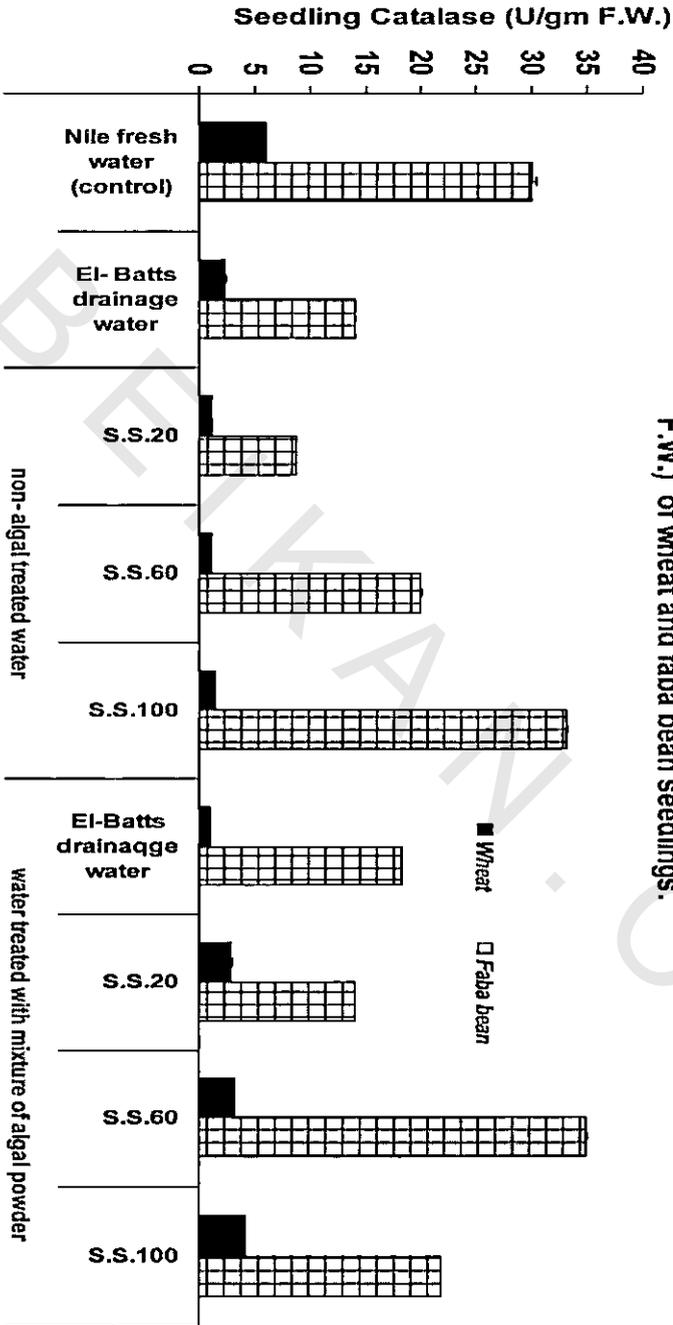


Fig. (18): Effect of low quality and algal treated irrigation water on catalase activity (U/gm F.W.) of wheat and faba bean seedlings.

4.4.3 Vegetative growth parameters:

The data obtained and the mean values/plant were computed for shoot height, root length, fresh and dry weights, leaf number and leaf area/ plant.

4.4.3.1 Wheat:

4.4.3.1.1 Shoot height (cm):

The results presented in Table (18 and 19) and Figure (19) indicated that shoot height of wheat plants were significantly affected by different irrigation treatments used at 5 and 9- weeks old plants. The maximum shoot height values at 5 and 9- weeks old plants (16.8 and 35.07 cm) were attained from irrigation with the Nile fresh water (control). Irrigation with El- Batts drainage water before algal treated significantly decreased shoot height at 5 and 9- weeks old plants by 20.24 and 16.65%, respectively, compared with the control, however, algal treated water of El- Batts drainage decreased the shoot height at 5 and 9- weeks old plants by 15.48 and 6.67%, respectively, compared with the control. Using the synthetic solutions contained 20, 60 and 100 ppm heavy metals caused very highly significant reductions in shoot height at 5- weeks old plants by 31.55, 32.74 and 40.48%, respectively, and at 9- weeks old plants by 19.87, 22.81 and 28.63%, respectively, as compared to the control. Generally, irrigating wheat plants with El- Batts drainage water before or after algal treated increased the shoot height at 5 and 9- weeks old plants than all the synthetic solution (20, 60 and 100 ppm heavy metals) before or after algal treating.

However, high significant differences in shoot height were noticed at 5 or 9- weeks old plants between synthetic solutions of 20 ppm and 60 ppm heavy metals, either before or after algal treatment, but increasing heavy metal concentrations in irrigated water from 20 to 100 or from 60 to 100 ppm before or after algal treatment significantly decreased shoot height at 5- weeks old plants by 32.74 and 40.48% and at 9- weeks old plants by 22.81 and 28.63%, respectively, compared with the control. The corresponding values of heavy metal concentrations decrease shoot height of wheat plants irrigated with algal treated water at 5- weeks old plants by 24.40 and 33.33%, and at 9- weeks old plants by 13.89 and 22.07%, respectively.

It is obvious that increasing heavy metals concentration in irrigated water significantly decreased the shoot height of wheat plants at 5 or 9- weeks old plants. Irrigation with algal treated low quality water showed significant increases in shoot height of all water treatments, but still less than the Nile fresh water.

4.4.3.1.2 Root length (cm):

Data represented in Table (18 and 19) and Figure (20) point out that the root length of wheat plants irrigated with Nile fresh water was significantly higher than those irrigated with El- Batts drainage water or synthetic solutions of 20, 60 and 100 ppm heavy metals at 5- weeks old plants by 20.16, 42.92, 42.92 and 68.84%, respectively, and at 9- weeks old plants by 17.74, 25.0, 38.12 and 64.11%, respectively. Also, root length of wheat plants irrigated with El- Batts drainage water increased than those irrigated with

synthetic solution of 20 ppm heavy metals at 5 and 9- weeks by 19.18 and 6.17%, respectively.

It is clear that as the heavy metals concentration increased in irrigated water the reduction in root length increased significantly. However, the bioremediation of heavy metals from irrigated water (algal treated water) leads to an increase in root length of wheat plants over the non- algal treated water.

These results concluded that irrigating wheat plants with low quality water caused adverse effects on the root length at the two growth stages (5 and 9- weeks old). Also, the reduction in the root length was significantly increased with increasing the heavy metals concentration in irrigation water, compared to the control. In addition, treated algal water increased the root length at 5 and 9- weeks old plants over the non- algal treated ones .

4.4.3.1.3 Shoot fresh weight (gm):

As can be noticed from Table (18 and 19) and Figure (21) that the shoot fresh weight of wheat at the two growth stages (5 and 9- weeks old) appeared to decrease due to low quality water irrigation before or after algal treatment, as compared to the Nile fresh water irrigation.

Irrigation with El- Batts drainage water before or after algal treatment significantly reduced the shoot fresh weight at 5- weeks old plants by 28.95 and 18.86%, respectively, and at 9- weeks old plants by 16.18 and 8.22%, respectively, when compared with Nile fresh water (control).

Treatment of synthetic solution (20, 60 and 100 ppm heavy metals) with algae increase shoot fresh weight at 5- weeks old plants by 12.42, 20.0 and 23.88%, respectively, and at 9- weeks old plants by 15.76, 6.53, and 12.93%, respectively, over the non- algal treated synthetic solutions. Increasing heavy metals concentration in irrigated water to 100 ppm gave the lowest fresh weight of wheat shoot (1.340 and 2.243 gm) at 5 and 9 weeks plant old.

4.4.3.1.4 Shoot dry weight (gm):

The data listed in Table (18 and 19) and Figure (22) reflects the effects of different irrigation treatments on the shoot dry weight of wheat plants.

The maximum shoot dry weight at 5 and 9- weeks old plants, i.e. 0.375 and 0.807 gm, respectively, were obtained from the Nile fresh water, whereas irrigation with synthetic solution of 100 ppm heavy metals gave the minimum shoot dry weight values of wheat plants (0.261 and 0.423 gm).

Irrigation with El- Batts drainage water increased shoot dry weight at 5- weeks old plants by 6.46, 12.59 and 19.92% and at 9- weeks old plants by 11.34, 28.89 and 62.41%, than the shoot dry weight of plants irrigated with synthetic solutions contained 20, 60 and 100 ppm of heavy metals, respectively.

On the other hand, treating El- Batts drainage water or synthetic solutions of 20, 60, and 100 ppm heavy metals with algae caused increases in shoot dry weight more than the non- treated ones at the two growth stages, but the values obtained still below the control value.

4.4.3.1.5 Leaf number/ plant:

The data illustrated in Table (18 and 19) and Figure (23) clearly show that using the Nile fresh water (control) for irrigation increase the leaf number/ plant at 5 and 9- weeks old plants (5.33 and 7.67 leaves/ plant), whereas high significant reductions in the leaf number/ plant (2.66 and 4.33 leaves/ plant) at 5 and 9- weeks old plants, were observed when using the synthetic solution of 100 ppm heavy metal concentration for irrigation.

In case of using El- Batts drainage water in irrigation, the leaf number/ plant was decreased non- significantly at 5 and high significantly at 9- weeks old plants by 18.76 and 30.51% respectively, compared with the control. However using El- Batts algal treated water reduced the leaf number/ plant at 5 and 9- weeks old plants than the Nile fresh water by 12.57 and 13.04%, respectively, without significant effect.

Using algal treated synthetic solution of 100 ppm heavy metals in irrigation reduced the leaf number/ plant at 5 weeks plant old by 25% than algal synthetic solutions of 20 or 60 ppm heavy metals. Similar finding were obtained at 9- weeks old. Algal treatment of El- Batts drainage water and synthetic solutions of 20, 60 and 100 ppm heavy metals concentration increased the leaf number/ plant than the non- algal treated ones at 5- weeks old plants by 7.62, 20.12, 20.12 and 12.78%, respectively, and at 9- weeks old plants by 12.57, 12.57, 13.40 and 15.47%, respectively.

4.4.3.1.6 Leaf area/ plant (cm²):

The results presented in Table (18 and 19) and Figure (24) revealed that irrigation with the Nile fresh water produced the maximum leaf area at 5 and 9- weeks old plants, i.e. 116.53 and 181.27 cm², respectively, whereas, the minimum leaf area/ plant at 5 and 9- weeks old plants (57.27 and 81.57 cm²) were resulted from irrigation with synthetic solution contained 100 ppm heavy metal concentration.

The leaf area/ plant at the two growth stages, obtained from irrigation with El- Batts drainage water (80.23 and 133.53 cm²) exceeded those observed from irrigation with synthetic solutions of 20, 60 and 100 ppm by 20.88, 23.05, and 40.09 %, respectively, at 5- weeks stage and by 12.66, 24.18 and 63.70%, respectively, at 9- weeks stage.

Using synthetic solutions of 20, 60 and 100 ppm heavy metals in irrigation gave significant differences in leaf area/ plant at 5 and 9- weeks old plants.

Algal treating of El- Batts drain water and synthetic solution 20, 60 and 100 ppm heavy metals concentration increased leaf area/ plant than the non- algal treated ones at 5- weeks stage by 20.03, 17.01, 15.84 and 15.89%, respectively. At 9- weeks of treatment the corresponding increment values were 19.43, 19.49, 26.17 and 31.21%, respectively.

It can be concluded that as the concentration of heavy metals in irrigation water increased, the leaf area/ plant of wheat significantly decreased, but treating these water with algae can induced an inhibition to this reduction in leaf area/ plant at the two growth stages.

Table (18): Effect of low quality and algal treated irrigation water on some vegetative growth parameters of wheat plants at 5- weeks from planting.

Water treatments	5 weeks						
	Shoot height (cm)	Root length (cm)	Shoot fresh weight (gm)	Shoot dry weight (gm)	Leaf no. per plant	Leaf area per plant (cm ²)	
Nile fresh water (control)	16.8 ±0.44	5.97 ±0.12	2.28 ±0.03	0.375 ±0.01	5.33 ±0.33	116.53 ±6.9	
El-Batts drainage water	13.4** ±0.17	4.97* ±0.23	1.62*** ±0.03	0.313 n.s. ±0.02	4.33 n.s. ±0.33	80.23* ±7.3	
Non-algal treated water	S.S.20	11.5*** ±0.25	4.17*** ±0.07	1.61*** ±0.04	0.294** ±0.001	3.33** ±0.33	66.37** ±2.3
	S.S.60	11.3*** ±0.12	4.17** ±0.22	1.45*** ±0.07	0.278** ±0.01	3.33** ±0.33	65.20** ±3.4
	S.S.100	10.0*** ±0.09	3.53*** ±0.23	1.34*** ±0.04	0.261** ±0.02	2.67** ±0.33	57.27** ±3.6
Water treated with mixture of algal powder	El-Batts	14.2 n.s. ±0.29	5.43 n.s. ±0.19	1.85** ±0.04	0.354 n.s. ±0.03	4.67 n.s. ±0.33	96.30 n.s. ±3.2
	S.S.20	13.1** ±0.12	4.83** ±0.12	1.81** ±0.01	0.317 n.s. ±0.01	4.00 n.s. ±0.58	77.67* ±1.3
	S.S.60	12.7*** ±0.12	4.77 n.s. ±0.18	1.74* ±0.02	0.305 n.s. ±0.01	4.00 n.s. ±0.58	75.53 n.s. ±2.5
S.S.100	11.2** ±0.23	4.03 n.s. ±0.15	1.66** ±0.04	0.297 n.s. ±0.01	3.00 n.s. ±0.58	66.37 n.s. ±2.4	

Non significant n.s. at $P > 0.05$ Highly significant (**) at $P \leq 0.01$
 Significant (*) at $P \leq 0.05$ Very highly significant (***) at $P \leq 0.001$
 S.S.20 = Synthetic solution of heavy metals (4 ppm of Cd, 4 ppm of Pb, 4 ppm of Ni, 4 ppm of Zn and 4 ppm of Cu)
 S.S.60 = Synthetic solution of heavy metals (12 ppm of Cd, 12 ppm of Pb, 12 ppm of Ni, 12 ppm of Zn and 12 ppm of Cu)
 S.S.100 = Synthetic solution of heavy metals (20 ppm of Cd, 20 ppm of Pb, 20 ppm of Ni, 20 ppm of Zn and 20 ppm of Cu)
 Mixture of algal powder (10 gm of powder of *U. lactuca*, *C. mediterranea* and *J. rubens*)

Table (19): Effect of low quality and algal treated irrigation water on some vegetative growth parameters of wheat plants at 9- weeks from planting.

Water treatments	9 weeks						
	Shoot height (cm)	Root length (cm)	Shoot fresh weight (gm)	Shoot dry weight (gm)	Leaf no./plant	Leaf area/plant (cm ²)	
Nile fresh water (control)	35.07 ±0.38	7.50 ±0.26	4.053 ±0.06	0.807 ±0.01	7.67 ±0.33	181.27 ±3.7	
El-Batts drainage water	29.23*** ±0.24	6.37* ±0.23	3.397* ±0.19	0.687*** ±0.01	5.33** ±0.33	133.30*** ±4.8	
Non-algal treated water	S.S.20	28.10*** ±0.17	6.00** ±0.12	2.957*** ±0.06	0.617*** ±0.02	5.33** ±0.33	118.53*** ±4.6
	S.S.60	27.00*** ±0.46	5.43** ±0.20	2.860*** ±0.06	0.533*** ±0.02	5.00* ±0.58	107.53*** ±3.1
S.S.100	25.03*** ±0.47	4.57*** ±0.20	2.243*** ±0.04	0.423*** ±0.02	4.33** ±0.33	81.57*** ±2.5	
Water treated with mixture of algal powder	El-Batts	32.73** ±0.55	6.97 n.s. ±0.27	3.720 n.s. ±0.10	0.747* ±0.01	6.00 n.s. ±0.58	159.47** ±1.7
	S.S.20	30.67*** ±0.24	6.67* ±0.12	3.423** ±0.03	0.693** ±0.01	6.00 n.s. ±0.58	141.63** ±1.7
S.S.60	30.20** ±0.40	6.30* ±0.23	3.047 n.s. ±0.04	0.603* ±0.01	5.67 n.s. ±0.33	135.67** ±2.7	
S.S.100	27.33** ±0.26	5.20* ±0.12	2.533* ±0.07	0.497** ±0.01	5.00 n.s. ±0.58	107.03** ±2.5	

Non significant n.s. at P > 0.05
Significant (*) at P ≤ 0.05

Highly significant (**) at P ≤ 0.01
Very highly significant (***) at P ≤ 0.001

S.S.20 = Synthetic solution of heavy metals (4 ppm of Cd, 4 ppm of Pb, 4 ppm of Ni, 4 ppm of Zn and 4 ppm of Cu)

S.S.60 = Synthetic solution of heavy metals (12 ppm of Cd, 12 ppm of Pb, 12 ppm of Ni, 12 ppm of Zn and 12 ppm of Cu)

S.S.100 = Synthetic solution of heavy metals (20 ppm of Cd, 20 ppm of Pb, 20 ppm of Ni, 20 ppm of Zn and 20 ppm of Cu)

Mixture of algal powder (10 gm of powder of *U. lactuca*, *C. mediterranea* and *J. rubens*)

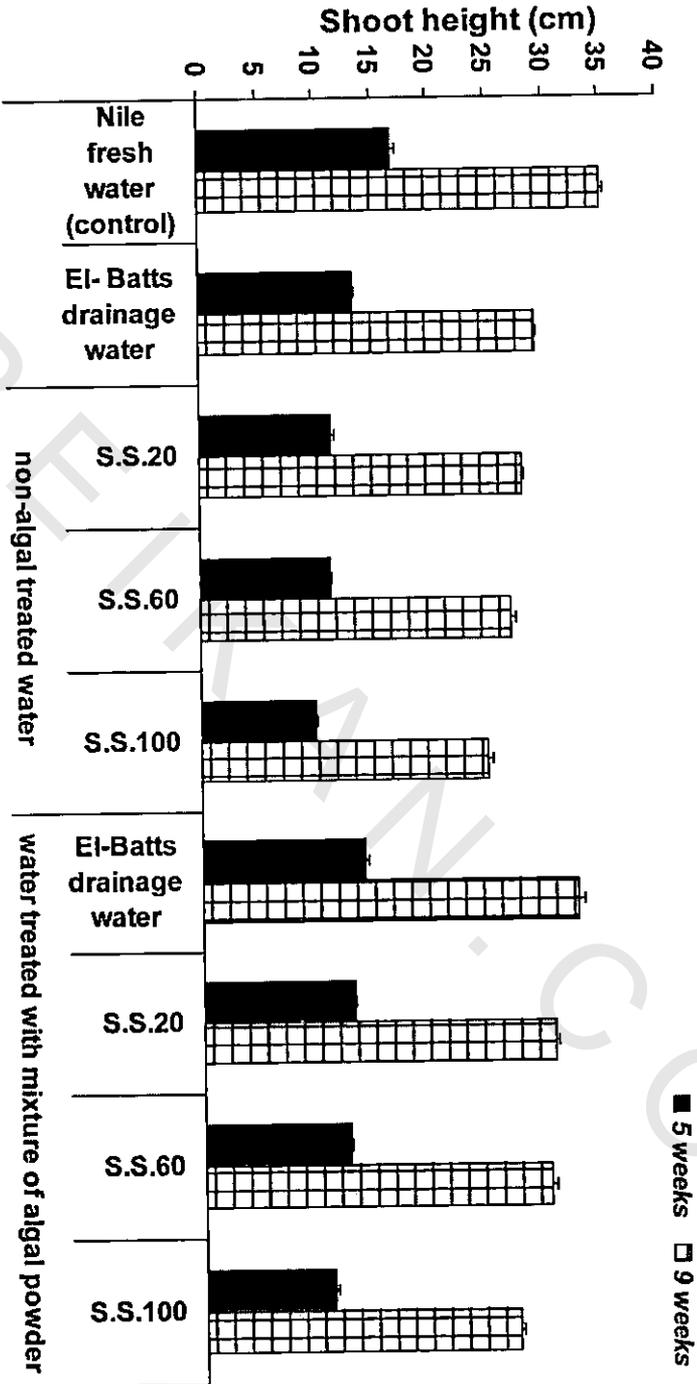


Fig. (19): Effect of low quality water and algal treated irrigation water on shoot height (cm) of wheat plants at 5 and 9-weeks from planting.

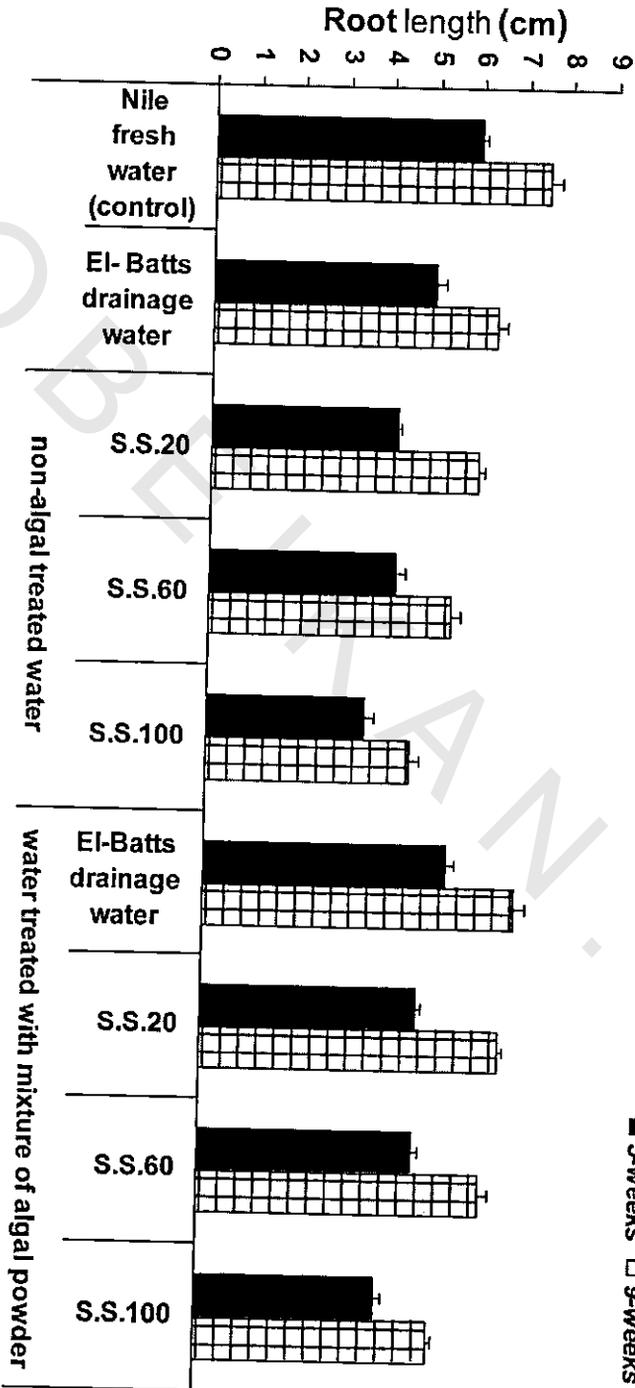


Fig. (20): Effect of low quality water and algal treated irrigation water on root length (cm) of wheat plants at 5 and 9-weeks from planting.

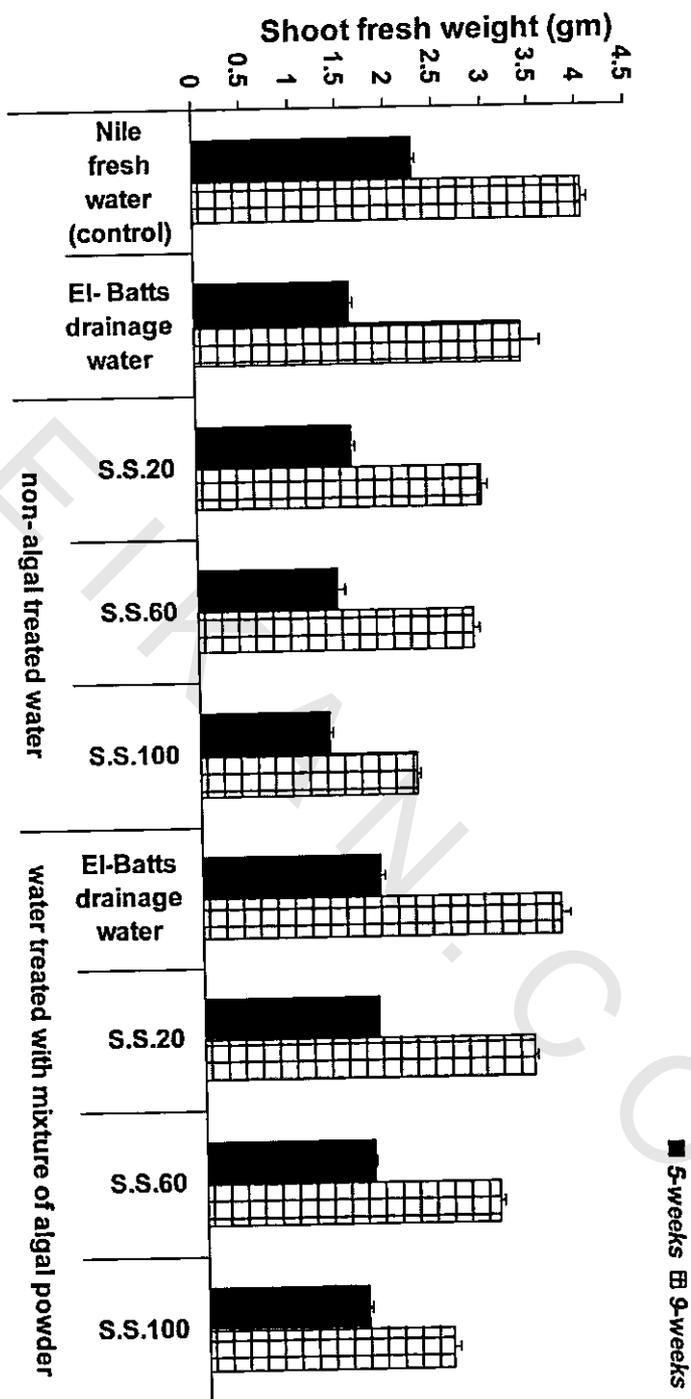


Fig. (21): Effect of low quality water and algal treated irrigation water on shoot fresh weight (gm) of wheat plants at 5 and 9-weeks from planting.

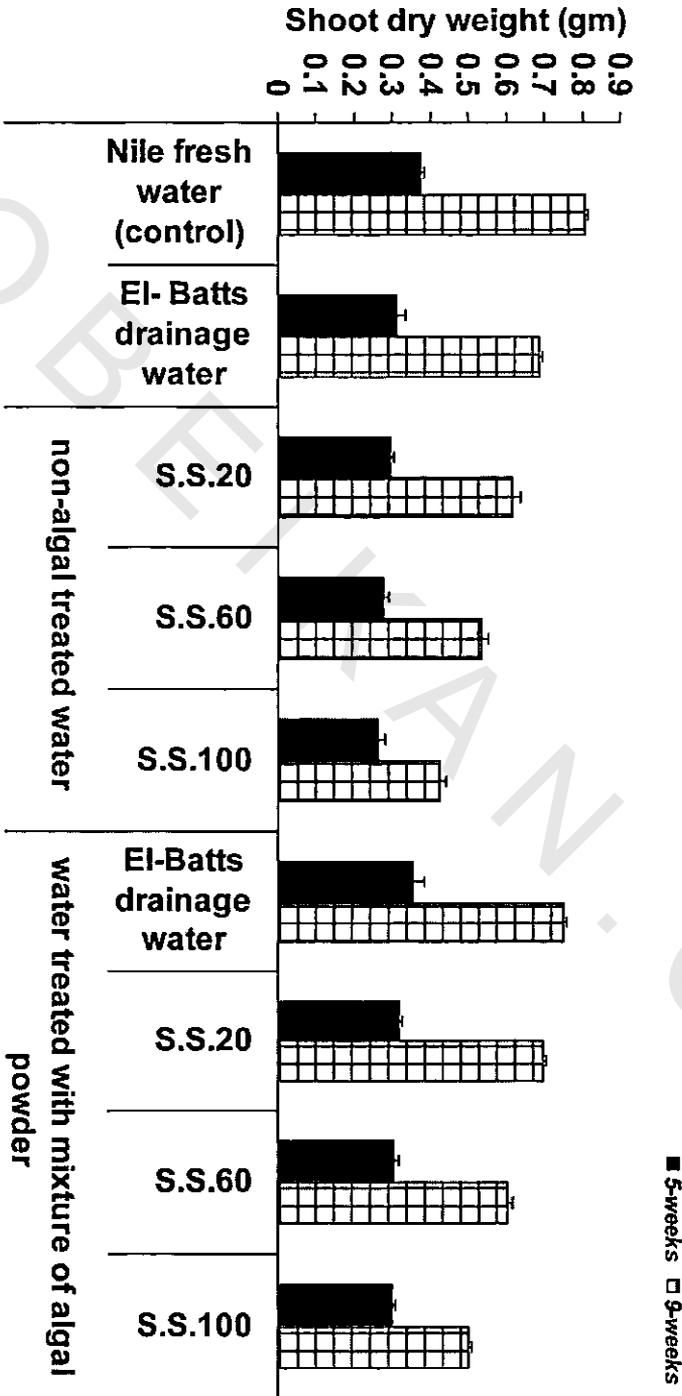


Fig. (22): Effect of low quality water and algal treated irrigation water on shoot dry weight (gm) of wheat plants at 5 and 9-weeks from planting.

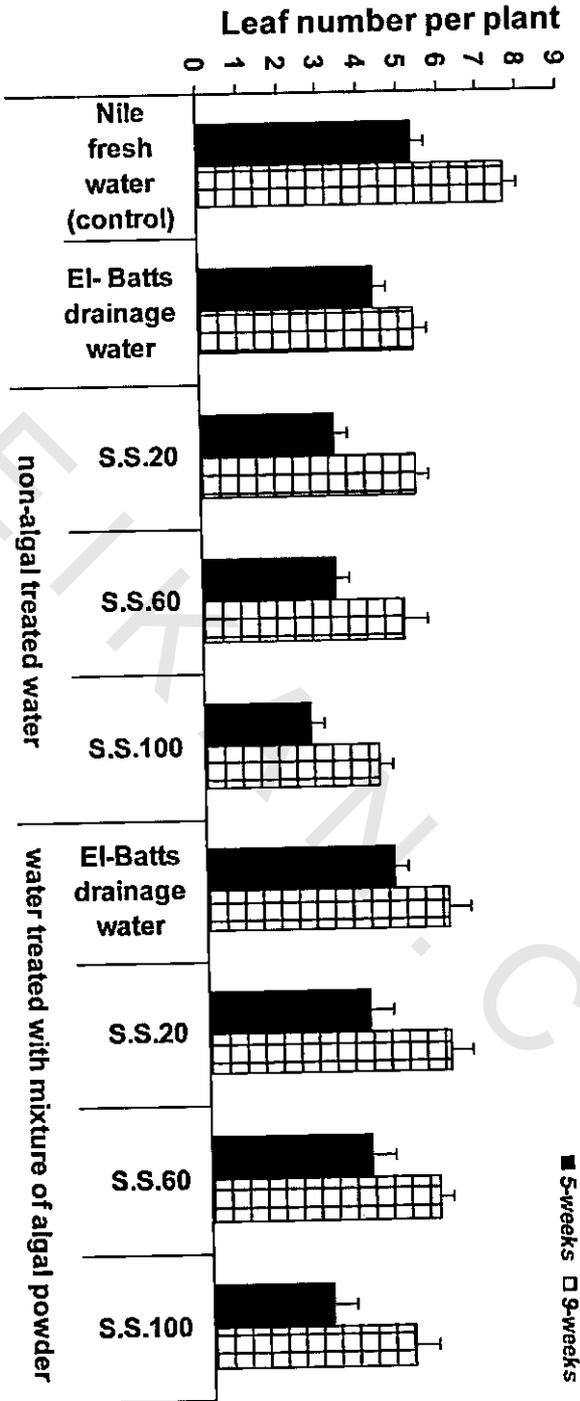


Fig. (23): Effect of low quality water and algal treated irrigation water on leaf number per plant of wheat at 5 and 9-weeks from planting.

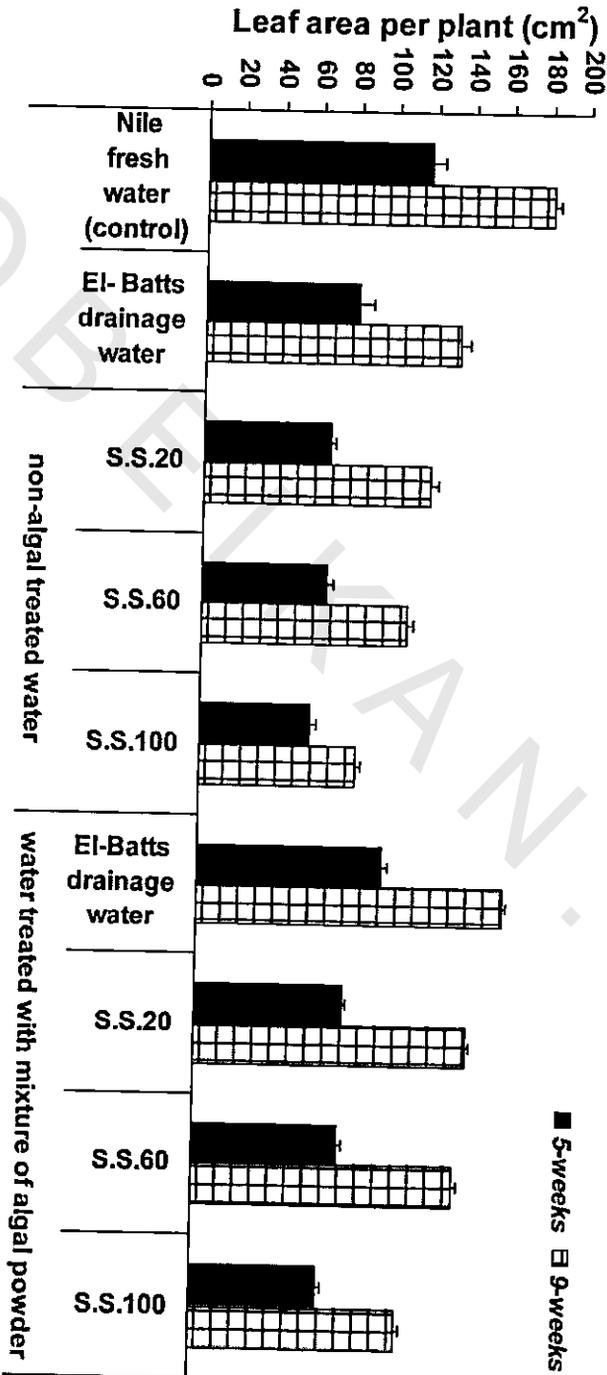


Fig. (24): Effect of low quality water and algal treated irrigation water on leaf area per plant (cm²) of wheat at 5 and 9-weeks from planting.

4.4.3.2 Faba bean:

4.4.3.2.1 Shoot height (cm):

It is clear from data recorded in Table (20 and 21) and Figure (25) that irrigating faba bean plants with El- Batts drainage water caused significant decreases in shoot height at 5 and 9- weeks old plants than the control by 8.11 and 6.33%, respectively. However, the shoot height of faba bean irrigated with algal treated of El-Batts decreased than the control by 3.38 and 3.10%, respectively. These results revealed that using treating low quality water with algae in irrigation caused a remarkable increases in shoot elongation as a result of heavy metals removal by algal powders.

The adverse effect of heavy metals in irrigated water on faba bean shoot height can be noticed clearly when the synthetic solutions contained 20, 60 and 100 ppm heavy metals were used in irrigation. The shoot height at 5- weeks old of faba bean plants irrigated with El- Batts drainage water before algal treatment was superior than those obtained from synthetic solutions of 20, 60 and 100 ppm heavy metals concentration by 1.38, 3.57 and 8.09%, respectively, whereas after algal treatment the superiority of El- Batts water over the synthetic solutions (20, 60 and 100 ppm) in shoot height reached 2.69, 5.0 and 8.39%, respectively. Similar results were achieved at 9- weeks old plants, where shoot height

resulted from El-Batts drainage water before algal treatment was higher than those obtained from synthetic solutions 20, 60 and 100 ppm by 2.64, 3.27 and 6.64%, respectively. After algal treatment, shoot height of El-Batts was higher by 2.35, 3.73 and 7.34%, respectively, for algal treated synthetic solutions of 20, 60 and 100 ppm heavy metals.

It could be concluded that irrigation faba bean plants with low quality water significantly decreased shoot height of plants at 5 or 9- weeks old plants, when compared with Nile fresh water irrigation, but the reduction at 9- weeks old plants was less than at 5- weeks old plants. However, algal treating for low quality water induced pronounced increase in shoot height than non- algal treated water.

4.4.3.2.2 Root length (cm):

Table (20 and 21) and Figure (26) indicated that root length of faba bean plants was varied due to different treatments of irrigated water at the two growth stages, i.e. 5 and 9- weeks old.

The maximum root length at 5 and 9- weeks old plants (11.17 and 13.97 cm) was observed with the Nile fresh water, whereas the lowest ones (6.47 and 8.80 cm) were detected from irrigation with synthetic solution of 100 ppm heavy metals.

Irrigation with El- Batts drainage water significantly decreased root length at 5 and 9 weeks old plant by 12.26 and 8.88%, respectively, compared with the control. However, irrigation with El- Batts algal treated water decreased the root length at 5 and 9 weeks by 7.52 and 4.08%, respectively, when compared with Nile fresh water, but without any significant differences.

Algal treatment of synthetic solutions 20, 60 and 100 ppm heavy metals leads to an increase in the root length of 5- weeks old plants, over non- treated ones by 13.36, 19.40 and 12.83%, respectively, whereas the corresponding values in root length at 9- weeks old plants were 7.31, 8.37 and 7.16%, respectively.

It is obvious that treating low quality water by algal powder resulted in an increase in root length, but this increment are still below the control values.

4.4.3.2.3 Shoot fresh weight (gm):

The results presented in Table (20 and 21) and Figure (27) revealed that the highest fresh weight of faba bean at 5 and 9- weeks old plants, i.e. 26.07 and 46.40 gm, respectively, were observed from irrigation by Nile fresh water (control). However, irrigation with non- treated synthetic solution at level 100 ppm heavy metals

gave the lowest shoot fresh weight (18.38 and 35.07 gm, respectively).

Irrigating faba bean plants with algal treated water of El-Batts or synthetic solutions of heavy metals resulted in increases in shoot fresh weight at 5- weeks old plants than the non- algal treated water by 4.82, 5.72, 4.84 and 6.91%, respectively, and by 4.02, 4.62, 5.09 and 3.22%, respectively for 9- weeks old plants.

These results proved that the faba bean shoot fresh weight significantly decreased at the two growth stages as heavy metals concentration increased in irrigated water and this adverse effect can be reduced by treating low quality water used in irrigation with algal powder.

4.4.3.2.4 Shoot dry weight (gm):

Table (20 and 21) and Figure (28) showed that using the Nile fresh water in irrigation gave the highest shoot dry weight at the two growth stages, i.e. 4.620 and 9.766 gm, respectively.

Irrigation with El- Batts drainage water significantly decreased shoot dry weight at 5 and 9- weeks old plants by 20.35 and 12.62%, respectively, comparing to those obtained from the Nile fresh water. However, the differences between shoot dry weight of plants irrigated with algal treated, observed from El- Batts

drainage water and synthetic solution of 20 ppm heavy metals at 5- and 9- weeks old plants were non-significant.

Algal treated of low quality water, i.e. El- Batts drainage water, synthetic solutions contained 20, 60 and 100 ppm heavy metals led to increases in shoot dry weight than the same non- algal treated ones at 5- weeks old plants by 7.34, 7.37, 10.30 and 10.39%, respectively, and at 9- weeks old plants by 7.79 ,11.02, 12.55 and 7.60%, respectively.

It is evident from the previous results that using algae in treating of low quality water is a beneficial method in raising the shoot dry weight of faba bean plants at the two growth stages.

4.4.3.2.5 Leaflets number/ plant:

Table (20 and 21) and Figure (29) clarified that irrigating faba bean plants with synthetic solution of 20, 60, and 100 ppm heavy metals concentration significantly decreased the leaflet number/ plant at 5- weeks old plants by 13.94, 17.42 and 22.30%, respectively, and at 9- weeks old plants by 19.61, 20.98 and 26.86%, respectively, compared to irrigation with Nile fresh water (control).

On the other hand, algal treated El- Batts drainage water or synthetic solutions of 20, 60 and 100 ppm heavy metals induced increases in the leaflets number/ plant than non- algal treated ones at

5- weeks old plants by 7.69, 9.31, 12.66 and 12.11%, respectively, whereas the corresponding values of increment at 9- weeks old plants were 6.67, 6.58, 7.44 and 6.43%, respectively.

It is evident that the sharpest reduction in the leaflets number/ plant at 5 and 9- weeks old plants was occurred when plants were irrigated with non- algal synthetic solution of 100 ppm heavy metals, compared with the control, whereas treating this water with algae reduced the inhibition effects of heavy metals on leaflets appearance at 5 and 9- weeks old plants by 12.11 and 6.43%, respectively.

4.4.3.2.6 Leaflets area/ plant (cm²):

The data recorded in Table (20 and 21) and Figure (30) indicate that the leaflets area/ plant in this study were significantly varied from each other at the two vegetation growth stages, due to the effect of different irrigation treatments.

Very highly significant reductions in leaflets area/ plant were occurred when plants were irrigated with low quality water either at 5 and 9- weeks old plants, comparing to the Nile fresh water.

In the case of irrigation with El- Batts drainage water, the leaflets area/ plant at the two growth stages were significantly reduced by 45.61 and 21.57%, respectively, than the control. However, the leaflets area/ plant, obtained from El- Batts drainage water were superior than those detected from irrigation with synthetic solutions of 20, 60 and 100 ppm heavy metals

concentration by 12.99, 20.82 and 32.11%, respectively, at 5- week old plants and by 27.21, 30.70 and 45.46%, respectively, at 9- weeks old plants.

On the other hand, treating the low quality water (i.e. El-Batts drain, synthetic solutions contained 20, 60 and 100 ppm heavy metals) with algae increase the leaflets area/ plant than the non-algal treated ones at 5- weeks old plants by 62.70, 51.72, 53.13 and 47.70%, respectively, and at 9- weeks old plants by 15.66, 21.52, 16.40 and 15.52%, respectively.

Table (20): Effect of low quality and algal treated irrigation water on some vegetative growth parameters of faba bean plants at 5- weeks from planting.

Water treatments	5 weeks						
	Shoot height (cm)	Root length (cm)	Shoot fresh weight (gm)	Shoot dry weight (gm)	Leaflets no./plant	Leaflet area/plant (cm ²)	
Nile fresh water (control)	29.60 ±0.40	11.17 ±0.15	26.07 ±0.73	4.640 ±0.13	28.7 ±0.88	602.9 ±15	
El-Batts drainage water	27.20* ±0.46	9.80** ±0.12	21.13** ±0.37	3.680* ±0.22	26.0 n.s. ±0.58	327.9*** ±8.4	
Non-algal treated water	S.S.20	26.83** ±0.18	8.23*** ±0.19	20.29** ±0.29	3.680** ±0.12	24.7** ±0.33	290.2*** ±7.1
	S.S.60	26.23** ±0.29	6.70*** ±0.21	19.83** ±0.41	3.300** ±0.14	23.7** ±0.33	271.4*** ±13
	S.S.100	25.00*** ±0.12	6.47*** ±0.24	18.38*** ±0.33	3.080*** ±0.07	22.3** ±0.88	248.2*** ±6.8
Water treated with mixture of algal powder	El-Batts	28.60 n.s. ±0.50	10.33 n.s. ±0.23	22.18 n.s. ±0.23	3.950 n.s. ±0.17	28.0 n.s. ±0.58	533.5*** ±12
	S.S.20	27.83* ±0.22	9.33* ±0.23	21.47 n.s. ±0.43	3.930 n.s. ±0.12	27.0* ±0.58	440.3*** ±9.4
	S.S.60	27.17 n.s. ±0.38	8.00 n.s. ±0.45	20.79 n.s. ±0.54	3.640 n.s. ±0.05	26.7** ±0.33	415.6*** ±7.6
S.S.100	26.20* ±0.32	7.30 n.s. ±0.40	19.65 n.s. ±0.45	3.400 n.s. ±0.10	25.0 n.s. ±0.58	366.6*** ±8.1	

Non significant n.s.

Significant (*) at P > 0.05

Highly significant (**)

at P ≤ 0.01

Very highly significant (***)

at P ≤ 0.001

S.S.20 = Synthetic solution of heavy metals (4 ppm of Cd, 4 ppm of Pb, 4 ppm of Ni, 4 ppm of Zn and 4 ppm of Cu)

S.S.60 = Synthetic solution of heavy metals (12 ppm of Cd, 12 ppm of Pb, 12 ppm of Ni, 12 ppm of Zn and 12 ppm of Cu)

S.S.100 = Synthetic solution of heavy metals (20 ppm of Cd, 20 ppm of Pb, 20 ppm of Ni, 20 ppm of Zn and 20 ppm of Cu)

Mixture of algal powder (10 gm of powder of *U. lactuca*, *C. mediterranea* and *J. rubens*)

able (21): Effect of low quality and algal treated irrigation water on some vegetative growth parameters of faba bean plants at 9- weeks from planting.

Water treatments	9 weeks						
	Shoot height (cm)	Root length (cm)	Shoot fresh weight (gm)	Shoot dry weight (gm)	Leaflets no./plant	Leaflets area/plant (cm ²)	
Nile fresh water (control)	52.60 ±0.31	13.97 ±0.18	46.400 ±1.1	9.767 ±0.23	51.0 ±1.7	1271.50 ±19	
El-Batts drainage water	49.27** ±0.38	12.73* ±0.26	41.533* ±0.75	8.567* ±0.20	45.0 n.s. ±1.7	997.20** ±46	
Non-algal treated water	S.S.20	47.97**** ±0.15	9.57**** ±0.33	37.667** ±0.52	7.567** ±0.30	41.0** ±0.58	783.87**** ±17
	S.S.60	47.67**** ±0.23	9.20**** ±0.23	37.300** ±0.69	7.433** ±0.30	40.3** ±0.88	762.97**** ±20
Water treated with	S.S.100	46.00**** ±0.45	8.80**** ±0.26	35.066**** ±0.60	6.667**** ±0.15	37.3** ±0.88	685.53**** ±33
	El-Batts	50.97* ±0.38	13.40 n.s. ±0.26	43.200 n.s. ±0.53	9.233 n.s. ±0.19	48.0 n.s. ±1.7	1153.40* ±36
mixture of algal powder	S.S.20	49.77**** ±0.18	10.27 n.s. ±0.22	39.400* ±0.26	8.400 n.s. ±0.26	43.7* ±0.33	952.60** ±17
	S.S.60	49.07* ±0.35	9.97 n.s. ±0.26	39.200 n.s. ±0.32	8.367 n.s. ±0.32	43.3 n.s. ±0.88	888.07* ±28
S.S.100	47.23 n.s. ±0.26	9.43 n.s. ±0.18	36.200 n.s. ±0.52	7.167* ±0.12	39.7 n.s. ±0.67	791.90 n.s. ±31	

Non significant n.s. at P > 0.05
 Significant (*) at P ≤ 0.05
 Highly significant (**) at P ≤ 0.01
 Very highly significant (***) at P ≤ 0.001
 S.S.20 = Synthetic solution of heavy metals (4 ppm of Cd, 4 ppm of Pb, 4 ppm of Ni, 4 ppm of Zn and 4 ppm of Cu)
 S.S.60 = Synthetic solution of heavy metals (12 ppm of Cd, 12 ppm of Pb, 12 ppm of Ni, 12 ppm of Zn and 12 ppm of Cu)
 S.S.100 = Synthetic solution of heavy metals (20 ppm of Cd, 20 ppm of Pb, 20 ppm of Ni, 20 ppm of Zn and 20 ppm of Cu)
 Mixture of algal powder (10 gm of powder of *U. lactuca*, *C. mediterranea* and *J. rubens*)

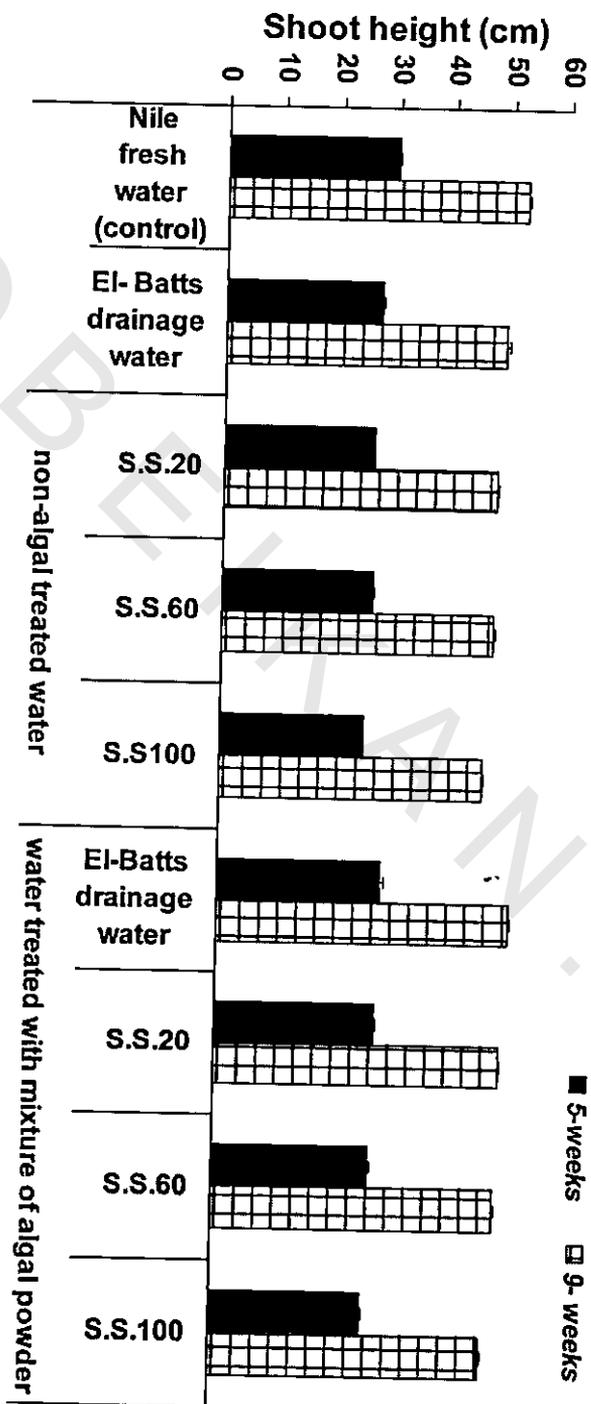


Fig. (25): Effect of low quality water and algal treated irrigation water on shoot height (cm) of faba bean plants at 5 and 9 - weeks from planting.

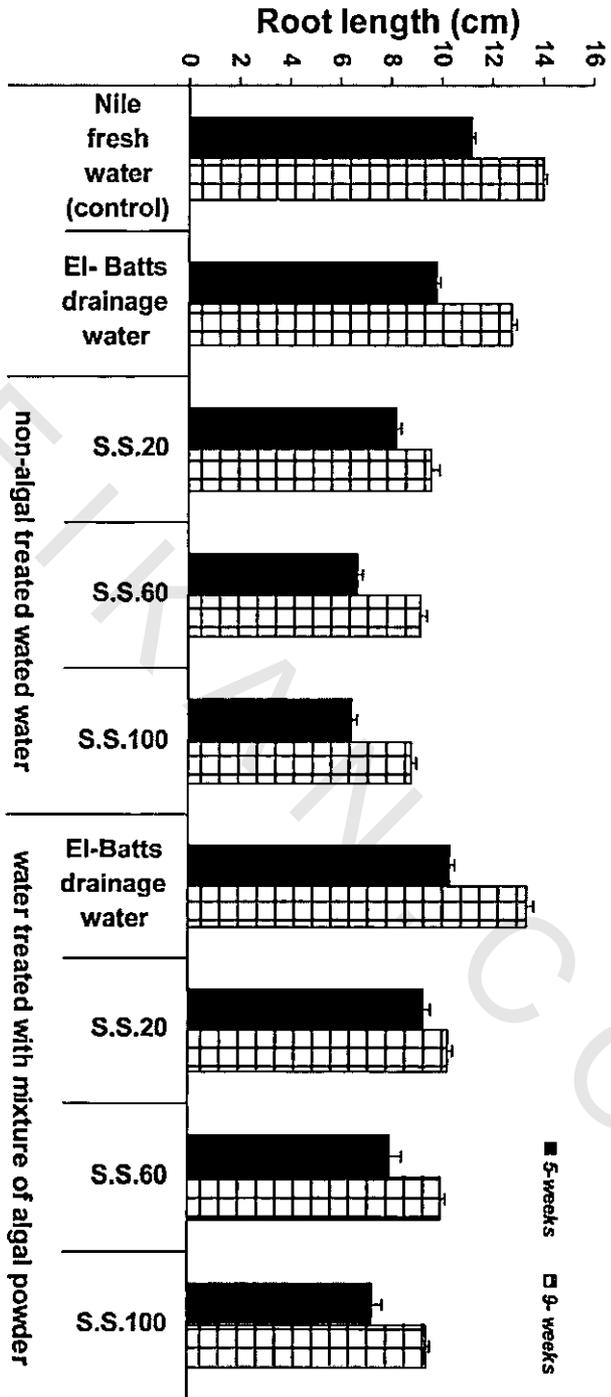


Fig. (26): Effect of low quality water and algal treated irrigation water on root length (cm) of faba bean plants at 5 and 9-weeks from planting.

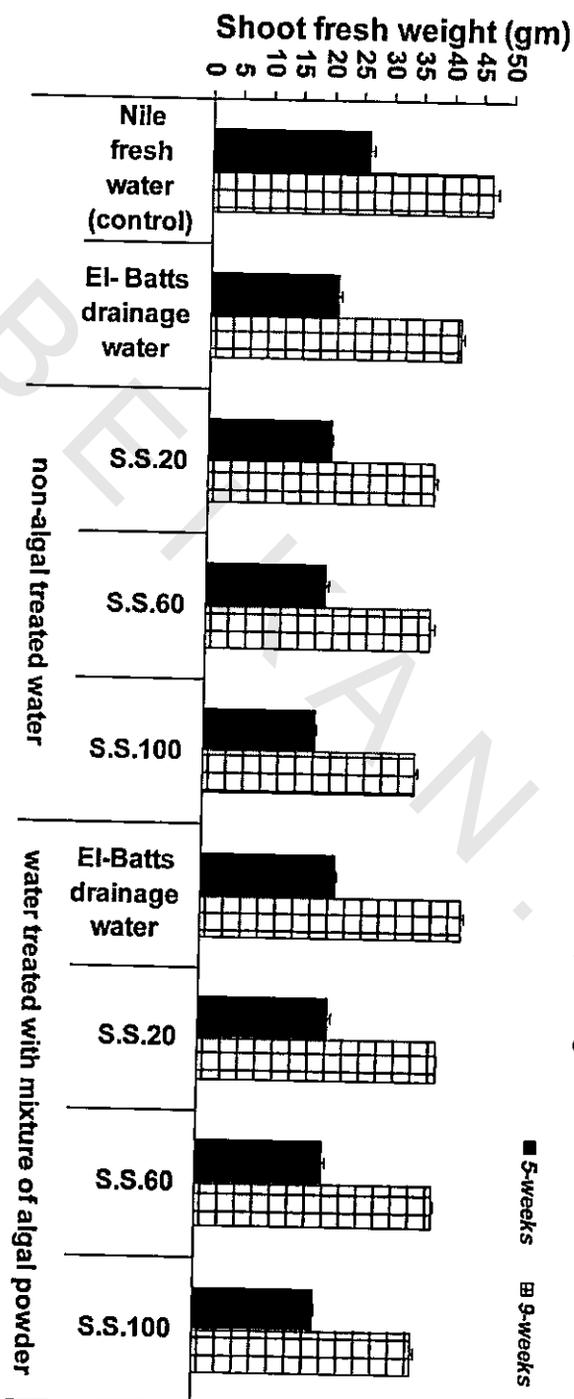


Fig. (27): Effect of low quality water and algal treated irrigation water on shoot fresh weight (gm) of faba bean plants at 5 and 9 - weeks from planting.

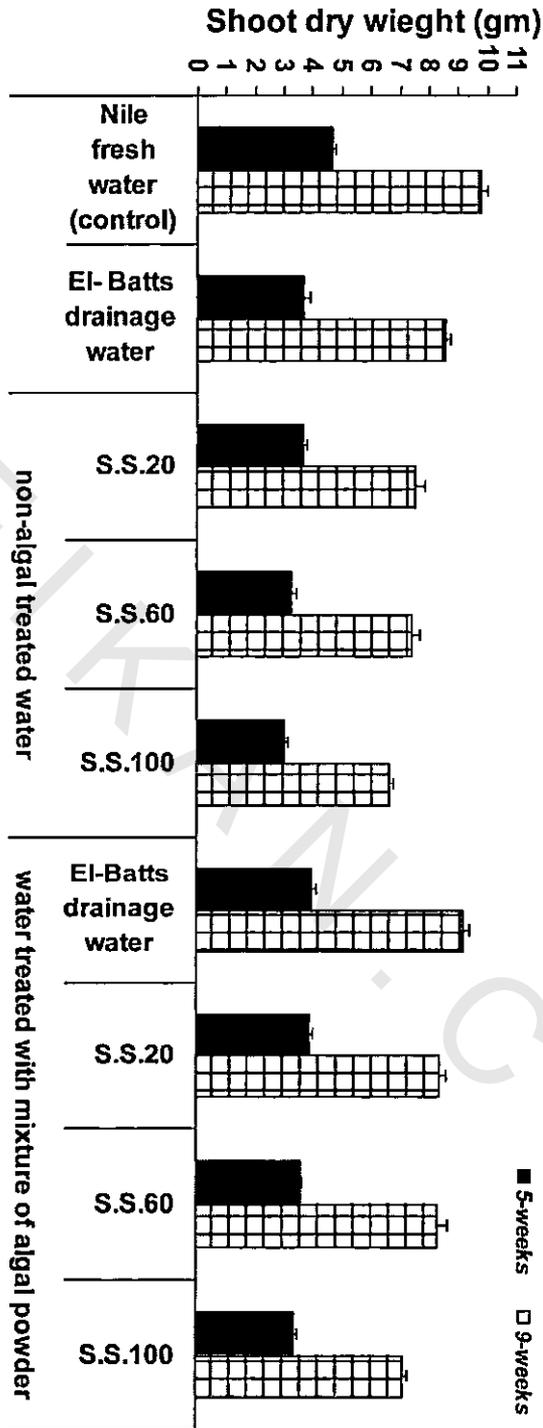


Fig. (28): Effect of low quality water and algal treated irrigation water on shoot dry weight (gm) of faba bean plants at 5 and 9 weeks from planting.

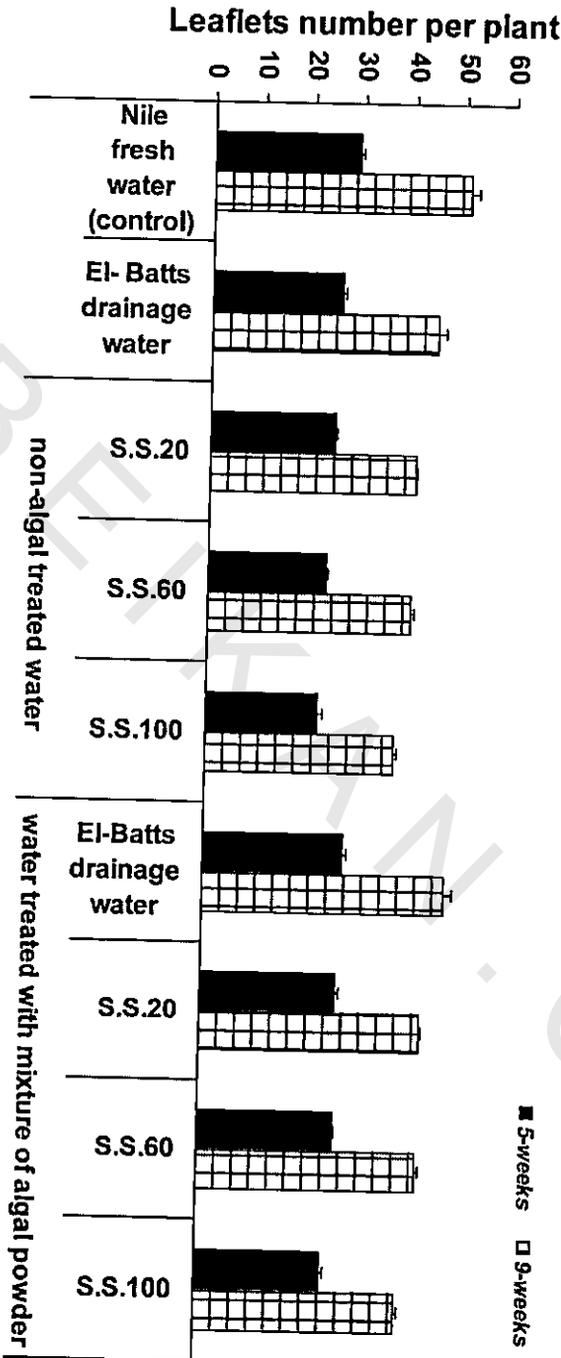


Fig. (29): Effect of low quality water and algal treated irrigation water on leaflets number per plant of faba bean at 5 and 9-weeks from planting.

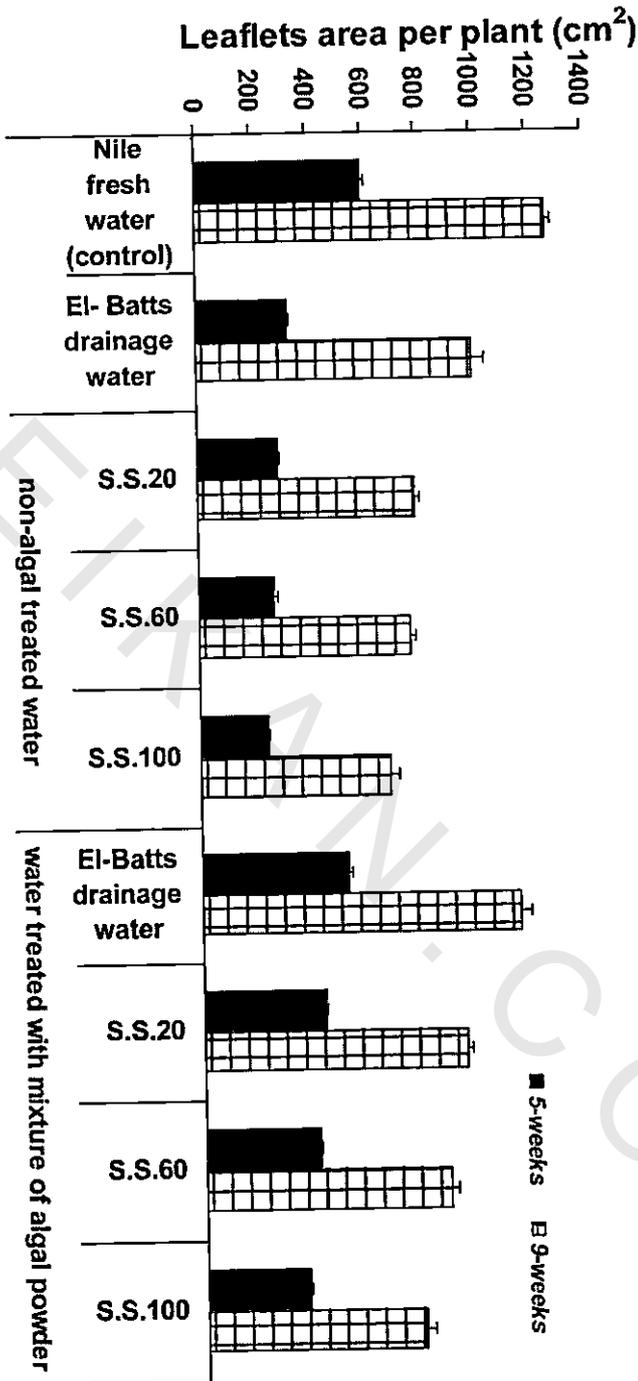


Fig. (30): Effect of low quality water and algal treated irrigation water on leaflets area per plant of faba bean at 5 and 9-weeks from planting.

4.4.4 Photosynthetic pigments:

4.4.4.1 Wheat:

Photosynthetic pigment contents, i.e. chlorophyll a, b, carotenoids and total pigments in relation to irrigation with treated and non- algal treated drainage and synthetic solutions were estimated in wheat leaves at 5 and 9 weeks old plants are presented in Table (22 and 23) and graphed in Figures (31 and 32). It is clear from the results that, chlorophyll a and b, a+b, carotenoids and total pigments at the two vegetative growth stages (5 and 9- weeks old plants) appeared to decrease by increasing heavy metals concentration when irrigated with low quality water. However, there was an increase in all pigments content as a result of the irrigation with algal treated water of all heavy metal concentrations (El-Batts, synthetic solutions 20, 60 and 100 ppm) compared with non- treated ones.

Maximum values of chlorophyll a at 5 and 9- weeks old plants were observed in plants irrigated by Nile fresh water (2.730 and 7.627 mg/gm F.W.), followed by El-Batts algal treated water (2.423 and 6.137 mg/gm F.W.), then algal treated synthetic solution of 20 ppm heavy metals (2.13 and 4.84 mg/gm F.W.).

Concerning, chlorophyll b at 5 and 9- weeks old plant irrigation with Nile fresh water gave the highest values, i.e. 1.34 and 3.86% mg/gm F.W., respectively. However irrigation with non-treated El-Batts water or synthetic solutions caused highly significant reduction in chlorophyll b at 5-weeks old plants by

61.44, 63.41, 66.05 and 78.67%, respectively, when compared with the control. At 9-weeks old plants the corresponding reduction percentage were 29.66, 42.44, 64.96 and 89.22%, respectively. On the other hand, treating El- Batts water or synthetic solutions of 20, 60 and 100 ppm with algae induced very highly significant decreases in chlorophyll b than the control at 5- weeks old plant by 3.32, 14.53, 19.64 and 32.67%, respectively. At 9- weeks old plant the reduction percentage than the control were 15.46, 32.05, 43.33 and 73.09%, respectively.

Regarding the carotenoids content at 5 and 9- weeks old plants, the maximum values were detected from irrigation with Nile fresh water (2.880 and 5.340 mg/gm F.W.). Irrigation with algal treated drainage and synthetic solutions gave non-significant increases in the carotenoids content than non-algal treated ones at 5 and 9- weeks old plants; but they were lower than the control.

With respect to total pigments, the highest total pigment values at 5 and 9- weeks old plants (6.954 and 16.830 mg/gm F.W.) were obtained from irrigation with Nile fresh water, whereas the lowest ones (3.641 and 7.240 mg/gm F.W.) were obtained from non-algal synthetic solution of 100 ppm heavy metals. The algal treated of El- Batts drainage water significantly increased the total pigments at 5 and 9- weeks old plants by 32.34 and 18.72%, respectively, compared with the non-algal treatment drainage. These obtained results were found to be true for the algal treated synthetic solutions of 20, 60 and 100 ppm heavy metals concentration at 5 and 9- weeks old plants.

Table (22): Effect of low quality and algal treated irrigation water on leaf pigments content of wheat plants at 5- weeks from planting.

Water treatments	5 weeks					
	Chlorophyll (a) (mg/gm F.W.)	Chlorophyll (b) (mg/gm F.W.)	Chlorophyll (a + b) (mg/gm F.W.)	Carotenoids (mg/gm F.W.)	Total pigments (mg/gm F.W.)	
Nile fresh water (control)	2.730 ±0.16	1.340 ±0.047	4.070 ±0.11	2.880 ±0.28	6.954 ±0.22	
El-Batts drainage water	1.813* ±0.17	0.830*** ±0.013	2.643** ±0.18	2.110 n.s. ±0.24	4.753** ±0.37	
Non-algal treated water	S.S.20	1.677** ±0.12	0.820*** ±0.012	2.497*** ±0.13	1.630* ±0.17	4.123** ±0.30
	S.S.60	1.563** ±0.05	0.807*** ±0.008	2.370*** ±0.05	1.427** ±0.13	3.797** ±0.14
	S.S.100	1.500** ±0.11	0.750*** ±0.007	2.250*** ±0.10	1.390** ±0.18	3.641*** ±0.16
Water treated with mixture of algal powder	El-Batts	2.423* ±0.12	1.297*** ±0.004	3.720** ±0.12	2.571 n.s. ±0.14	6.292* ±0.25
	S.S.20	2.130 n.s. ±0.19	1.170*** ±0.019	3.301* ±0.19	1.830 n.s. ±0.12	5.131* ±0.20
	S.S.60	1.980** ±0.09	1.120*** ±0.020	3.100** ±0.09	1.787 n.s. ±0.22	4.887* ±0.26
	S.S.100	1.750 n.s. ±0.05	1.010*** ±0.024	2.765** ±0.64	1.513 n.s. ±0.15	4.273 n.s. ±0.20

Non significant n.s. at P > 0.05

Significant (*) at P ≤ 0.05

S.S.20 = Synthetic solution of heavy metals (4 ppm of Cd, 4 ppm of Pb, 4 ppm of Ni, 4 ppm of Zn and 4 ppm of Cu)

S.S.60 = Synthetic solution of heavy metals (12 ppm of Cd, 12 ppm of Pb, 12 ppm of Ni, 12 ppm of Zn and 12 ppm of Cu)

S.S.100 = Synthetic solution of heavy metals (20 ppm of Cd, 20 ppm of Pb, 20 ppm of Ni, 20 ppm of Zn and 20 ppm of Cu)

Mixture of algal powder (10 gm of powder of *U. lactuca*, *C. mediterranea* and *J. rubens*)

Highly significant (**)

Very highly significant (***)

at P ≤ 0.01

at P ≤ 0.001

Table (23): Effect of low quality and algal treated irrigation water on leaf pigments content of wheat plants at 9- weeks from planting.

Water treatments	9 weeks					
	Chlorophyll (a) (mg/gm F.W.)	Chlorophyll (b) (mg/gm F.W.)	Chlorophyll (a + b) (mg/gm F.W.)	Carotenoids (mg/gm F.W.)	Total pigments (mg/gm F.W.)	
Nile fresh water (control)	7.627 ±0.45	3.860 ±0.12	11.490 ±0.08	5.340 ±0.20	16.830 ±0.030	
El-Batts drainage water	S.S.20	5.267** ±0.37	2.977** ±0.06	8.247*** ±0.04	2.950** ±0.41	11.197*** ±0.06
	S.S.60	4.390** ±0.31	2.710** ±0.10	7.100*** ±0.13	2.610** ±0.32	9.710*** ±0.12
Non-algal treated water	S.S.60	4.193** ±0.42	2.340*** ±0.10	6.536*** ±0.06	2.433** ±0.35	8.966*** ±0.02
	S.S.100	3.413** ±0.30	2.040*** ±0.07	5.450*** ±0.09	1.790*** ±0.25	7.240*** ±0.03
Water treated with mixture of algal powder	El-Batts	6.137 n.s. ±0.32	3.343** ±0.06	9.483*** ±0.11	3.813 n.s. ±0.37	13.293*** ±0.02
	S.S.20	4.840 n.s. ±0.25	2.923 n.s. ±0.05	7.763** ±0.07	3.317 n.s. ±0.21	11.080*** ±0.03
	S.S.60	4.790 n.s. ±0.10	2.693* ±0.08	7.483** ±0.18	3.017 n.s. ±0.35	10.503*** ±0.09
	S.S.100	3.863 n.s. ±0.24	2.230 n.s. ±0.02	6.090** ±0.04	2.143 n.s. ±0.11	8.233*** ±0.01

Non significant n.s. at P > 0.05

Significant (*) at P ≤ 0.05

Highly significant (***) Very highly significant (****)

at P ≤ 0.01 at P ≤ 0.001

S.S.20 = Synthetic solution of heavy metals (4 ppm of Cd, 4 ppm of Pb, 4 ppm of Ni, 4 ppm of Zn and 4 ppm of Cu)

S.S.60 = Synthetic solution of heavy metals (12 ppm of Cd, 12 ppm of Pb, 12 ppm of Ni, 12 ppm of Zn and 12 ppm of Cu)

S.S.100 = Synthetic solution of heavy metals (20 ppm of Cd, 20 ppm of Pb, 20 ppm of Ni, 20 ppm of Zn and 20 ppm of Cu)

Mixture of algal powder (10 gm of powder of *U. lactuca*, *C. mediterranea* and *J. rubens*)

Fig. (31): Effect of low quality and algal treated irrigation water on photosynthetic pigments content (mg/gm F.W.) of wheat plants at 5-weeks from planting.

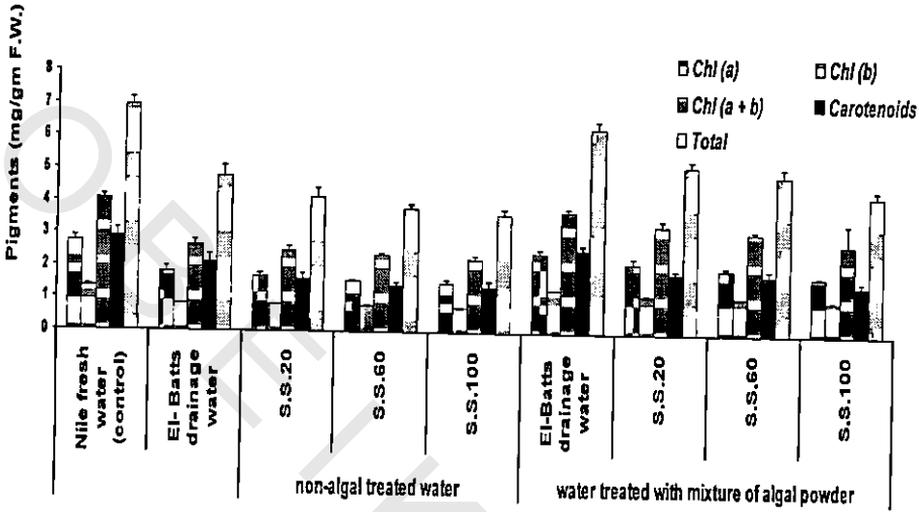
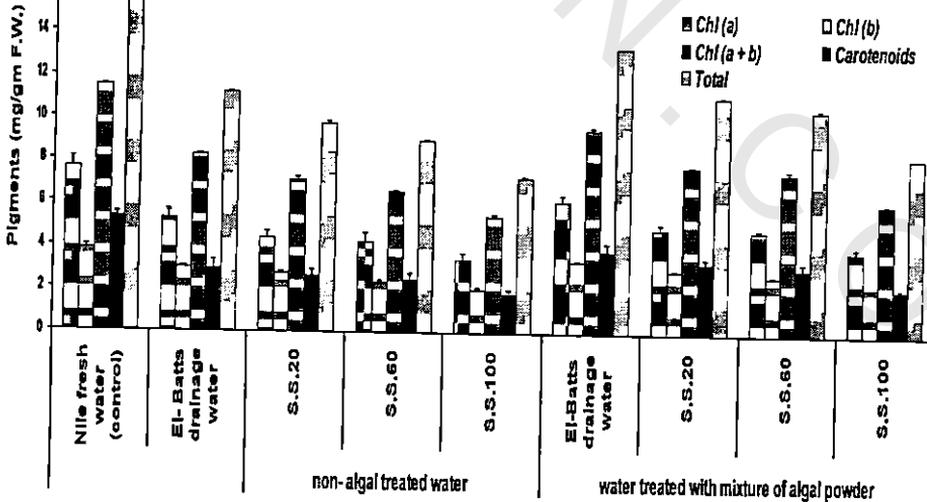


Fig. (32): Effect of low quality and algal treated irrigation water on leaf photosynthetic pigments content (mg/gm F.W.) of wheat plants at 9-weeks from planting.



4.4.4.2 Faba bean:

The data recorded in Table (24 and 25) and Figures (33 and 34) demonstrated that the photosynthetic pigments in faba bean leaflets (chlorophyll a, chlorophyll b, chlorophyll a+b, carotenoids and total pigments) at 5 and 9- weeks old plants from planting were significantly affected by different untreated irrigation treatments applied in this study.

It is evident that irrigating faba bean plants with low quality water, i.e. El-Batts drainage water or synthetic solution of 20, 60 and 100 ppm heavy metals caused considerable reduction in chlorophyll a at 5- weeks old plants by 27.98, 48.09, 49.63 and 55.50%, respectively, when compared with plants irrigated by Nile fresh water. However, the corresponding reduction values in chlorophyll a at 9-weeks old plants were 21.57, 29.57, 30.32 and 34.22%, respectively.

The results revealed that treating El-Batts drainage water with algae gave non-significant difference in chlorophyll a at 5 and 9- weeks old plants, as compared with the control.

Increasing heavy metal concentrations in irrigated water before algal treatment from 20 to 60 or 100 ppm decreased significantly chlorophyll a at 5 and 9-weeks old plants. Also, the treated water of 20, 60 and 100 ppm heavy metals increased chlorophyll a content in leaflets at 5 and 9- weeks old plants, but without significant differences.

Regarding chlorophyll b in leaflets of faba bean, results indicated that the maximum values were resulted from irrigating with Nile fresh water at 5 and 9-weeks old plants.

Irrigating with El-Batts drainage water reduced chlorophyll b by 34.89 and 23.06% at 5 and 9- weeks old plants than the control. More reduction in chlorophyll b were noticed as heavy metals concentration in irrigated water increased at 5 and 9- weeks old plants.

Irrigation with algal treated water of El-Batts drainage or synthetic solutions of 20, 60 and 100 ppm heavy metals at 5 and 9-weeks old plants caused increases in chl b than the non-treated water.

Concerning the carotenoids content of faba bean leaflets, data illustrated in Table (24 and 25) and Figures (33 and 34) show gradual decreases in carotenoids with increasing heavy metals concentration in irrigation water. The maximum carotenoids content at 5 and 9- weeks plants old were observed from using Nile fresh water, followed by algal treated water of El-Batts drainage. The lowest carotenoids values at 5 and 9- weeks plants old (1.050 and 3.717 mg/gm F.W.) were detected from irrigation with synthetic solution contained 100 ppm heavy metals.

The results indicated that irrigation with El-Batts drainage water at 5-weeks old plants significantly increased carotenoids than irrigation with synthetic solution of 20 ppm heavy metals. On the other hand, there was highly significant increase in carotenoids at 9-

weeks old plants to a value near that obtained from with Nile fresh water irrigation due to algal treatment of El-Batts drainage water and synthetic solution of 20 ppm heavy metals.

With respect to total pigments at 5 and 9- weeks old plants the results revealed that increasing heavy metals in irrigation water induced substantial role in total pigments reduction in faba bean leaflets. Total pigments were significantly decreased at 5 and 9- weeks old plants by irrigation with El-Batts drainage water compared to the control.

Irrigation by treated low quality water, i.e. El-Batts and synthetic solutions of 20, 60 and 100 ppm heavy metals with algae resulted in significant increases in total pigments than non- treated ones at 5- weeks plants by 29.89, 37.30, 34.09 and 33.38%, respectively, whereas the corresponding values at 9- weeks old plants reached 12.43, 12.25, 13.1 and 8.02%, respectively.

As a general trend, the obtained results pointed out that photosynthetic pigments content of faba bean leaflets irrigated with algal treated water increased as plant age increased from 5 to 9- weeks. Also, the photosynthetic pigments were significantly inhibited with using low quality water contained different concentrations of heavy metals, comparing with Nile fresh water. However, bioremediation of heavy metals (algal treated water) caused remarkable increases in photosynthetic pigments than the non- algal treated ones, but this increment did not reached the levels that obtained by using Nile fresh water, either at 5- weeks or at 9- weeks old plants.

Table (24): Effect of low quality and algal treated irrigation water on leaf pigments content of faba bean plants at 5- weeks from planting.

Water treatments	5 weeks					
	Chlorophyll (a) (mg/gm F.W.)	Chlorophyll (b) (mg/gm F.W.)	Chlorophyll (a + b) (mg/gm F.W.)	Carotenoids (mg/gm F.W.)	Total pigments (mg/gm F.W.)	
Nile fresh water (control)	3.506 ±0.02	2.396 ±0.03	5.903 ±0.05	2.930 ±0.05	8.833 ±0.06	
El-Batts drainage water	2.525** ±0.22	1.560*** ±0.51	4.089*** ±0.19	2.067** ±0.15	6.155** ±0.34	
Non-algal treated water	S.S.20	1.820*** ±0.05	1.160*** ±0.05	2.980*** ±0.01	1.623** ±0.22	4.603*** ±0.22
	S.S.60	1.767*** ±0.17	0.950*** ±0.13	2.717*** ±0.12	1.400*** ±0.04	4.117*** ±0.10
	S.S.100	1.560*** ±0.12	0.813*** ±0.14	2.373*** ±0.21	1.050*** ±0.04	3.423*** ±0.17
Water treated with mixture of algal powder	El-Batts	3.055 n.s. ±0.03	2.113** ±0.06	5.168** ±0.06	2.827** ±0.10	7.995** ±0.15
	S.S.20	2.430*** ±0.03	1.710*** ±0.03	4.140*** ±0.05	2.180 n.s. ±0.13	6.320** ±0.17
	S.S.60	2.157 n.s. ±0.31	1.340 n.s. ±0.10	3.496* ±0.22	2.023** ±0.12	5.519** ±0.19
S.S.100	1.767 n.s. ±0.06	1.157 n.s. ±0.11	2.923 n.s. ±0.11	1.647* ±0.18	4.567** ±0.07	

Non significant n.s. at P > 0.05
 Significant (*) at P ≤ 0.05
 Highly significant (**) at P ≤ 0.01
 Very highly significant (***) at P ≤ 0.001
 S.S.20 = Synthetic solution of heavy metals (4 ppm of Cd, 4 ppm of Pb, 4 ppm of Ni, 4 ppm of Zn and 4 ppm of Cu)
 S.S.60 = Synthetic solution of heavy metals (12 ppm of Cd, 12 ppm of Pb, 12 ppm of Ni, 12 ppm of Zn and 12 ppm of Cu)
 S.S.100 = Synthetic solution of heavy metals (20 ppm of Cd, 20 ppm of Pb, 20 ppm of Ni, 20 ppm of Zn and 20 ppm of Cu)
 Mixture of algal powder (10 gm of powder of *U. lactuca*, *C. mediterranea* and *J. rubens*)

Table (25): Effect of low quality and algal treated irrigation water on leaf pigments content of faba bean plants at 9- weeks from planting.

Water treatments	9 weeks					
	Chlorophyll (a) (mg/gm F.W.)	Chlorophyll (b) (mg/gm F.W.)	Chlorophyll (a + b) (mg/gm F.W.)	Carotenoids (mg/gm F.W.)	Total pigments (mg/gm F.W.)	
Nile fresh water (control)	9.243 ±0.10	5.303 ±0.35	14.547 ±0.44	5.243 ±0.06	19.790 ±0.50	
El-Batts drainage water	7.240* ±0.52	4.080* ±0.26	11.320** ±0.23	4.423*** ±0.07	15.743** ±0.35	
Non-algal treated water	S.S.20	6.510*** ±0.31	3.590** ±0.23	10.100** ±0.39	4.397*** ±0.03	14.497** ±0.42
	S.S.60	6.443*** ±0.27	2.183** ±0.39	8.627*** ±0.37	4.163* ±0.27	12.790*** ±0.31
	S.S.100	6.080*** ±0.16	2.037*** ±0.21	8.117*** ±0.33	3.717** ±0.22	11.833*** ±0.45
Water treated with mixture of algal powder	El-Batts	7.703 n.s. ±0.42	4.803 n.s. ±0.23	12.507* ±0.22	5.197** ±0.08	17.703** ±0.17
	S.S.20	6.950 n.s. ±0.34	4.137 n.s. ±0.12	11.087 n.s. ±0.34	5.187** ±0.16	16.273* ±0.50
	S.S.60	6.907 n.s. ±0.11	2.823 n.s. ±0.17	9.730 n.s. ±0.19	4.733 n.s. ±0.20	14.463* ±0.39
S.S.100	6.380 n.s. ±0.14	2.407 n.s. ±0.13	8.787 n.s. ±2.8	4.003 n.s. ±0.43	12.790 n.s. ±0.49	

Non significant n.s. at P > 0.05

Significant (*) at P < 0.05

Highly significant (***)

at P < 0.01

S.S.20 = Synthetic solution of heavy metals (4 ppm of Cd, 4 ppm of Pb, 4 ppm of Ni, 4 ppm of Zn and 4 ppm of Cu)

S.S.60 = Synthetic solution of heavy metals (12 ppm of Cd, 12 ppm of Pb, 12 ppm of Ni, 12 ppm of Zn and 12 ppm of Cu)

S.S.100 Synthetic solution of heavy metals (20 ppm of Cd, 20 ppm of Pb, 20 ppm of Ni, 20 ppm of Zn and 20 ppm of Cu)

Mixture of algal powder (10 gm of powder of *U. lactuca*, *C. mediterranea* and *J. rubens*)

Fig. (33): Effect of low quality and algal treated irrigation water on photosynthetic pigments content (mg/gm F.W.) of faba bean plants at 5-weeks from planting.

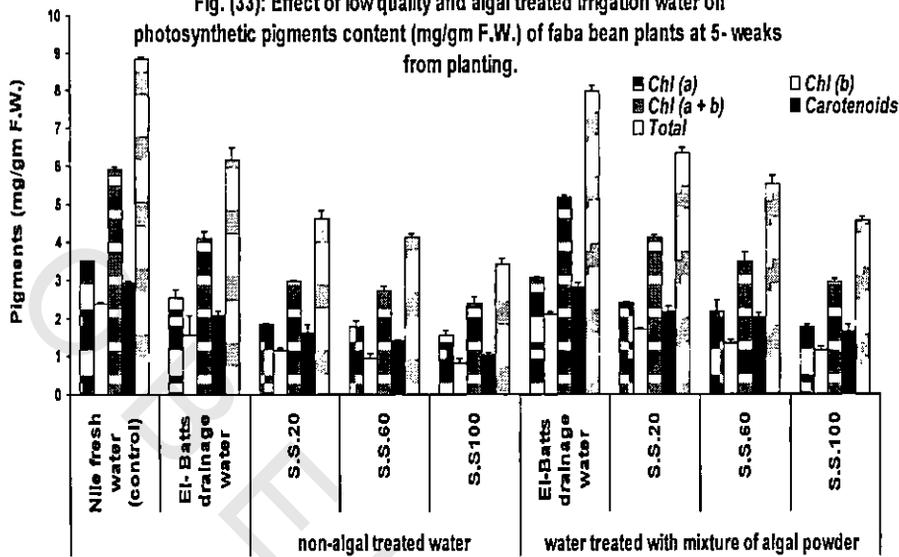
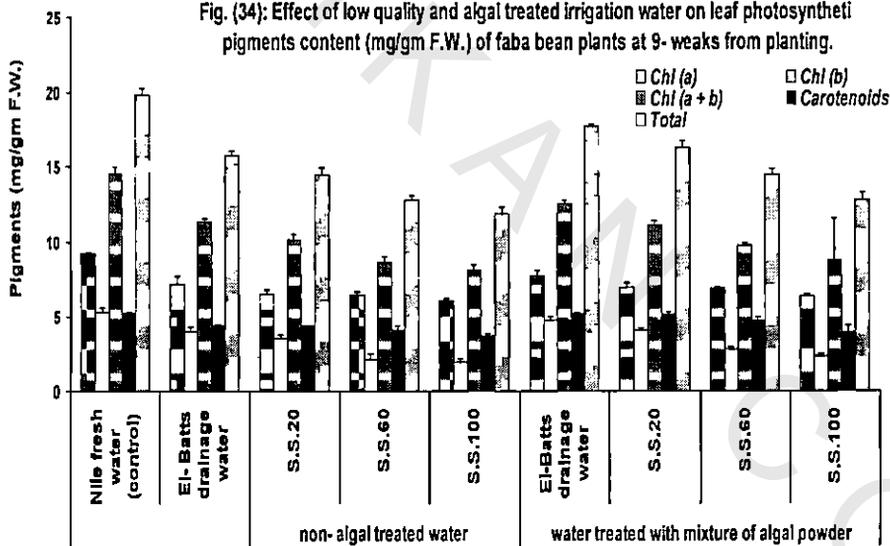


Fig. (34): Effect of low quality and algal treated irrigation water on leaf photosynthetic pigments content (mg/gm F.W.) of faba bean plants at 9-weeks from planting.



4.4.5 Chemical components of seeds:

4.4.5.1 Total carbohydrate content (%):

4.4.5.1.1 Wheat:

The results presented in Table (26) and Figure (35) reveal that the total carbohydrate content values in wheat grains were varied significantly due to the different low quality water, before and after algal treatment.

The highest carbohydrate content value (77.98%) was obtained from the Nile fresh water (control), whereas the lowest one (40.21%) was detected from irrigating wheat plants with synthetic solution at level 100 ppm of heavy metals concentration.

Irrigating wheat plants with El-Batts drainage water significantly reduced the total carbohydrate content of grains by 27.0%, however algal treatment of El-Batts reduced the grains carbohydrate content by 22.29%, when compared with the control treatment. These results proved that the application of algal powder to treat El-Batts drainage water caused a significant decrease in the adverse effect of low quality water on the total carbohydrate content of grains.

It is evident that increasing the heavy metals concentration in irrigation water from 20, 60 and 100 ppm, resulted in very high significant decreases in the total carbohydrate content of wheat grains, than those obtained from the control by 37.87, 44.40 and 48.44%, respectively.

The algal treated of El-Batts drainage water and synthetic solutions of 20, 60 and 100 ppm of heavy metals concentration caused highly significant increases in total carbohydrate content, than those obtained from non- algal treated ones by 6.46, 13.95, 15.4 and 9.82%, respectively.

4.4.5.1.2 Faba bean:

The data illustrated in Table (27) and Figure (35) indicate that irrigating faba bean plants with the Nile fresh water gave the highest value of total carbohydrate content in seeds (65.36%), whereas the lowest value (35.3%) was resulted from irrigation of synthetic solution of 100 ppm heavy metals concentration.

Irrigating faba bean plants with El-Batts drainage water and synthetic solutions of 20, 60 and 100 ppm levels of heavy metals concentration significantly decreased the total carbohydrate in seeds by 25.0, 35.0, 41.0 and 46.0%, respectively, when compared with Nile fresh water.

The reductions in total carbohydrate content of seeds, obtained from plants irrigated with algal treated El-Batts drainage water and synthetic solutions of 20, 60 or 100 of ppm of heavy metals concentration reached about 21.0, 29.0, 34.0 and 40.0%, respectively, compares with Nile fresh water.

It is evident that treating the low quality water of El-Batts drainage and synthetic solutions of 20, 60 or 100 of ppm heavy metals with algae induced very high significant increases in total

carbohydrate of faba bean seeds by 4.0, 6.0, 7.0 and 6.0% respectively, than the same values before algal treatment.

These results reveal the synergetic effect of algal treatment on improving the quality of irrigation low quality water and its role in reducing the adverse effects of heavy metals in water.

4.4.5.2 Total protein content (%):

4.4.5.2.1 Wheat:

The results shown in Table (26) and Figure (36) reveal that water treatments have significant effects on the total protein content of wheat grains. Irrigating wheat plants with the Nile fresh water significantly increased the total protein content in grains than those resulted from irrigation with El-Batts drainage water and synthetic solutions of 20, 60 and 100 ppm of heavy metals concentration by 17.69, 25.07, 36.93 and 47.02%, respectively. However, the total protein content of grains resulted from irrigation with Nile fresh water was surpassed those obtained from algal treated water of El-Batts drain and synthetic solutions of 20, 60 or 100 ppm of heavy metals concentration by 12.33, 19.04, 28.14 and 38.96%, respectively.

On the other hand, treating El-Batts drain water and synthetic solution of 20, 60 or 100 ppm of heavy metals concentration significantly increased the total protein content of wheat grains over the non- algal treated ones by 4.77, 5.07, 6.86 and 5.30%, respectively.

4.4.5.2.2 Faba bean:

The results of Table (27) and Figure (36) show that irrigating faba bean plants with Nile fresh water gave the highest protein content of seeds (20.7%), whereas the lowest protein content in seeds was observed from irrigation with synthetic solution of 100 ppm level of heavy metals concentration (12%). Irrigating with El-Batts drainage water decreased the total protein content of seeds by 4.55 than that obtained from Nile fresh water. Also, irrigating faba bean plants with algal treated water of El-Batts drain showed very highly significant effect on total protein content of seeds when compared with the non-algal treated water of El-Batts drain.

Regarding the effects of irrigation with synthetic solutions of 20, 60 or 100 ppm of heavy metals concentration on total protein content of seeds, the data indicate that the total protein content of faba bean seeds were significantly reduced by 6.0, 6.83 and 8.7%, respectively, compared with that obtained from Nile fresh water.

On the other hand, a very weak increases in total protein content were resulted from using algal treated synthetic solutions of 20, 60 and 100 ppm level of heavy metals concentration, as compared with the non-algal synthetic solutions treatments.

4.4.5.3 Heavy metals content (mg/kg):

4.4.5.3.1 Wheat:

The effects of low quality water before and after algal treatment on the heavy metals content, i.e. Cd^{+2} , Pb^{+2} , Ni^{+2} , Zn^{+2} and Cu^{+2} in wheat grains are presented in Table (26) and Figure (37).

It is clear that the lower heavy metals content in wheat grains (Cd^{+2} , Pb^{+2} , Ni^{+2} , Zn^{+2} and Cu^{+2}) were resulted from irrigation with the Nile fresh water (control).

The values of Cd^{+2} , Pb^{+2} , Ni^{+2} , Zn^{+2} and Cu^{+2} in wheat grains were varied significantly from each other due to the low quality water content of these heavy metals either before or after algal treating.

Irrigation with El-Batts drainage water after algal treating induced very high significant decrease in wheat grains content from Cd^{+2} , Pb^{+2} , Ni^{+2} , Zn^{+2} and Cu^{+2} by 22.0, 21.77, 22.05, 17.41 and 60.62%, respectively, than irrigation with raw El- Batts drainage water.

The heavy metals content in wheat grains (Cd^{+2} , Pb^{+2} , Ni^{+2} , Zn^{+2} and Cu^{+2}) were significantly increased by 10.31, 69.89, 2.64, 40.15 and 64.77%, respectively, by increasing these heavy metals concentration in irrigation water from 20 to 60 ppm and before algal treating. On the other hand, increasing the heavy metals concentration from 20 to 60 ppm in synthetic solutions after algal treatment resulted in significant increases of Cd^{+2} , Pb^{+2} , Ni^{+2} , Zn^{+2}

and Cu^{2+} content in wheat grains by 9.54, 17.42, 1.15, 7.88 and 65.51%, respectively. These results reveal that the using of treated low quality water in irrigation caused pronounced reduction in heavy metals content of wheat grains than non-algal treated water even though the concentration of heavy metals increased in irrigation water, except for Cu^{+2} content.

It is obvious that rising the heavy metals concentration in irrigation water to 100 ppm, either for non-algal treated or algal treated water resulted in the higher values of heavy metals content in wheat grains, but the increase of heavy metals content of wheat grains resulted from algal treated water was less than that obtained from irrigation with non-algal treated water.

4.4.5.3.2 Faba bean:

The results recorded in Table (27) and Figure (38) reveal that the heavy metals content of faba bean seeds were significantly affected by low quality water used in irrigation before and after algal treatment.

The minimum heavy metals content, i.e. Cd^{2+} , Pb^{2+} , Ni^{2+} , Zn^{2+} and Cu^{2+} in faba bean seeds were observed from irrigation with Nile fresh water (control), whereas irrigating with synthetic solution of 100 ppm heavy metals gave the maximum faba bean seeds content from heavy metals.

Irrigating faba plants with algal treated water of El-Batts drain showed very high significant decrease in heavy metals content of seeds, i.e. Cd^{+2} , Pb^{+2} , Ni^{+2} , Zn^{+2} and Cu^{+2} by 20.71, 31.56, 26.53,

20.29 and 40.12%, respectively, compared with irrigation by non-treated El- Batts drainage water.

Increasing heavy metals concentration in synthetic solution from 20, 60 and 100 ppm, significantly increased the faba bean seeds content from Cd^{+2} by 2.68 and 17.61%, Pb^{+2} by 46.21 and 93.21%, Ni^{+2} by 0.47 and 15.18%, Zn^{+2} by 24.44 and 35.26% and Cu^{+2} by 35.71 and 92.0%, respectively.

On the other hand, there was a very high significant decrease in heavy metals content of faba bean seeds, i.e. Cd^{+2} , Pb^{+2} , Ni^{+2} , Zn^{+2} and Cu^{+2} by 27.17, 43.42, 25.34, 21.04 and 55.42%, respectively, after using algal treated water of 20 ppm heavy metals in irrigation, in comparison with non-algal treated corresponding ones. However, using algal treated water contained 60 ppm heavy metals in irrigation caused very high significant decrease in Cd^{+2} , Pb^{+2} , Ni^{+2} , Zn^{+2} and Cu^{+2} in faba bean seeds by 17.98, 33.36, 24.03, 31.98 and 10.51%, than the same heavy metals resulted from irrigation with non-algal treated water of 60 ppm heavy metals. Also, irrigation with algal treated water of 100 ppm heavy metals significantly decreased Cd^{+2} , Pb^{+2} , Ni^{+2} , Zn^{+2} and Cu^{+2} content in faba bean seeds than the same ones resulted from irrigation with non-algal treated water by 15.32, 45.02, 28.54, 37.21 and 22.18%, respectively.

It could be concluded that algae play an effective role in reducing heavy metals effects of low quality water.

Table (26): Effect of low quality and algal treated irrigation water on some chemical components of wheat grains at harvesting.

Water treatments	Wheat							
	Total Carbohydrate (%)	Total protein (%)	Cd ²⁺ (mg/kg)	Pb ²⁺ (mg/kg)	Ni ²⁺ (mg/kg)	Zn ²⁺ (mg/kg)	Cu ²⁺ (mg/kg)	
Nile fresh water (control)	77.98 ± 0.026	9.38 ± 0.012	0.412 ± 0.026	0.436 ± 0.059	1.410 ± 0.12	22.00 ± 0.034	1.097 ± 0.006	
El-Batts drainage water	56.92*** ± 0.059	7.97*** ± 0.021	6.946*** ± 0.12	15.640*** ± 0.093	13.613*** ± 0.021	20.850** ± 0.23	1.699** ± 0.098	
Non-algal treated water	S.S.20	48.45*** ± 0.11	7.50*** ± 0.10	9.120*** ± 0.14	22.205*** ± 0.26	15.407*** ± 0.019	22.930*** ± 0.091	2.027*** ± 0.11
	S.S.60	43.36*** ± 0.13	6.85*** ± 0.025	9.990*** ± 0.27	37.725*** ± 0.091	15.812*** ± 0.042	32.140*** ± 0.034	3.340*** ± 0.067
Water treated with algal powder	S.S.100	40.21*** ± 0.16	6.36*** ± 0.035	11.318*** ± 0.21	50.600*** ± 0.089	17.560*** ± 0.21	37.520*** ± 0.021	4.623*** ± 0.013
Water treated with algal powder	El-Batts	60.60*** ± 0.015	8.35*** ± 0.023	5.418** ± 0.18	12.235*** ± 0.073	10.610*** ± 0.042	17.220*** ± 0.14	0.669*** ± 0.018
	S.S.20	55.21*** ± 0.031	7.88*** ± 0.012	7.135*** ± 0.034	17.190*** ± 0.087	12.180*** ± 0.031	18.585*** ± 0.15	1.238** ± 0.059
S.S.60	S.S.60	50.04*** ± 0.030	7.32*** ± 0.015	7.814*** ± 0.048	20.185*** ± 0.12	12.314*** ± 0.032	20.086*** ± 0.048	2.049*** ± 0.75
	S.S.100	44.16*** ± 0.017	6.75*** ± 0.017	9.615** ± 0.16	34.545*** ± 0.11	14.120*** ± 0.14	21.460*** ± 0.086	3.101*** ± 0.035

Non significant n.s. at P > 0.05

Significant (*) at P ≤ 0.05

Highly significant (**) at P ≤ 0.01

Very highly significant (***) at P ≤ 0.001

S.S.20 = Synthetic solution of heavy metals (4 ppm of Cd, 4 ppm of Pb, 4 ppm of Ni, 4 ppm of Zn and 4 ppm of Cu)

S.S.60 = Synthetic solution of heavy metals (12 ppm of Cd, 12 ppm of Pb, 12 ppm of Ni, 12 ppm of Zn and 12 ppm of Cu)

S.S.100 = Synthetic solution of heavy metals (20 ppm of Cd, 20 ppm of Pb, 20 ppm of Ni, 20 ppm of Zn and 20 ppm of Cu)

Mixture of algal powder (10 gm of powder of *U. lactuca*, *C. mediterranea* and *J. rubens*)

Table (27): Effect of low quality and algal treated irrigation water on some chemical components of faba bean seeds at harvesting.

Water treatments	Total Carbohydrate (%)	Total protein (%)	Fabu bean					
			Heavy metal					
			Cd ²⁺ (mg/kg)	Pb ²⁺ (mg/kg)	Ni ²⁺ (mg/kg)	Zn ²⁺ (mg/kg)	Cu ²⁺ (mg/kg)	
Nile fresh water (control)	65.36 ±0.026	20.70 ±0.006	0.689 ±0.080	0.462 ±0.080	2.126 ±0.068	13.940 ±0.11	1.050 ±0.007	
El-Batts drainage water	49.02*** ±0.044	16.15*** ±0.012	6.260*** ±0.053	18.865*** ±0.12	12.830*** ±0.074	17.995*** ±0.073	1.163*** ±0.004	
Non-algal treated water	S.S.20	42.48*** ±0.040	14.70*** ±0.015	8.894*** ±0.11	23.880*** ±0.039	14.640*** ±0.27	20.395*** ±0.034	1.750*** ±0.019
	S.S.60	38.56*** ±0.035	13.87*** ±0.046	9.132*** ±0.071	34.915*** ±0.13	14.710*** ±0.091	25.380*** ±0.042	2.375*** ±0.042
Water treated	S.S.100	35.29*** ±0.012	12.00*** ±0.017	10.460*** ±0.044	46.140*** ±0.50	16.980*** ±0.066	27.586*** ±0.031	3.360*** ±0.003
	El-Batts	51.63*** ±0.025	16.97*** ±0.025	5.186*** ±0.065	14.340*** ±0.13	10.140*** ±0.11	14.960*** ±0.083	0.830*** ±0.024
mixture of algal powder	S.S.20	46.40*** ±0.036	15.52*** ±0.017	6.994*** ±0.076	16.650*** ±0.11	11.680*** ±0.077	16.850*** ±0.053	1.126*** ±0.046
	S.S.60	43.14*** ±0.064	14.70*** ±0.015	7.740*** ±0.073	26.180*** ±0.15	11.860*** ±0.096	19.230*** ±0.13	2.148* ±0.052
S.S.100	39.22*** ±0.031	12.62*** ±0.021	9.070*** ±0.003	31.816*** ±0.12	13.210*** ±0.026	20.105*** ±0.093	2.750*** ±0.011	

Non significant n.s. at P > 0.05 Highly significant (**)
 Significant (*) at P ≤ 0.05 Very highly significant (***)
 at P ≤ 0.001
 S.S.20 = Synthetic solution of heavy metals (4 ppm of Cd, 4 ppm of Pb, 4 ppm of Ni, 4 ppm of Zn and 4 ppm of Cu)
 S.S.60 = Synthetic solution of heavy metals (12 ppm of Cd, 12 ppm of Pb, 12 ppm of Ni, 12 ppm of Zn and 12 ppm of Cu)
 S.S.100 = Synthetic solution of heavy metals (20 ppm of Cd, 20 ppm of Pb, 20 ppm of Ni, 20 ppm of Zn and 20 ppm of Cu)
 Mixture of algal powder (10 gm of powder of *U. lactuca*, *C. mediterranea* and *J. rubens*)

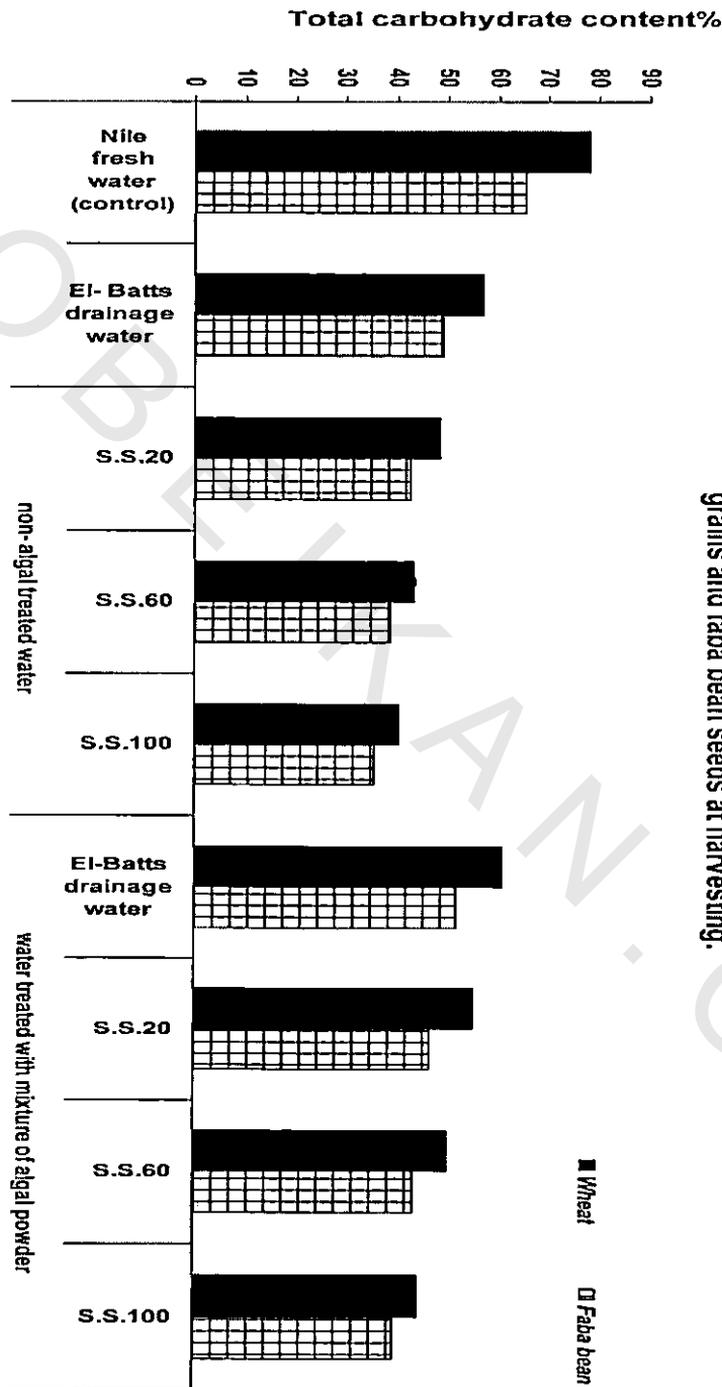


Fig. (35): Effect of low quality and algal treated irrigation water on total carbohydrate percentage of wheat grains and faba bean seeds at harvesting.

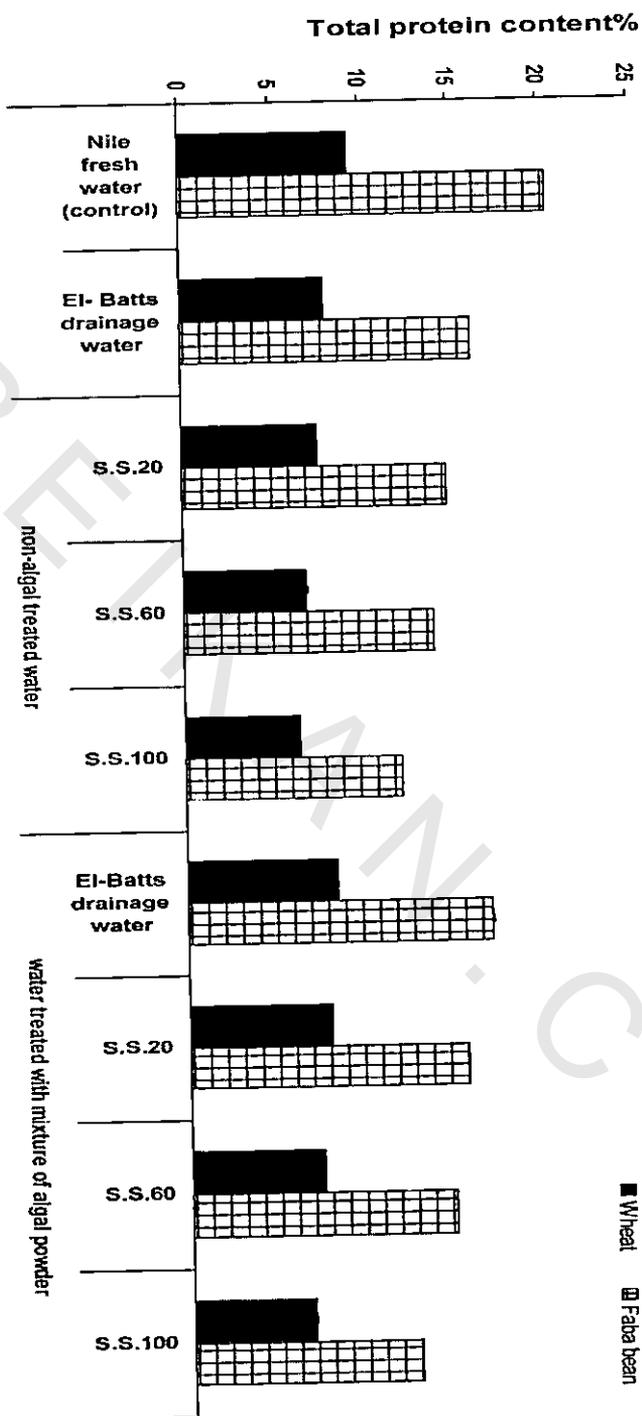


Fig. (36): Effect of low quality and algal treated irrigation water on total protein percentage of wheat grains and faba bean seeds at harvesting.

Fig. (37): Effect of low quality and algal treated irrigation water on the heavy metals content (mg/kg) of wheat grains at harvesting.

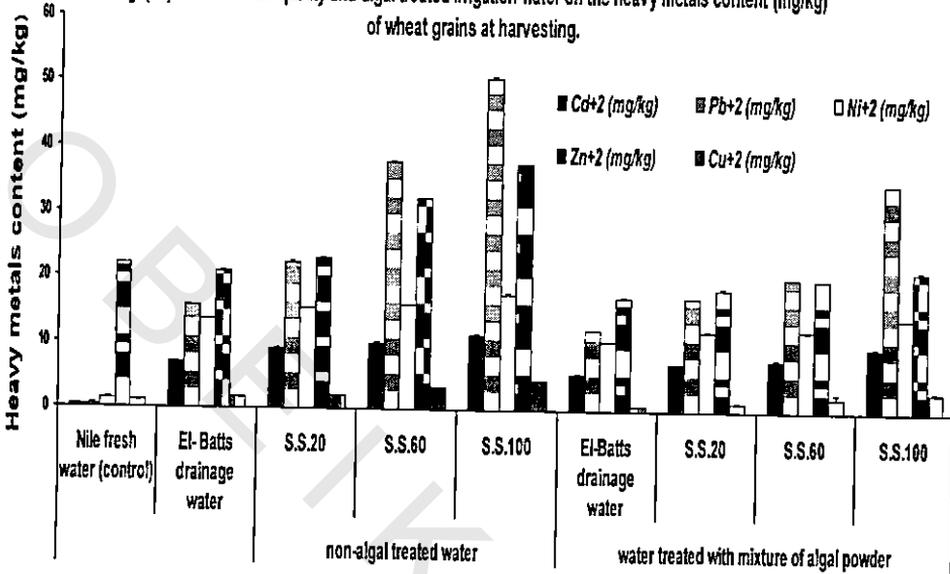


Fig (38): Effect of low quality and algal treated irrigation water on the heavy metals content (mg/kg) of faba bean seeds at harvesting.

