Improving Growth and Productivity of Fennel Plant Exposed to Pendimethalin Herbicide: Stress–Recovery Treatments

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Abstract: The present experiments were carried out during two successive winter seasons (2008/2009 and 2009/2010) in the green house of the Botany Department, National Research Centre of Egypt. The present study aimed to improve the growth and productivity of fennel plant under physiological stress of the herbicide pendimethalin. A three hour-pre-sowing seed treatment in methionine, tryptophan and pyrimidine derivative substance (SG93) each at 100 and 500mg/l was applied. Whereas, the herbicide pendiemthalin (8.5ml/l) was supplied as pre-sowing soil corporation. The results indicated that the herbicide caused significant reduction in growth parameters of the fennel plant estimated as shoot length (cm) and fresh and dry weight per plant at the age of 84 and 119 days. The stress of the pendiemthalin herbicide was reflected in the significant decreases in the photosynthetic pigment contents of fennel leaves at both stages and in the content of total protein. Significant increases in total phenolic and free amino acids were recorded as well. The herbicide exposure, however, had led to a decline in plant productivity in the measured yield components. But oil percentage or quality were not influenced. Noticeable counteraction effects on growth and productive capacity of fennel were achieved by the pre-sowing-seed soaking treatment in the amino acids methionine and tryptophan each at 100mg/l and in the pyrimidine derivative SG93 at 500mg/l. Interestingly better performance was obtained in case of the dual treatments, i.e. with the seed treatment under the exposure to the herbicide as pre-emergence soil application.

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1. Introduction:

Fennel (*Foeniculum vulgare* Mill. *Apiaceae*) is a perennial hemicryptophyte plant inhabits the Mediterranean basin. It is known as a medicinal aromatic herb as its fruit is used in the remedy against digestive disorders. Bitter fennel is used as food flavor, in liqueurs and in the perfumery industry (Tanira, *et al*., 1996). The major volatile (essential) oil constituents of the plant are anethole and fenchone (Simandi, *et al*., 1999). Fennel extracts proved to have anti-inflammatory, antispasmodic, carminative, diuretic, expectorant, laxative, analgesic, stimulant of gastrointestinal mobility and are used in treatment of nervous disturbances (Choi and Hwang, 2004). Anand *et al*. (2008) reported the anticancer activity of anethole of fennel seeds.

Pendimethalin (stomp) is a dinitroaniline herbicide; applied as pre-emergence soil corporation; is generally used for selective weed control in different economic crops. It acts on cell division by blocking mitotic division and causing accumulation of abnormal microtubular structures (Fennell *et al*., 2006). It is known to be persistant in soil with different crops up to 75 day after sowing (Asha and Tomar, 2008).

In this respect, it has been found that the inhibitory stress effects of several herbicides on crop plants during weed control could be minimized and / or alleviated through exogenous application of some growth agents (Hassan *et al*., 1996). In other cases, nutrient elements (Nalewaja and Matysiak, 1991), amino acids, pryimidine and purine bases exerted similar protective effects

(Hassan and Gad, 2003; Hassan *et al*., 2006; El-Awadi, 2007).

The application of these substances act, however, as protectants to crop plants against herbicide damage without reducing activity on the target weed species as explained by Davies (2001). Davies *et al*. (1998) reported that these protectants acted through increased activities of cytochrome P_{450}, glutathione-s-transfereases (GSTs) or via raising glutathione levels

In this connection, the adverse effects of the dinitroaniline herbicide (butralin) on chromosomes of both somatic and germ cells of mice were reversed by using thiola (N- (2-mercaptopropionyl) glycine) prior to the herbicide treatment (Abd El-Aziz and Hassan, 1994). Forgacs *et al*. (2000) pointed that the amino acids arginine, histidine, lysine, ornithine, phenylalanine and tryptphan bind to 2, 4-D and the binding process is of a saturation character. More recently, in his study, El-Awadi (2007) proved the stress-recovery actions of the amino acids tryptophan and methionine on the damagable effects of butralin and pendimethalin on both physiological and cytological levels in faba bean and wheat. Meanwile, the pyrimidine derivative substance SG93 was found to modulate plant growth response of different plant species under other abiotic stress conditions (Hassasn *et al*., 2006)

In the present study we aimed to test the stress-recovery actions of the amino acids methionine and tryptophan in addition to the pyrimidine derivative substance SG93 as protectants to the medicinal plant *(Foeniculum vulgare* Mill.) under the exposure to the dinitroaniline herbicide pendimethalin. In this, a pre-sowing seed soaking treatment is applied. Our objective is to improve growth and productivity of fennel plant under the stress of such an herbicide.

2. Materials and Methods

Pot experiment was carried out during two successive winter seasons (2008-09-2009-10) in the wire house of Botany Department in the National Research Centre of Egypt.

I-Cultivation and treatments:

Fennel seeds were selected, sterilized in sodium hypochlorite solution (1%) for 15 minutes, washed thoroughly with distilled water, and then soaked in the following solutions for 3 hours:

1- Distilled water (control).
2- In methionine
3- In tryptophan and
4-In the pyrimidine derivative (SG93- Fig.1, constructed by the Department of Pharmaceutical Industry of the National Research Centre).

All at 100 and 500mg/l. The pots contained equal amounts (about 12Kg) of sieved soil (clay and sand; 2: 1 v/v) and were divided into 14 groups. The soil was pre-plant incorporated in seven groups in case of pendimethalin. At 2cm depth, each 10 seeds were sown in each pots (30-cm diameter) at the 17th of Nov. Stomp (pendimethalin) was applied as soil application (pre-emergence) at the day of sowing. Treatment was carried out in the early morning. The amount of the herbicide stomp applied per pot was calculated according to the surface area as related to the area of a feddan ($4200m^2$). Standard agricultural practices were carried out as recommended. Each treatment included 5 replicates = 50 plant. The pots / treatments were distributed following a complete randomized design of distribution.

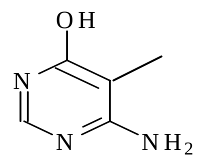

Figure 1: Chemical formula of SG93

II- Growth and yield measurements:

Plant samples were taken at the juvenile (age - 84 days) and at the fruiting (age- 119 days) from sowing. Plant height, number of leaves, number of branches, fresh and dry weight of the shoots were recorded at both stages.

Yield of fennel plant was recorded as the number of umbels per plant, the number of seeds per umbel and weight of seeds per umbel and per plant at the end of experiment.

III- Biochemical analyses:

Photosynthetic pigments were estimated in fresh tissues of fennel leaves according to (Wettstein, 1957). Protein percentage was determined according to

A.O.A.C. (1990). Total Free amino acids were determined using the ninhydrin colorimetric method defined by Plummer (1978). Following the method reported by Snell and Snell (1952), total phenolic contents were estimated.

Seed fixed oil content, was determined as reported in the (A.O.A.C., 1990) with Soxhelt apparatus using petroleum ether (40-60^{o}C).

The essential oil was extracted from the dry seeds and estimated referring to the British Pharmacopoeia (1980), dehydrated over anhydrous sodium sulfate and then kept at refrigerators (-4^{o}c) till GC analysis.

Essential oil of fennel seeds was analyzed by GC using an Agilent Technologies, (6890N Network GC system, U.S.A.) using capillary column HP 5% (30 m x 320 Um), 0.25um film thickness. Oven temperature was programmed at 70°C for 2 min. from 700°.190°C at rate of 4 ml/min. and finally 250°C (15 min) with N2: H2: Air at 30:30:300 ml/min. The temperature of the detector (FID) was maintained at 280°C. Identification of the oil components was based on the comparison of the Rts of the separated compounds with those of standard compounds that injected under the same conditions and confirmed for the major compounds by their relative retention indices.

IV- Statistical analysis:

A complete experimental randomized block design with 5 replicates was adopted. Combined results` analysis of the average values of the two seasons was carried out and the values of LSD were calculated as described by Snedecor and Cochran (1980).

3. Results:

a. Effect of pendimethalin, amino acids and pyrimidine derivative on fennel growth

Table (1) show that pre-sowing application of pendimethalin caused a significant decrease in the length of shoots, number of leaves, number of branches per plant and in fresh and dry weight (g) of shoots of fennel plants, at both growth stages of 84 and 119 days as compared to the control.

Pre-soaking fennel seeds in the low concentration (100mg/l) of methionine or tryptophan and the high concentration (500mg/l) of pyrimidine derivative (SG93) significantly increased the length of shoots, number of leaves and number of branches per plant and fresh and dry weight (g) of shoots as compared to control at both growth stages. Other treatments appeared no considerable influence on growth promotion.

Application of pendimethalin herbicide in interaction with the pre-sowing growth factor seed treatments, i.e. methionine, tryptophan and pyrimidine derivative substance SG93 significantly improved growth parameters of the fennel plant (Table 1). Significant increases in shoot length, number of leaves and number of branches per plant and fresh and dry weight (g) of shoots were recorded as compared to sole treatments of the growth substances. In this respect, maximum effect was recorded in response to the lower concentration treatment methionine in combination with the pendimethalin.

b. Effect of pendimethalin, amino acids and the pyrimidine derivative on fennel yield:

Data presented in Table (2) indicated the inhibitory action of the pendimethalin herbicide on fennel plant productivity. Significant reduction in number of umbels per plant, number of seeds per umbel and in the weight of seeds per umbel and per plant were recorded as compared to the control. The productive capacity was, however, restored under the influence of the pre-sowing seed treatment. Thus, at the low concentration of methionine and tryptophan, and with the high concentration of pyrimidine derivative substance SG93 significant increases in the number of seeds per umbel and weight of seeds per umbel and per plant were obtained.

Additive augmentation of the productivity was achieved in respect to the dual interaction treatments, i.e under exposure to the herbicide in combination with the growth factors` seed treatments. Therefore, number of umbels per plant, number of seeds per umbel and in weight of seeds per umbel and per plant increased significantly in comparison to sole growth factor treatments (Table 2). From the results, the amino acid methionine treatment showed the most prominent positive effects on productivity of the fennel plant, followed by that of tryptophan and pyrimidine derivative SG93.

Table 1: Effect of soil application of pendimethalin, amino acids and pyrimidine derivative on the growth of fennel at 84 and 119 day-old plants.

		Shoot length (cm)		No. of leaves		No. of branches		Shoot FW (g)		Shoot DW (g)	
	mg/l	A	B	A	B	A	B	A	B	A	B
Control	0	51.45	64	8.09	20.31	5.09	8.76	11.96	16.49	1.56	3.3
Pendimethalin	8.5ml/l	43.44	57.64	6.74	17.25	4.26	7.32	10.03	14.61	1.32	2.83
Methionine	100	56.83	79.93	10.11	25.37	5.88	11.16	13.22	22.20	1.72	4.44
	500	54.29	71.97	8.66	22.34	5.19	10.12	12.63	18.89	1.64	3.79
Tryptophan	100	55.17	71.3	8.91	22.36	5.37	10.52	12.83	19.76	1.67	3.95
	500	54.48	69.85	8.45	21.21	5.15	9.58	12.67	17.46	1.64	3.51
Pyrimidine derivative	100	53.89	66.12	8.97	22.52	6.26	12.7	12.53	17.92	1.63	3.58
	500	55.65	71.31	9.09	22.81	5.49	10.81	12.94	19.80	1.68	3.96
Methionine + Pendimethalin	100	59.07	82.17	11.22	28.17	5.73	11.36	13.94	23.61	1.81	4.72
	500	55.49	72.4	9.0	22.59	5.41	10.00	12.90	19.93	1.68	3.99
Tryptophan + Pendimethalin	100	56.11	73.16	9.52	23.90	6.26	12.7	13.05	20.92	1.69	4.19
	500	55.31	71.36	8.86	22.25	5.49	10.81	12.86	18.44	1.67	3.69
Pyrimidine derivative + Pendimethalin	100	54.91	72.93	9.22	23.14	5.59	10.36	12.81	18.62	1.66	3.72
	500	57.06	75.20	9.74	24.53	6.09	11.57	13.28	21.61	1.72	4.32
L.S.D	1%	2.51	3.99	0.61	2.09	0.48	1.11	0.85	1.87	0.11	0.38
	5%	1.78	2.82	0.43	1.48	0.34	0.78	0.60	1.32	0.08	0.27

Table 2: Effect of soil application of pendimethalin, amino acids and pyrimidine derivative on the yield of fennel.

	mg/l	No. of umbels/ plant	No. of seeds/ umbel	Wt. of seeds/umbel	Wt. of seeds /plant
Control	0	9.68	114.33	1.43	13.89
Pendimethalin	8.5ml/l	8.34	85.33	0.93	7.78
Methionine	100	10.38	129.46	1.85	19.28
	500	9.97	119.74	1.59	15.88
Tryptophan	100	10.13	122.36	1.68	17.05
	500	9.69	116.37	1.52	14.8
Pyrimidine derivative	100	9.90	118.33	1.56	15.47
	500	10.25	127.86	1.78	18.41
Methionine + Pendimethalin	100	11.43	147.6	2.35	26.85
	500	10.38	125.85	1.75	18.31
Tryptophan + Pendimethalin	100	11.03	139.95	1.67	21.78
	500	10.15	118.58	1.92	16.62
Pyrimidine derivative + Pendimethalin	100	10.20	124.09	1.68	17.23
	500	10.73	136.92	1.99	21.32
L.S.D	1%	0.95	15.23	0.21	3.70
	5%	0.67	10.77	0.15	2.62

c. Effect of pendimethalin, amino acids and pyrimidine derivative on the some biochemical constituents of fennel

1-Photosynthetic pigment contents:

The results indicated in Table (3) show that the pre-emergence application of the herbicide pendimethalin caused significant reduction in the photosynthetic pigment contents of fennel leaves, throughout the duration of the experiment. Such inhibitory effect under the stress of the herbicide was significantly counteracted via the seed exposure treatments. However, low concentration with the amino acids and the high concentration of SG93 had resulted in significant increases in leaf chlorophyll a, b and cartonoids. In this respect, the maximum increase was detected with the amino acid methionine. On the other hand, seed exposure to higher concentrations of the amino acids and the low concentration of pyrimidine derivative as well showed an insignificant effect.

From the same table, the combined treatments of the amino acids and the pyrimidine derivative under the exposure of the herbicide pendimethalin induced extra elevation of the photosynthetic fennel leaf pigmentation. Therefore, the estimated chlorophylls a, b, and carotenoid contents had exceeded that in the corresponding levels under the single treatments with either the amino acids or the pyrimidine derivative substance as well. This trend was observed at both growth stages of the plant, i.e. 84 and 119 age-days. Seed exposure to the low concentration of each of the amino acids and the high concentration of the pyrimidine derivative substance (SG93) had favored other treatments (Table 3).

2-Total phenolic content:

As shown in Table (3), soil application of pendimethalin caused significant increase in total phenolic contents in fennel plants, as compared to the untreated control. Similarly sole treatments with both concentrations of the amino acid tryptophan, pyrimidine derivative SG93 and high concentration of the amino acid methionine induced significant increases in total phenolic contents. On the contrary, low concentration of the amino acid methionine caused non-significant effect in the contents of total phenolic contents.

The combined treatments of pre-sowing seed-soaking in both concentrations of the amino acid methionine and in the pyrimidine derivative substance under the exposure to the pendimethalin herbicide resulted in an increase in the total phenolic contents as compared to the control (Table 3).On the other side, combined treatment with the amino acids tryptophan at both concentrations showed insignificant effect on the total content phenolic contents.

3-Total free amino acid content:

Soil corporation of the dinitroaniline herbicide pendimethalin caused significant increase of total free amino acids content in the fennel plant as compared to the control. Except with the pyrimidine seed treatment at 500mg/l, the estimated total free amino acid contents were elevated over the control in response to the single amino acids and to the pyrimidine substance SG93 seed treatments as well.

On the other hand, dual treatments with both the amino acids and the pyrimidine derivative in interaction with the herbicide pendimethalin resulted in high total free amino acids than that estimated in the control, with an exception of the amino acid methionine at its low concentration 100mg/l (Table 3).

4. Total protein content:

As shown in Table (3), total protein content was significantly reduced in fennel plant due to the exposure to the pendimethalin herbicide in comparison to the control. Such inhibitory effect was reversed via the pre-sowing seed-soaking treatment in the growth factors under test. This was true at all of their concentrations except that of the tryptophan at its high one (500 mg/l). In comparison to the control, the latter resulted in significant reduction in the total protein content of fennel as compared to the control.

The combined treatments of pre-sowing fennel seed soaking treatment with both concentrations of the growth substances; methionine, tryptophan and pyrimidine derivative with soil corporation of the pendimethalin herbicide showed an enhancement effect on total protein accumulation in fennel plant as compared to the control (Table 3).

Table 3: Effect of soil application pendimethalin, amino acids and pyrimidine derivative on photosynthetic pigment contents, total phenolic content, total free amino acids content and total protein content of fennel plants.

	mg/l	Ch. A (mg /g f. wt.)		Ch. B (mg /g f. wt.)		Cart. (mg /g f. wt.)		Total phenolic content (mg/g d. wt.)	Total free amino acids (mg/g d. wt.)	Total protein (mg/g d. wt.)
		A	B	A	B	A	B			
Control	**0**	0.659	0.791	0.198	0.233	0.302	0.415	33.07	32.38	13.44
Pendimethalin	**8.5ml/L**	0.484	0.699	0.175	0.203	0.261	0.367	47.03	35.91	11.88
Methionine	**100**	0.706	0.794	0.242	0.259	0.342	0.453	31.49	48.97	15.83
	500	0.679	0.821	0.205	0.238	0.32	0.425	36.65	36.56	18.13
Tryptophan	**100**	0.698	0.842	0.226	0.249	0.326	0.438	39.87	48.30	18.33
	500	0.663	0.791	0.208	0.242	0.315	0.408	39.17	47.60	7.50
Pyrimidine derivative	**100**	0.667	0.824	0.204	0.235	0.315	0.418	47.03	37.98	20.00
	500	0.688	0.824	0.232	0.248	0.333	0.438	36.10	27.85	15.21
Methionine + Pendimethalin	**100**	0.768	0.907	0.262	0.304	0.381	0.515	41.87	28.68	15.42
	500	0.723	0.873	0.223	0.259	0.340	0.434	40.96	53.07	16.67
Tryptophan + Pendimethalin	**100**	0.725	0.896	0.233	0.280	0.351	0.477	34.82	53.56	14.58
	500	0.701	0.829	0.215	0.250	0.325	0.427	33.78	41.42	15.21
Pyrimidine derivative + Pendimethalin	**100**	0.683	0.843	0.223	0.263	0.326	0.425	40.91	37.10	15.00
	500	0.737	0.862	0.238	0.270	0.355	0.441	40.01	36.83	16.56
L.S.D	**1%**	0.026	0.053	0.020	0.022	0.028	0.027	3.18	1.56	0.80
	5%	0.018	0.036	0.014	0.015	0.019	0.019	2.25	1.11	0.56

A- Juvenile growth stage 84 days B- Fruiting growth stage 119days

5- Effect of pendimethalin, amino acids and pyrimidine derivative on the oil content and composition:

From the data presented in Table (4), the exposure to the pendimethalin herbicide resulted in significant increase in the fixed oil percentage of the yielded fennel seeds as compared to the control. Whereas methionines at both its concentration- seed treatments and the pyrimidine substance at its low one caused significant decreases in the fixed oil percentage. Tryptophan at 100 and 500mg/l, and pyrimidine derivative (500mg/l) treatments tended to elevate the fixed oil percentage to high significant levels in comparison to other treatments (Table 4). From the same table, the pendimethalin herbicide combination treatments with either methionine at both its concentrations or with the prymidine derivative substance at its higher one increased significantly the fixed oil percentage in the yielded fennel seeds as compared to the control. The effect of the other treatments was more or less proximal with the control.

The essential oil of the produced fennel seeds in all treatments were subjected to fractionation using gas chromatography (GC). Anethol, 1, 8 cineol and fenchone are recorded as the main components of the essential oil of fennel seeds (Table 4). As compared to the control, anethole percentage ranged from 85.61 to 87.58 % while 1, 8 cineol and fenchone ranged from 3.70 to 5.72% and 3.7% to4.47 respectively. The highest percentage of anethole was obtained in the treatment 100mg/l methionine-seed–treated plants. Whereas, a considerable increase in the percentage of 1.8 cineol was recorded in response to the pyrimidine derivative material-seed-treatment (Table 4). On the contrary, the application of tryptophan and pyrimidine substance (SG93) both at the 500mg/l concentration resulted in remarkable decreases in the percentage of fenchone (Table 4).

In the dual treatments with pendimethalin herbicide combined with the growth factors` seed-soaking treatments, the absence of estragol was recorded. The main component of the analyzed essential oil was also anethole (85.6%-90.60%), 1,8cineol (4.86%-6.73%) and fenchone (3.62-7.73). Both concentrations of methionine and tryprophan seed treatments had induced the highest percentage of anethole, whereas the methionine produced the essential oil with a high percentage of 1, 8 cineol in the yielded seed of fennel plant (Table 4).

Table 4: Effect of soil application pendimethalin, amino acids and pyrimidine derivative on fennel oil content and composition.

	mg/l	Essential oil %	Fixed oil %	Major essential oil constituents (%)							
				αPinene	D Limonene	1,8 Cineol	Fenchone	Anethol	Estragol(M ethyl chavicol)	Known	Unknown
Control	**0**	0.79	5.82	0.37	0.07	5.09	4.13	86.11	0.05	4.18	95.82
Pendimethalin	**8.5 ml/l**	1.09	7.78	0.40	-	6.51	3.93	89.14	-	99.58	0.42
Methionine	**100**	0.89	4.80	0.36	0.02	4.93	4.13	87.58	0.53	97.55	2.45
	500	0.95	5.46	0.39	0.11	4.50	4.12	85.61	0.84	95.57	4.43
Tryptophan	**100**	0.78	6.05	0.23	0.11	5.72	4.10	87.53	0.18	97.87	2.13
	500	1.09	6.49	0.33	0.13	6.22	3.70	87.14	0.23	97.75	2.25
Pyrimidine derivative	**100**	1.03	5.28	0.34	0.09	3.97	4.47	86.22	0.73	96.63	3.37
	500	1.06	6.68	0.48	0.17	4.38	3.80	86.77	0.67	96.27	3.73
Methinione + Pendimethalin	**100**	1.10	7.00	0.50	0.21	6.10	3.62	89.44	-	99.37	0.63
	500	0.94	6.70	0.60	0.21	6.73	4.60	87.86	-	99.40	0.60
Tryptophan + pendimethalin	**100**	0.97	5.39	0.42	0.16	4.86	4.77	87.9	-	97.69	2.31
	500	1.26	5.92	0.48	0.17	5.87	7.73	85.6	-	99.37	0.63
Pyrimidine derivative + Pendimethalin	**100**	1.08	5.86	0.35	-	5.35	3.73	90.60	-	99.68	0.32
	500	1.25	6.70	0.36	-	5.33	3.78	90.51	-	99.62	0.32
L.S.D	**1%**	0.04	0.33	-	-	-	-	-	-	-	-
	5%	0.03	0.24	-	-	-	-	-	-	-	-

4. Discussion:

Effect of the single application of the herbicide pendimethalin on fennel:

In the present result, the adverse effects of the dinitroaniline herbicide pendimethalin on the growth of fennel plant were detected in the reduction of shoot length, number of leaves per plant, number of branches per plant and fresh and dry matter accumulation. These results are supported with those obtained by Meena and Mehta (2009). Similar observations were previously mentioned on garlic by Adam *et al*. (1996). The growth-induced inhibition of the herbicide was, however reflected on the productivity as yield component characteristics which were markedly declined. Similar to the present observations ; Kothari (2002) and Meena and Mehta 2009 had reported that pendimethalin reduced yield components, i.e. the number of umbels/plant number of umbellate/umbel, number of seed/umbellate seeds and straw yields of fennel. In this respect, one may attribute the decline in fennel yield in response to the exposure to the herbicide pendimithilin to the disturbance effects on the photosynthetic process due to the suppression of the biosyntheses of the photosynthetic pigments (Shabana *et al*., 2001).

Starratt and Lazarovits (1999) recorded an increase in free amino acids in melon seedlings in response to exposure to dinitroaniline herbicides. In the present results, similar observations are noted on the fennel plant. This may explain the significant reduction observed in total protein content. In this connection, another dinitroaniline herbicide butralin caused remarkable reduction in protein, carbohydrate, leghaemoglobin and ureide in the nodule fraction of soybean (Mahmoud *et al*., 1996). In contradiction to these results are those reported by Panneerselvam *et al*. (1998) on soybean, as a result of pendimethalin application.

It is reported herein that soil application of pendimethalin which caused significant increase in the total phenolic contents over the control; could be compared with those obtained by Abd El Wahed *et al*. (2003) due to the herbicide thiobencarb influences on rice.

In the yielded fennel seeds, while significant increases in essential and in fixed oil percentages were recorded as compared to the control, no changes in the fractions were obtained in response to the herbicide. These percentages were 89.14% anethol, 6.51 - 1, 8 cineol and 3.93 fenchone, but with the absence of estrigol and D lominene. These results are supported by the findings of Chaudhary (2000) and Kothari, *et al.* (2002) on fennel and on rose-scented geranium. They also reported that pendimethalin herbicide had not impaired the quality of essential oil.

Herbicide stress-recovery via pre-sowing seed-soaking treatments:

In the present study, seed amino acid treatments induced noticeable counteraction of the pendimethalin-induced-growth inhibition in fennel. Thus, shoot elongation, total number of leaves and branches, as well as fresh and dry matter accumulation were significantly enhanced, particularly at low concentrations of methionine and tryptophan as well as at the high concentration of the pyrimidine substance SG93. In case of the dual treatments with the herbicide, such influence was sustained reaching higher level of growth promotiom. Such growth promotion led to an improvement in yield components of the fennel plant. Such observations are in agreement with the alleviation of the adverse effects of herbicides due to amino acid treatments (Devine and Preston, 2000) and to a pyrimidine derivative substance (Hassan and Gad, 2003).

The positive significant protecting effects of the pre-sowing seed-soaking treatments with the growth factors under investigation on leaf photosynthetic pigments content either as sole treatment or under exposure of pendimethalin are proved herein. The lower concentration treatments of the amino acids and the higher one of the pyrimidine substance SG93 exerted the best resultsmin this respect. Similar trends were obtained on the total phenolic content, total free amino acids and protein content. On the other hand, a synergistic effect had resulted in the interaction treatments, i.e. with growth factors` application under the exposure to the herbicide pendimethalin. Thus revealed extra elevations in total phenolic, total free amino acid and in total protein content, as compared to those of sole treatments. Similarly an enhancement effect of the growth factors in interaction with herbicide exposure was obtained in the estimated percentage of the fixed and essential oil percentages in the yielded fennel seeds. This implicated the results obtained by El-Awadi and Hassan (2010) on fennel and by Talaat (2005) on *Pelargonium graveolens* L. In addition to their role in protein synthesis, amino acids are the basic molecules in biosynthesis of primary and secondary metabolites in plants (Coruzzi and Last, 2000).Therefore, their exogenous application might compensate the metabolic stress process achieved by a given herbicide, mainly through rendering higher availability of energy resources. In the present work, the amino acids methionine and tryptophan applied as pre-sowing seed soaking treatment had achieved a stress-recovery action against the dinitroaniline herbicide pendimethalin.

This herbicide is found to act as a mitotic inhibitor (Fennell *et al*., 2006).

Thus methionine counteraction effect could be either via its functions in the process of mRNA translation to begin protein synthesis (Lodish *et al*., 2000) or as a regulatory molecule in the form of S-adenosylmethionine (SAM) (Hesse and Hoefgen, 2003). Also methionine enhanced the polyamine accumulation which are controlled by stress signaling (Panicot *et al*., 2002), furnishing aspartate levels (Hesse *et al*., 2004) and linking with growth hormones such as cytokinins, auxins and brassinosteroids (Maxwell and Kieber, 2004), which interfere with cell division.

The amino acid tryptophan is known to participate in pathways relevant to biosynthesis of auxins and other natural products. In this connection its application was reported to enhanced growth rates, photosynthetic pigment, total sugars and free amino acid contents in geranium plants (Talaat (2005). This effect was attributed to its action as a precursor for IAA biosynthis (Normanly *et al*., 2004).

In the present results a stress-recovery action of the pyrimidine derivative substance SG93 against the induced-inhibitory effect of the pendimethalin herbicide was achieved. This could be interpreted in the light that pyrimidines are playing variable roles in biological processes in plants. They are the building blocks for nucleic acid synthesis, energy sources, synthesis of sucrose, polysaccharides as well as production of important secondary metabolites (Stasolla *et al*., 2003).

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