RESULTS AND DISSCUSSION

I- Laboratory experiments:

Germination process:

As shown in Table (1) the lowest concentration of each treatment gave a 100% of germination. Meanwhile, the highest concentration of each treatment gave less germination percentage when compared with the lowest concentration. Despite of that, the highest concentration of each treatment still higher more than the control. Also, in this respect it could be noticed that, the lowest germination percentage existed in case of all treatment, was that of paclobutrazol treatment at the level used i.e. one part per million. Since, the percentage of germination recorded only 38% meanwhile, it was 92% in case of control treatment.

Also, it could be noticed that the treatment of paclobutrazol at 1 ppm combined with boron and sulphur at 50 ppm, also decreased germination percentage less than control treatment but still more than the paclobutrazol alone. Since, for this treatment PP_{333} at 1 ppm combined with sulphur + boron each at 50 ppm percentage was 66%. Meanwhile, for paclobutrazol alone was 38%. That could be of interest because as obtained in different treatments increasing of all elements or benzyl adenine decreased germination percentages as indicated in Table (1).

So, it could be generally concluded that different applied treatments except PP_{333} being stimulated the germination of black cumin seed (*N. sativa*).

Table (1): Effect of different applied treatments on germination of black cumin (*Nigella sativa* L.) seeds during 2003-2004 seasons.

Characters / Treatments (ppm)	Number of germinated seeds	Germination percentage	Germination rate
Boron 50	50	100	7.58
Boron 250	49	98	7.53
Sulphar 50	50	100	7.87
Sulphar 250	48	96	7.53
K 100	50	100	7.85
K 500	49	98	7.63
BA 5	50	100	7.62
BA 25	47	94	8.05
NAA 10	50	100	7.53
NAA 50	47	94	7.75
PP_{333} 1	19	38	8.08
(B + S) 50 + 50	48	96	7.69
BA + (B +S) 5 + (50+50)	50	100	7.72
NAA + (B + S) 10 + (50 +50)	50	100	7.76
PP_{333} + (B + S) 1 + (50 + 50)	33	66	8.31
BA + NAA + (B + S) 5+ 10+ (50 +50)	50	100	7.71
Control	46	92	7.72

Mean value of 2003-2004 seasons.

Moreover, also in this respect, it could be noticed that each of BA at 5 ppm + (B+S each at 50 ppm), NAA at 10 ppm + (B+S each at 50 ppm) and BA at 5 ppm + NAA at 10 ppm + (B + S each at 50 ppm) both gave a 100% of germination. That could be also expected, because both the growth regulators is recommended to be principle also in cell division, that process is considered as a preliminary stage in germination process.

On the other hand, reduction of germination with paclobutrazol (the more common antigibberellin) could be also interpreted on the basis that, the first stip of germination is being the elongation of embryo cells that occurred directly with the action of gibberellin. So, retardment of gibberellin action by PP_{333} treatment led to that obvious reduction of germination percentage in case of PP_{333} treatment.

On the other hand, rate of germination was increased by the treatments of BA at 25 ppm, PP_{333} 1 ppm and PP_{333} combined with boron and sulphur each at 50 ppm. Meanwhile, it was slightly decreased with each of boron at 50 and 250 ppm, sulphur at 250 ppm, K at 500, BA at 5, NAA at 10 ppm, B + S 50 ppm for each and BA at 5 ppm + NAA at 10 ppm + (B + S) 50 ppm for each. Yet, BA at 5 ppm combined with boron and sulphur at 50 ppm for each gave the same value of control treatment (i.e., 7.72).

Because, PP_{333} is a common antigibberellin it decreased germination aspects. Since the stimulating effect of gibberellin on seed germination could be attributed to the fact that GA_3 affects the balance between endogenous growth promoters and inhibitors **(Jackson and Blundell, 1963),** meanwhile it activates enzymes connected with germination process **(Toole, 1956; Bolduce *et al.*, 1970 and Hawker and Bungey, 1976).** Meanwhile, PP_{333} completely reversed these effects.

Generally, results of the present study are being of great interest, because the law germination percentage of *Nigella sativa* seeds faced each of growers and researchers **(Wareing and Foda, 1957; Shah and Gupta, 1979; Miller and Holcomb, 1982; Mandal and Maity, 1993 and Boselah, 1995).**

II- Pot experiments:

II.1. Seedling emergence:

As shown in Table (2), it could be noticed that the most of applied treatments hastened seedling emergence of *N. sativa*. The only exhibition was that retardation of paclubutrazol at 1 ppm. Meanwhile, the combination of PP_{333} with boron and sulphur each at 50 ppm minimized that retardation to reach nearly one third of paclubutrazol when applied separately.

Also, as shown in Table (2) number of days required till first seedling appearance when related to the control are being more expressing. Since, different applied treatments shortened this number in comparison with the control. The only exception was that PP_{333} at one ppm since it shows about 6% retardation comparing with control. Yet, S at 50 and 250 ppm, K at 100 and 500 ppm, BA at 5 and 25 ppm, NAA at 10 and 50 ppm, B + S at 50 ppm for each as well as their combination with BA and NAA at 10 ppm + (B. + S. each at 50 ppm) were the more pronounced treatments for hastening of first seedling appearance.

With regard to the aspect of germination speed, also data in Table (2) clearly show that the all applied treatments increased its percentage. The only exception was that slight reduction (5%) with pp_{333} at 1 ppm.

II.2. Root growth :

II.2.1. Root length:

Data in Table (3) clearly show that all the applied treatments showed an inhibition of root growth at 66 days of plant age (i.e. first sample). This inhibition of root length reached to the level of significance in most cases.

Table (2): Effect of different applied treatments on seedling emergency of black cumin (*Nigella sativa* L) plants.

Characters / Treatments (ppm)	Number of days required for appearance of first seedling	Number of days before or after the control	% Relative to the control	% Speed of germination
Boron 50	13	+4	76.47	+23.53
Boron 250	13	+4	76.47	+23.53
Sulphar 50	12	+5	70.59	+29.41
Sulphar 250	12	+5	70.59	+29.41
K 100	12	+5	70.59	+29.41
K 500	12	+5	70.59	+29.41
BA 5	12	+5	70.59	+29.41
BA 25	12	+5	70.59	+29.41
NAA 10	12	+5	70.59	+29.41
NAA 50	12	+5	70.59	+29.41
PP_{333} 1	18	-1	105.88	-5.88
(B + S) 50 + 50	12	+5	70.59	+29.41
BA + (B +S) 5 + (50+50)	12	+5	70.59	+29.41
NAA + (B + S) 10 + (50 +50)	12	+5	70.59	+29.41
PP_{333} + (B + S) 1 + (50 + 50)	14	+3	82.35	+17.65
BA + NAA + (B + S) 5+ 10+ (50 +50)	14	+3	82.35	+17.65
Control	17	0	100.00	00.00

Mean values 2003-2004 seasons.

T3

On the other hand, at the second sample (176 days after sowing), treatments of BA at the two applied concentrations, NAA at 50 ppm; (B + S) at 50 ppm for each; BA at 5 ppm + (B + S each at 50 ppm); NAA at 10 ppm + (B + S each at 50 ppm); PP_{333} at 1 ppm + (B + S each at 50 ppm) and BA at 5 ppm + NAA at 10 ppm + (B + S each at 50 ppm) increased the root length of treated plants. Meanwhile the rest of treatments decreased root length in the second sample as well as the first one (the above mentioned results obtained during 2003 season). Yet, during 2004 season, nearly similar results existed either for the first sample or the second one.

In this respect, the effect of applied treatments upon root length is of great interest. Since, of the major problems those face the cultivation of this plant is that the weakness of root growth comparing with that of shoot system. The enhancement of either root growth as a whole or any of its characteristics could be in favourable amount reverse upon minimizing such problem.

Here, the enhancement of root growth by any of the applied treatment it must be preceded with the alteration of photosynthate allocation to be in favor of root portion.

II.2. 2. Root diameter:

As indicated in Table (3), the first sample the two seasons root diameter significantly was increased or decreased or did not show any effect in comparison with the control.

In this respect, clearly it could be noticed that benzyladenine alone or in combination with boron and sulphur showed significant increase of this diameter specially at the second stage of root growth.

On the other hand, at the second sample during the two seasons root diameter significantly increased with the most of applied treatments. Here, it could be noticed that BA at the two separately applied concentrations or when combined with boron and sulphur showed the highest increase of root diameter in both seasons.

Also, it could be noticed that each of PP_{333} alone or when combined with boron and sulphur as well as BA combined with NAA + (B + S) significantly increased this diameter.

The above mentioned result are also of great interest, since, extention of root diameter means directly an increase of the phloem section area and that is accompanied with more photosynthate are being translocated into roots from shoots.

That, are being also of great interest for enhancement of Nigella growth to be more tolerable for each the soil boron fungi infection and flowers abscission (the two habits are being commonly occurred in flowering stage of this plant).

<u>II.2. 3. Root size:</u>

As shown in Table (3) in most cases different applied treatments significantly increased the root size of treated plants in comparison with the control. Also, it could be noticed that increases of root size reached its maximum during the two times of measuring (i.e., 1^{st} and 2^{nd} samples) with boron + sulphur treatment in 2003 season. Values were 1.033 & 1.433 cm/plant, respectively. Yet in the second sample the highest significant value existed with BA at 5 ppm + (B + S each at 50 ppm) (1.533 cm / plant) in 2003 season and with PP_{333} at 1 ppm + (B + S each at 50 ppm) (1.500 in 2004 season).

Here, of interest to reach an increase in the size of root system of *Nigella sativa* plant with any treatment. Since, as previously mentioned, wilting and death of *Nigella sativa* plants just following stage being evocated is a great problem that face *Nigella sativa* growth and productivity as well.

In this respect, **Mostafa *et al.* (1996)** reported that, this result may be due to that using B at suitable level with suitable method of application led to increase and activate the formed roots to absorb the necessary elements for flower initiation and development, besides boron increases the relative amounts of phosphosynthate translocated to each region, specially that of flower initiated consequently stimulated florets development **(Sisler *et al.*, 1958 and Sorokina, 1971).** Similar trend of results was obtained by **Valk *et al.* (1991)** on tulip plant.

II.3. Shoot measurements:

II.3.1. Plant height:

As shown in Table (4), at the first sample during 2003 and 2004 seasons different applied treatments showed little effect upon plant height. In this respect boron at 50 ppm, sulphur at 250 ppm and K at 500 ppm during 2003 season as well as B at 50 ppm and BA at 5 ppm combined with B and S in 2004 season showed an increase of this height.

On the other hand, at the second sample during the two seasons different treatments obviously affected this character. Here, the treatment of BA and NAA each combined with B and S as well as NAA alone at 50 ppm exhibited the greatest plant height during 2003 season (Figs. 1 & 2).

Table (4): Effect of different applied treatments on stem characteristics of black cumin (*Nigella sativa* L.) at two stages (vegetative and reproductive growths i.e. 66 and 176 days of plant age) during 2003 and 2004 seasons.

Characters	Plant height Cm/plant		Stem diameter Cm/plant		Plant height Cm/plant		Stem diameter Cm/plant	
Seasons	2003	2004	2003	2004	2003	2004	2003	2004
Samples / Treatment (ppm)	First sample (Vegetative growth)				Second sample (Reproductive growth)			
Boron 50	31.67	32.00	0.283	0.317	35.33	38.67	0.667	0.650
Boron 250	28.00	27.33	0.267	0.283	33.00	32.67	0.467	0.427
Sulphar 50	28.33	26.67	0.233	0.227	30.00	30.67	0.390	0.387
Sulphar 250	32.33	24.33	0.283	0.250	34.67	33.67	0.417	0.400
K 100	30.67	27.33	0.233	0.217	35.00	33.00	0.417	0.417
K 500	30.33	25.67	0.290	0.290	35.00	33.00	0.417	0.417
BA 5	26.00	22.33	0.333	0.333	31.67	31.00	0.533	0.533
BA 25	28.67	25.67	0.357	0.373	38.67	36.33	0.850	0.917
NAA 10	29.33	26.33	0.233	0.207	38.00	39.33	0.413	0.433
NAA 50	24.00	21.67	0.283	0.273	45.33	42.00	0.367	0.383
PP_{333} 1	27.00	29.33	0.313	0.297	36.00	38.67	0.567	0.600
(B + S) (50 + 50)	29.00	30.33	0.370	0.330	37.33	38.33	0.517	0.500
BA + (B +S) 5 + (50+50)	36.00	35.33	0.303	0.323	41.00	42.67	0.4483	0.520
NAA + (B + S) 10 + (50 +50)	29.00	28.33	0.253	0.217	45.67	47.33	0.48	0.500
PP_{333} + (B + S) 1 + (50 + 50)	22.00	20.67	0.320	0.300	31.67	33.33	0.517	0.510
BA + NAA + (B + S) 5+ 10+ (50 +50)	25.33	22.67	0.290	0.317	41.00	39.67	0.510	0.517
Control	27.33	25.67	0.283	0.223	37.67	32.67	0.323	0.333
L.S.D at 0.05	4.07	3.56	0.05	0.05	3.55	3.68	0.07	0.05
L.S.D at 0.01	5.60	4.91	0.07	0.07	4.88	5.07	0.01	0.07

Fig. (1)

Fig. (2)

Figs. (1 & 2): Effect of NAA alone at 50 ppm (Fig. 1) or NAA at 10 ppm combined with boron and sulphur each at 50 ppm (Fig. 2) on plant height of *Nigella sativa* L.

Meanwhile, in 2004 season the maximum plant height at the second sample was achieved with BA and NAA each combined with B and S as well as with BA at 5 ppm + NAA at 10 ppm + (B + S each at 50 ppm) and with B at 50 ppm.

The above mentioned results are being in high correlation with each of stem diameter and branches number as will mentioned after words.

II.3.2. Stem diameter:

As shown in Table (4) different applied treatments didn't show obvious effect upon stem diameter in the first sample during the assigned seasons. The only exception was that significant increase existed with B at 50 ppm, BA at 5 ppm and 25 ppm, PP_{333} at 1 ppm, B + S at 50 ppm for each, BA at 5 ppm + (B + S each at 50 ppm) and BA at 5 ppm + NAA at 10 ppm + (B + S each at 50 ppm). Meanwhile, in the two seasons significant decrease of stem diameter was existed only in case of K at 100 ppm, NAA at 10 ppm, NAA at 10 ppm + (B+S each at 50 ppm) meanwhile, significant reduction existed also with B at 250 ppm and with sulphur at 50 ppm but only in 2004 season. On the other hand, in the second sample the all applied treatments significantly increased this diameter during the two seasons. In this respect also it could be noticed that BA at 25 ppm that gave 0.85 and 0.92 cm in the two seasons, respectively, ranked the first in this respect. Meanwhile, B at 50 ppm followed by PP_{333} at 1 ppm represented the third and fourth position in this respect.

Here, it could be mentioned that BA as exogenous application or PP_{333} that estimate endogenous synthesis of cytokinin; both exhibited the highest increased of this diameter. In this respect, cytokinins known and will recommended to increase the extension growth of plant tissue **(Devlin and Witham, 1983 and Marschner, 1995).**

In addition, NAA and K gave the lowest stem diameter during the two seasons since auxins (as NAA) is known to stimulate longitudinal growth.

Also, spraying of B or GA_3 at 500 or 100 ppm, respectively caused further significant increases in plant height, number of leaves and branches and leaf area over the lower levels. These increases in growth characters of broad bean plants could be attributed to the increase in both cell division and cell elongation. In addition, the increment in vegetative growth characters could be explained on the basis that P, B or GA3 play major roles in protein synthesis and protoplasm formation. This may increase the proportion of protoplasm to cell wall with the result of increased cell size **(Marschner, 1986).**

The increase in vegetative growth characters, as a result of boron spray, may be due to that using B at suitable concentrations stimulate the division and the elongation in the cell of the new growth formed, besides, B is very closely related to the activity of meristems, especially apical meristems, consequently, increasing the plant height, number of branches and leaves and leaf area **(Sorokina, 1971; Marschner, 1986 and Abou-El-Magd *et al.*, 1989).** Similar trend of results was found by **Hassan (1985)** on common beans, **Ibrahim (1990)** on field beans, **Baghel and Sarnaik (1988)** on onion, **Singh *et al.* (1992)** on peas and **Mostafa *et al.* (1996)** on tuberous plants.

II.3. 3. Number of leaves:

As shown in Table (5) the number of formed leaves didn't show great variation when compared with control at the first sample during the two assigned seasons. However, in this sample, 50 ppm B, S at the two applied concentrations, 100 ppm K in 2003 season as well as B and S at the two applied concentrations for each; 100 ppm K, 5 ppm BA, B+S each at 50 ppm; BA at 5 ppm + (B+S each at 50 ppm); NAA at 10 ppm + (B+S each at 50 ppm) and PP_{333} at 1 ppm + (B+S each at 50 ppm) all of these increased leaves number to reach the high level of significance.

On the other hand at the second sample in both seasons high significant results were existed in case of all the applied combined treatments as well as B at 50 ppm, BA at 25 ppm and PP_{333} at 1 ppm but only it was during 2004 season for K at 100 ppm and NAA at 50 ppm.

In this respect, data clearly confirmed that NAA at 10 ppm combined with B and S each at 50 ppm were superior for increasing leaf formation, meanwhile, S at the two concentrations and BA at 5 ppm when each used separately did not show clear effect in this respect.

The above mentioned data about, increasing leaves number could be attributed mainly to that increase of formed shoots. Also, it could be noticed that exogenous application of cytokinins or estimation of endogenous cytokinins formation (by the application of paclobutrazol) is being related with the well recommended physiological effect of cytokinins for increasing branches formation.

T5

Also, increased of leaves number it means increase in photosynthetic area itself. Therby, high photosynthesis and more photosynthates creation is being expected. That could be reversed upon vigorous growth and more economic yield.

II.3.4. Number of branches:

As shown in Table (5) and Figs. (3 – 8) branches number didn't show great variation either between the first and second samples or during the two seasons. In this respect, it could be noticed that each of BA and PP_{333} have superiority for stimulation and that as previously mentioned is well recommended. Also, it could be noticed that K had less effect in this respect. Also, the final number and their length of branches at harvest time (i.e. at 176 days of plant age) was also consider in the present study.

Here, as shown in Table (5) total number of branches at harvest time during 2003 and 2004 seasons showed the two levels of significant. Since, B, BA, PP_{333}, (B + S each at 50 ppm), BA + (B + S each at 50 ppm), NAA + (B + S each at 50 ppm) and PP_{333} + (B +S each at 50 ppm) increased branch number to reach the high level of significant mostly during the two seasons. Meanwhile, nearly the rest of treatments exhibited the level of significant.

With regard to summation of branches height / plant it could be noticed that it behaved similarly as branches number. Since BA, PP_{333} were the most effective of different applied treatments.

Considering Tables (4) and (5) it could be noticed that the over effect of increasing branches number is being more obvious in the last stage of plant growth. That means that, black cumin plant responded retardly to various applied treatments, since the highest branches number is being formed after the second sample (i.e. after 66 or 176 days of plant age).

Fig. (3)

Fig. (4)

Fig. (5)

Figs. (3-5): Effect of certain applied treatments on branches number of treated black cumin plants.

Where:

Fig. (3): PP_{333} at 1 ppm.

Fig. (4): 5 ppm BA + 10 ppm NAA + (B+S each at 50 ppm).

Fig. (5): S at 50 ppm.

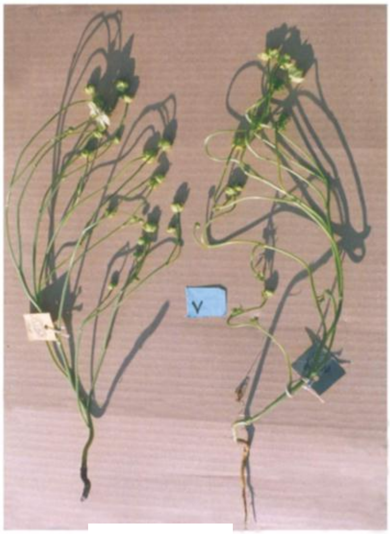


Fig. (6)

Fig. (7)

Fig. (8)

Figs. (6-8): Effect of certain applied treatments on branches number of treated black cumin plants.

Where:

Fig. (6): B + S each at 50 ppm.

Fig. (7): K at 100 ppm.

Fig. (8): 1 ppm PP_{333} + (B + S each at 50 ppm).

This behaviour of black cumin it may correlated not only with that slowly natural rate of *N. sativa* growth but also, minimum distribution of its root system.

Data in Table (5) clearly show that all the applied treatments increased the dry weight of shoots + fruits (i.e. dry weight of shoots and fruits) of black cumin during 2003 and 2004 seasons.

In this respect, the treatment of BA at 5 ppm + (B + S each at 50 ppm) exhibited the highest dry weight of shoots + fruits that reached 10.83 and 9.29 g/plant with percentage of 434 and 471% in relative to the control during 2003 and 2004 seasons, respectively. Yet, sulphur at 250 ppm, boron at the two applied concentrations, K at 100 ppm and NAA at 50 ppm gave the lowest increase in this respect.

In this respect, **Mostafa (1996)** show that, the single addition of B at 1.5 ppm or Mg at 10 ppm, significantly increased the production of leaves dry matter compared with the control, with one exception in the second season. Furthermore, the highest leaves dry weight was obtained by the application of the three nutrients B, Mn and Mg together at 1.5, 1.12 and 10 ppm, respectively. Theses results may be to attributed to the increases in leaves number or area or both of them. Similar trend of results was obtained by **Buzetti *et al.* (1991)** on soybean plants.

Also, the present data are going in harmony with those results obtained by **Ahmed (1993) and El-Badawy and Abd-Allah (1984)** who reported that, CCC increased branch number. They added that branch number may be attributed to the effect of this regulator on counteracting the apical dominance.

II.4. 1. Leaves characteristics:

Data in Table (6) clearly indicates the effect of different applied treatments on leaves characteristics (i.e. number of leaves per plant and leaf area per plant) of black cumin *Nigella sativa* L. plants during 2003 and 2004 seasons.

As for number of leaves per plant, the only BA at 25 ppm and NAA at 10 ppm insignificantly increased it at the first sample during 2003 seasons, meanwhile all different applied treatments increased this number to reach the high level of significance at the first and second samples during the two assigned seasons.

Regarding, the total leaf area per plant, it was high significantly increased during the two assigned seasons with different applied treatments Table (6). The only exception was that significant decrease with Boron at 50 ppm, 250 ppm and sulphur at 100 ppm existed during 2003 and 2004 seasons. Also, it could be noticed that the BA at 5 ppm + (B+S each at 50 ppm) treatment gave highest values in the second sample during the two assigned seasons. Since area reached to 6642.5 & 6142.37 cm^2 in the second sample during 2003 & 2004, respectively meanwhile, it was only 1588.90 & 1827.70 cm^2 per plant in the control during the same seasons.

On the other hand, sulphur at 50 ppm gave the lowest increase of this area during the two seasons. Yet, significant decreases existed with each of boron at the two applied concentrations and sulphur at 250 ppm during the two seasons.

T6

In this respect, increasing each of leaves number and area could be expected with some of the applied treatments. Of these, is the treatment of BA at 5 ppm + (B + S each at 50 ppm), since Benzyladenine is a shooting hormone **(Devlin and Witham, 1983 and Marschner, 1995)**. Therby, increasing both leaves number and their area, as well is mainly due to increasing of branches number (Table 6).

II.4.2. Absolute growth rate:

Data in Table (7) indicate that NAA at the highest concentration gave the highest increase of absolute growth rate (A.G.R). Value was 0.206 comparing only with 0.048 in case of control. Also, NAA at 10 ppm and B + S each at 50 ppm, PP_{333} at 1 ppm + (B + S each at 50 ppm) ranked the second in this respect.

On the other hand, sulphur at 250 ppm and B at 250 ppm significantly decreased the absolute growth rate to reach 0.027 & 0.033, respectively. The above mentioned results nearly were the same in both seasons.

Moreover, the above mentioned results are being more evident when calculated relatively to the control. For example, in the second season the treatment of NAA at 50 ppm gave 513.51% followed by PP_{333} at 1 ppm + (B + S each at 50 ppm) gave 375.04% comparing with 100% for the control. That means that such treatment (i.e., NAA at 50 ppm) gave A.G.R. 5 times more than control followed by PP_{333} at 1 ppm and B + S each at 50 ppm.

With regard to, the relative growth rate (RGR) data also in Table (7) clearly indicate that PP_{333} at 1 ppm followed by B + S each at 50 ppm exhibited the highest value of R.G.R. Meanwhile, K

T7

at 500, S at 250, BA + NAA + (B+S) at 5 + 10 + (50+ 50) ppm and B at 250 ppm gave the lowest values in this respect. That was obtained during the first season, but in the second one results were to some extent variant. Since, NAA at 50 ppm gave the highest value followed by BA at 25 ppm PP_{333} at 1 ppm and K at 100 ppm indescending order.

In addition, the above mentioned results are being more obvious when calculated as a percent of control. For example, in the second season the treatment of NAA at 50 ppm gave a percentage of 485% comparing with control. That means that NAA at 50 ppm gave R.G.R. more than 4 times followed by BA at 25 ppm that gave R.G.R. more than 2 times comparing with the control. Meanwhile, K at 100 ppm ranked the third in this respect.

II.4.3. Net assimilation rate (NAR):

Data presented in Table (7) clearly indicate that PP_{333} at 1 ppm gave the highest increase of net assimilation rate (NAR) value during two seasons, (e.g. it was 0.097 g/gm/day in the first season) comparing only with 0.039 in case of control. Also, B at 50 ppm, NAA at 10 ppm (B + S each at 50 ppm), B at 250 ppm, K at 100 ppm, B + S each at 50 ppm, S at 250 ppm, NAA at 10 ppm and NAA at 50 ppm ranked the second in this respect. Meanwhile, BA at 5 ppm + (B + S each at 50 ppm) BA at 5 ppm + NAA at 10 ppm + B + S each at 50 ppm, K at 500 ppm, BA at 5 & 25 ppm, S at 50 ppm and PP_{333} + B + S each at 50 ppm gave the lowest values in this respect. That was obtained in first season, but in the second one results were to some extent variant. Since, B at the highest concentration gave the highest increase followed by B at the lowest concentration, PP_{333} at 1 ppm, S at 250 ppm, B + S each at 50 ppm, K at 100 ppm, NAA at 50 ppm, NAA at 10 ppm + (B + S each at 50 ppm), NAA at 10 ppm and BA at 25 ppm in descending order.

Furthermore, the above mentioned results are being more evident when calculated relatively to the control. For example, in the first season the treatment of PP_{333} at 1 ppm gave percentage of 248.72% followed by B at 50 ppm gave 174.36% comparing with 100.00% for the control. That means that such treatments (i.e. PP_{333} at 1 ppm gave N.A.R. with about two times more than the control. Meanwhile, B at 50 ppm and NAA at 5 ppm + (B + S each at 50 ppm) ranked the second and the third in this respect.

II.4.4. Photosynthetic pigments:

As shown in Table (8) nearly different applied treatments clearly increased each of chorophyll a and b.

In this respect, chlorophylls (a + b) was decreased with K at 500 ppm. Yet, the rest of treatments increased this content. Also, in this respect, it could be noticed that the highest increase in chlorophyll achieved with the treatment of BA at 5 ppm + B and S each at 50 ppm in 2003 season and with BA at 5 ppm during 2004 season as well as with B at the two applied concentrations. Also, the above mentioned results are being more obvious when calculated on the basis of control.

The enhancement or stimulation of photosynthetic pigment biosynthesis could be of great interest, since that could be reversed upon photosynthetic process efficiency itself as well as its reversion upon increasing of the yielded seeds, i.e. the economic yield.

T8

On the other hand, for carotenoids it could be noticed that different applied treatments did not show clear effect as in case of chlorophyll. Since most treatments slightly increased or decreased it.

Here, also it could be noticed that the all applied treatments specially Benzyladenine combined with boron 50 ppm + sulphur at 50 ppm, obviously increased the total pigments as well in leaves of treated plants.

On the other hand, the treatment of elements mixture (i.e 50 ppm B + 50 ppm S) nearly gave the lowest values when even compared with control or other treatments.

Also, it may relate between carotenoids content and the quality and quantity of oil yielded (as well mentioned afterwords).

II.5. Histological studies:

II.5.1. Anatomy of the roots:

Data in Table (9) and Figs. (9-20) clearly show that different applied treatments highly increased root diameter. Root diameter in transverse sections reached its maximum with K at 100 ppm followed by benzyl adenine when used alone or in combination with NAA and elements mixture (i.e. boron and sulphur) as well as paclobutrazol. Here, also it could be noticed that increasing root diameter is mainly due to that increase of cortex and vascular tissues.

Increasing of vascular tissues are being of great interest, because that could reversed upon improvement of translocation for nutrients and the photosynthates as well. In other meaning

T9

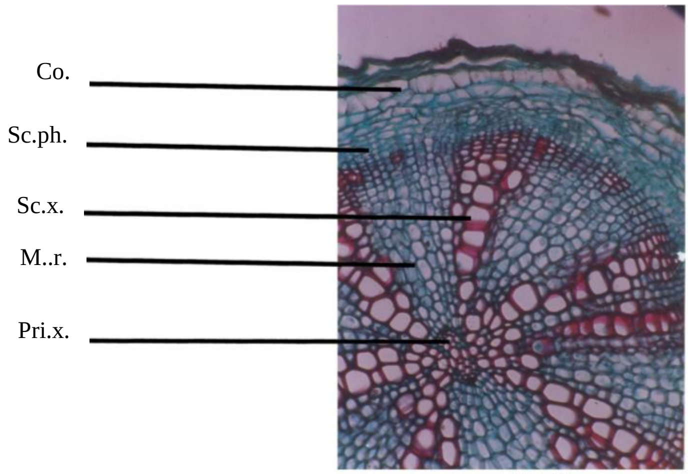


Fig. (9)

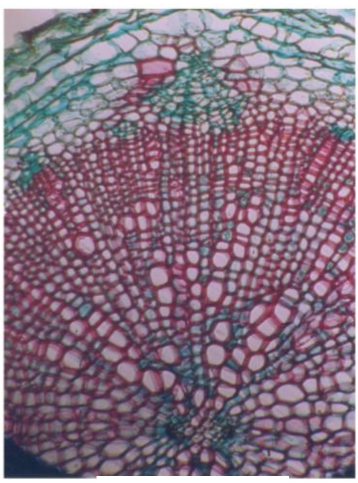


Fig. (10)

Fig. (11)

Figs. (9-11): Effect of different applied treatments on root anatomy of *Nigella sativa* L. (100 = X)

Fig. (9): Control Fig. (10): B at 50 ppm Fig. (11): S at 50 ppm

Where = Co. = cortex

Sc.ph. = secondary phloem Sc.x. = secondary xylem

Pri.x.= primary xylem M.r.= medulary rays .

Fig. (12)

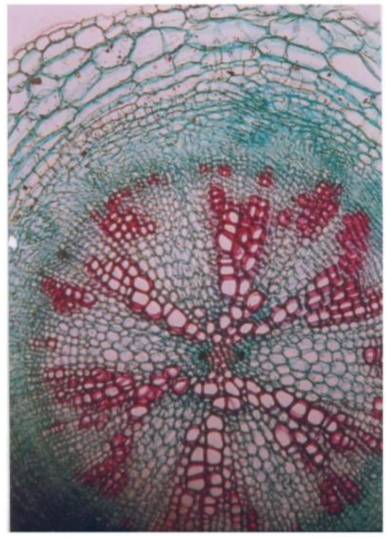


Fig. (13)

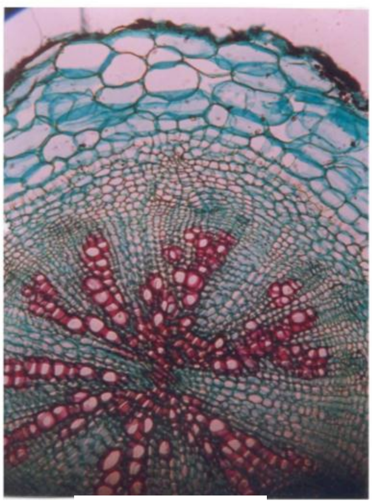


Fig. (14)

Fig. (15)

Figs. (12-15): Effect of different applied treatments on root anatomy of *Nigella sativa* L. (100 = X)

Fig. (12): K at 100 ppm.
Fig. (13): BA at 5 ppm.
Fig. (14): NAA at 10 ppm.
Fig. (15): PP_{333} at 1 ppm.

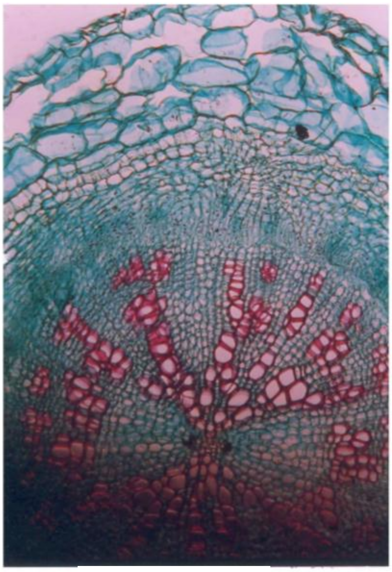


Fig. (16)

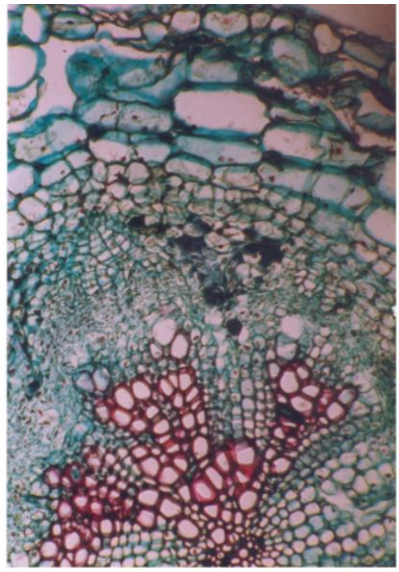


Fig. (17)

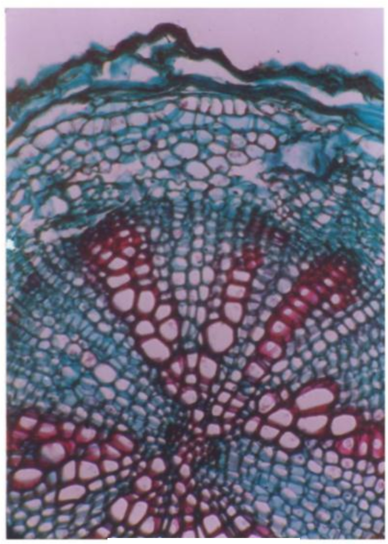


Fig. (18)

Figs. (16-18): Effect of different applied treatments on root anatomy of *Nigella sativa* L. (100 = X)

Fig. (16): B+S at 50 +50 ppm

Fig. (17): BA at 5 ppm + B+S at 50 + 50 ppm

Fig. (18): NAA at 10 ppm + B+S at 50 + 50 ppm

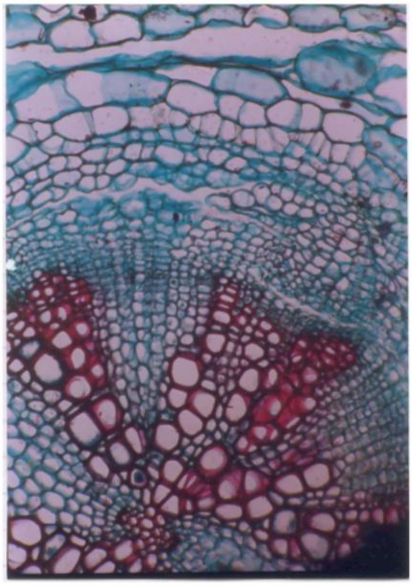


Fig. (19)

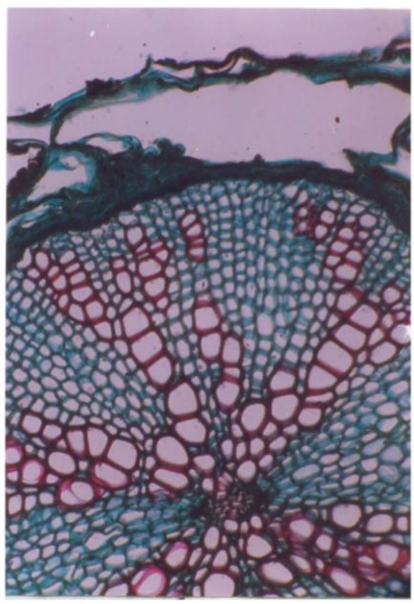


Fig. (20)

Figs. (19-20): Effect of different applied treatments on root anatomy of *Nigella sativa* L. (100 = X)

Fig. (19): PP_{333} at 1 ppm + B+S at 50 + 50 ppm

Fig. (20): BA at 5 ppm + NAA at 10 ppm + B+S at 50 + 50 ppm

translocation of water and different nutrients from soil to leaves from one side and photosynthates from leaves to various plant parts from the other. In addition the above mentioned results are being more evident when thickness of secondary xylem vessels are considered. Also, width of the largest xylem vessels was proportional to the width of stem diameter (Table 9).

II.5.2. Anatomy of the stems:

Data in Table (10) and Figs. (21-32) clearly show that different applied treatments increased stem diameter. In this respect, the obvious and highest increase was obtained with BA at 5 ppm + NAA at 10 ppm + (B + S, 50 ppm for each) followed by PP_{333} at 1 ppm + (B + S, 50 ppm for each); BA at 5 ppm + (B + S, 50 ppm for each); BA at 5 ppm; NAA at 10 ppm + (B + S, 50 ppm for each) and boron at 50 ppm in descending order.

Also, it could be noticed that stem diameter increase is mainly due to the obvious increase of stem wall thickness not to the diameter of hollow pith.

These results are of great interest because increase of stem wall thickness means increase and rising activity for efficiency each of the translocation rate of water and row material received from roots and efficiently, passage them to leaves. That not only, but also, increasing the wide of that passage of photosynthates from leaves to other plant parts. That, of course, could be reflected upon increasing growth and yield, as well.

For recommending our above suggestions, the translocation rates of photosynthates from leaves to other plant parts including fruits are completely related with the area of transverse phloem section.

T10

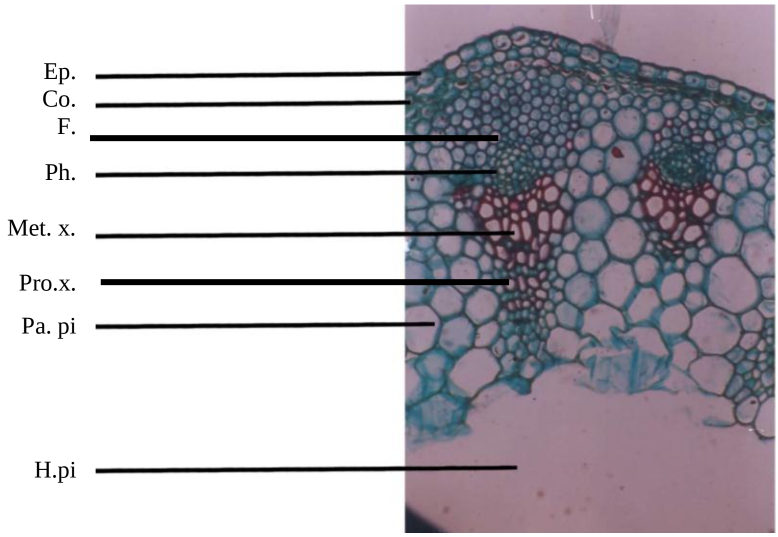


Fig. (21)

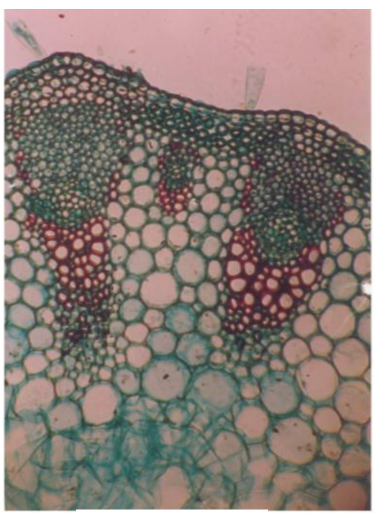


Fig. (22)

Fig. (23)

Figs. (21-23): Effect of different applied treatments on stem anatomy of *Nigella sativa* L. (100 = X)

Fig. (21): Control Fig. (22): B at 50 ppm Fig. (23): S at 50 ppm

Where = Ep. = Epiderms Co. = cortex

F. = Fibers Ph. = phloem

Met.x.= Meta xylem Pro.x. = Proto xylem

Pa.pi. = Parenchymatous pith **H.Pi. = Hollow pith**

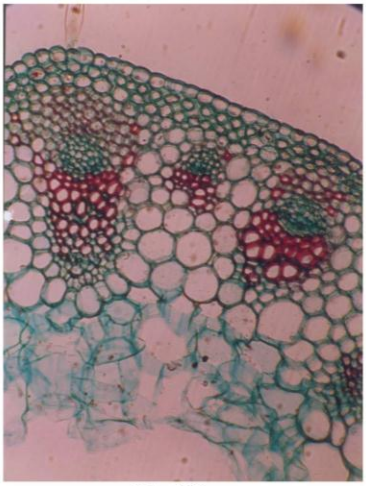
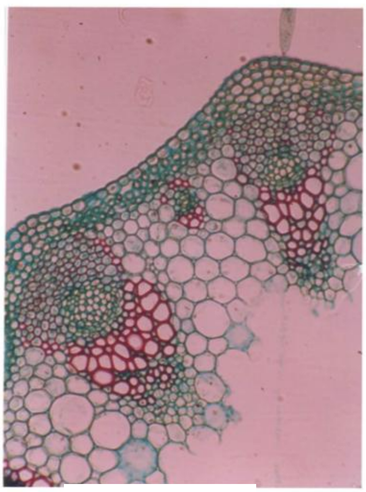


Fig. (24) **Fig. (25)**



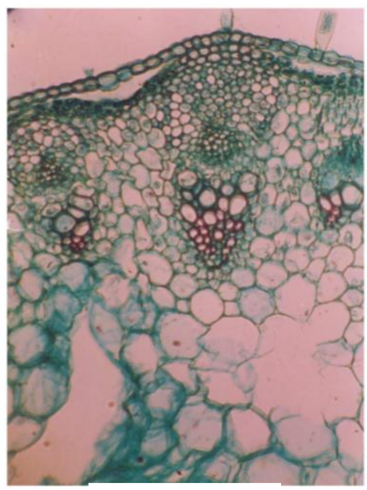


Fig. (26) **Fig. (27)**

Figs. (24-27): Effect of different applied treatments on stem anatomy of *Nigella sativa* L. (100 = X)

Fig. (24): K at 100 ppm
Fig. (25): BA at 5 ppm
Fig. (26): NAA at 10 ppm
Fig. (27): PP_{333} at 1 ppm

Fig. (28)

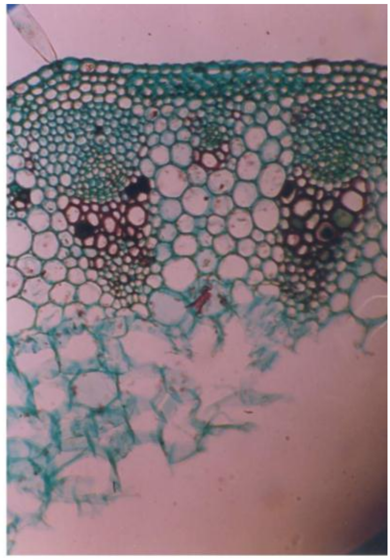


Fig. (29)

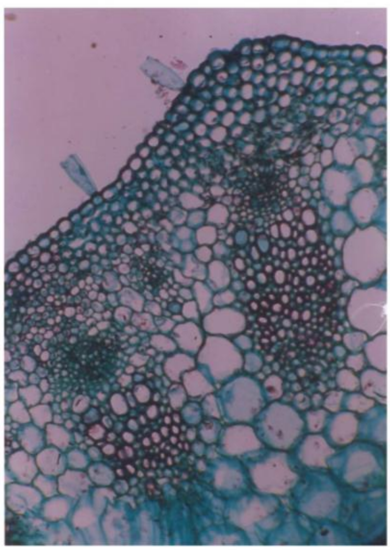


Fig. (30)

Figs. (28-30): Effect of different applied treatments on stem anatomy of *Nigella sativa* L. (100 = X)

Fig. (28): B+S at 50 +50 ppm

Fig. (29): BA at 5 ppm + B+S at 50 + 50 ppm

Fig. (30): NAA at 10 ppm + B+S at 50 + 50 ppm

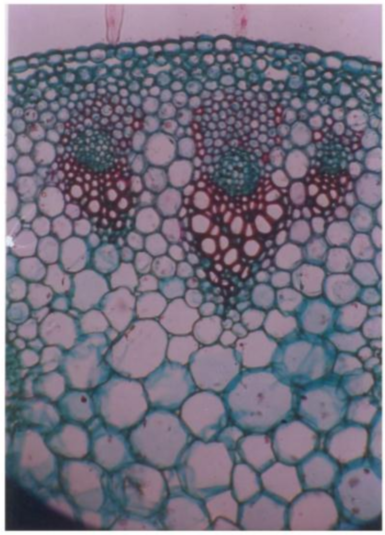


Fig. (31)

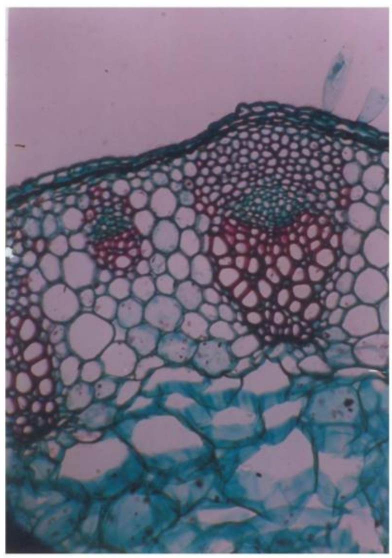


Fig. (32)

Figs. (31-32): Effect of different applied treatments on stem anatomy of *Nigella sativa* L. (100 = X)

Fig. (31): PP_{333} at 1 ppm + B+S at 50 + 50 ppm.

Fig. (32): BA at 5 ppm + NAA at 10 ppm + B+S at 50 + 50 ppm.

Also, data in Table (10) clearly show that paclobutrazol at 1 ppm decreased the number of vessels but it increased obviously the wide of xylem vessels (Fig. 15).

Many workers reported that application of CCC similar to PP_{333} to different legume plants caused increase in stem thickness by promoting the thickness of different tissues. On the other hand stem elongation was decreased due to CCC treatment **(El-Shaarawi and Megahed, 1976; Soliman, 1984; Khafaga *et al.*, 1986; El-Fouly *et al.*, 1988; Hussein, 1990 and Abdo, 1992).**

Also, **El-Shaarawi *et al.* (2004)** reported that in mung plant transverse sections of the upper region of main stem (seventh internode) at the age of 45 days revealed that the effect of CCC varied according to concentration used. The rate of 1000 ppm of CCC increased diameter of whole section, thickness of cortex, number of vascular bundles, size of vascular bundle, number of vessels per bundle and diameter of pith. On the other hand, all of these anatomical characters decreased when the rate of 1500 ppm CCC was used, in comparison with control. It could be concluded therefore, that while the rate of 1000 ppm stimulated the growth of upper internode in width the rate of 1500 ppm CCC retarded it.

Transverse sections of the median region (fifth internode) or basal one (third internode) of mung bean main stem showed that treatment with 1000 ppm or 1500 ppm of CCC promoted the radial growth of main stem at both regions.

The promotive effect occurred through increasing diameter of xylem cylinder, thickness of cortex, thickness of vascular cylinder, thickness of phloem and diameter of pith. Consequently the diameter of whole section increased due to treatment. Thickness of xylem increased by using the rate of 1000 ppm and slightly decreased at the rate of 1500 ppm of CCC when compared with that of untreated stems. The increase in thickness of cortex could be attributed to the increase in number of cortical layers and size of cells. The suggested stimulative effect of CCC on cambial activity might be responsible for the increased thickness of vascular cylinder of treated stems. It is worthy to note that, the two rates 1000 and 1500 ppm of CCC enhanced the radial growth of main stem when compared with control and the stems treated with 1000 ppm of CCC surpassed those treated with 1500 ppm in this respect. These results are in accordance with the findings of **El-Shaarawi and Megahed (1976) and Sakr (1977)** on bean, **Soliman (1984)** on soybean, **Khafaga *et al.* (1985)** on pea, **Khafaga *et al.* (1986)** on soybean, **Nagdy *et al.* (1989)** on soybean, **Hussein (1990)** on pea and **Abdo (1992)** on bean.

The above mentioned conclusion is being also more evident from the data in Table (10). Since, data show that treatments as paclobutrazol and benzyl adenine increased stem diameter are also gave the widest xylem vessels and paranchymatous tissue.

II.6. Phytohormones determination:

Effect of cartain treatments on the endogenous phytohormones profile:

According to the growth behaviour of plants in different applied treatments and the control as well during 2003 season; BA at 25 ppm, PP_{333} at 1 ppm, NAA at 50 ppm, BA at 25 ppm + (B + S each at 50 ppm) and the control were chosen for endogenous phytohormones in 2004 season.

Endogenous phytohormones including the growth promoters i.e., auxins, gibberellins, cytokinins and the growth inhibitor adscisic acid were determined in both roots and shoots of the assigned treatments at 66 days of plant age.

As shown in Table (11) and Figs. (33-37) the endogenous auxin (i.e., Indole-3-acetic acid, IAA) the treatments of Benzyl adenine (BA) at 25 ppm, paclobutrazol (PP_{333}) at 1 ppm and Naphthalene acetic acid at 50 ppm increased the endogenous amount of auxin in roots with more two, three and nine times, respectively than the control value. Since these values were, 17.94, 25.058 and 64.14 μg/100 gm with BA, PP_{333} and NAA, respectively meanwhile it was 7.10 μg/100 gm in control plants.

On the other hand, BA at 25 ppm + (B+S each at 50 ppm) decreased this endogenous amount of endogenous auxin in roots of treated plants to reach only 2.814 μg/100 gm comparing with 7.102 μg/100 gm in roots of control plants. That means that these treatments decreased the amount of endogenous auxin in roots of treated plants by about one third of control treatment.

In case of shoots, clearly it could be noticed that each of paclobutrazol at 1 ppm and NAA at 50 ppm highly increased the endogenous amount of auxin in treated shoots. Since, values were 279.346 and 21.003 μg/100 gm with PP_{333} at 1 ppm and NAA at 50 ppm, respectively meanwhile it was only 5.282 μg/100 gm in control shoots. That means that these two treatments increased

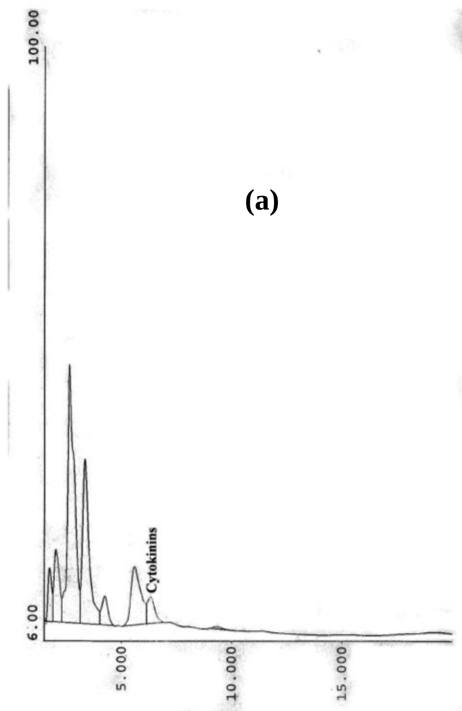
Table (11): Effect of certain applied treatments on endogenous hormonal profile in roots and shoots of *Nigella sativa* L. plants at 66 days of plant age during 2004 season µg/100g F.W.).

Phytohormones	Promoters			Inhibitors	Prom./ Inhib. rtio
	Indole acetic acid (IAA)	Abscisic acid (ABA)	Cytokinins	Abscisic acid (ABA)	(%)
Treatments (ppm)	**In roots**				
BA 25	17.941	2.213	12.330	13.190	245
PP_{333} 1	25.058	-	128.182	0.177	77125
NAA 50	64.144	-	12.900	-	-
BA + (B + S) 25 + (50+ 50)	2.814	-	2.412	-	-
Control	7.102	-	64.486	-	-
	In shoots				
BA 25	0.223	-	11.822	-	-
PP_{333} 1	279.346	-	39.064	-	-
NAA 50	21.003	-	29.008	-	-
BA + (B + S) 25 + (50+ 50)	2.424	-	8.296	1.114	972
Control	5.282	-	20.014	1.023	2530

Endo. = Endogenous. F.W. = Fresh weight.

Prom. = Promoters Inhib. = Inhibitors

Fig. (35): Diagram indicating the effect of NAA at 50 ppm treatment on the endogenous (a) cytokinins and (b) IAA, GA_3 & ABA in black cumin (*Nigella sativa* L.) roots at 66 days after sowing during 2004 season (µg/100 gm fresh weight).



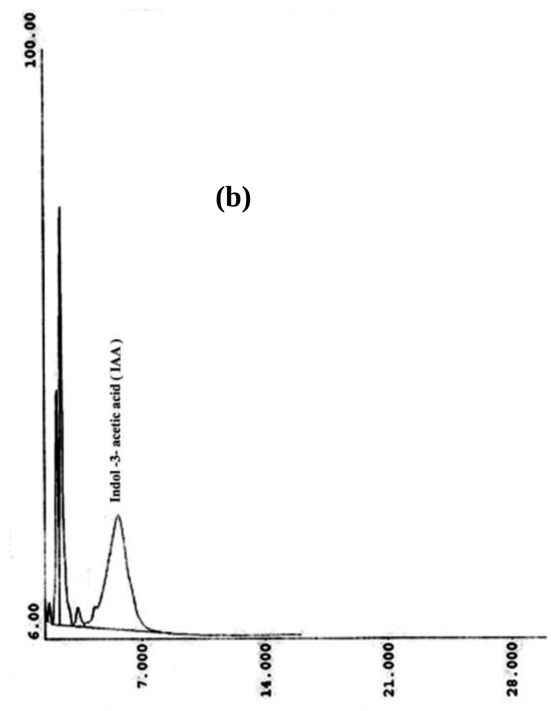


Fig. (36): Diagram indicating the effect of treatment (BA at 25 ppm combined with boron and sulphur mixture each at 50 ppm) on the endogenous (a) cytokinins and (b) IAA, GA_3 & ABA in black cumin (*Nigella sativa* L.) roots at 66 days after sowing during 2004 season (µg/100 gm fresh weight).

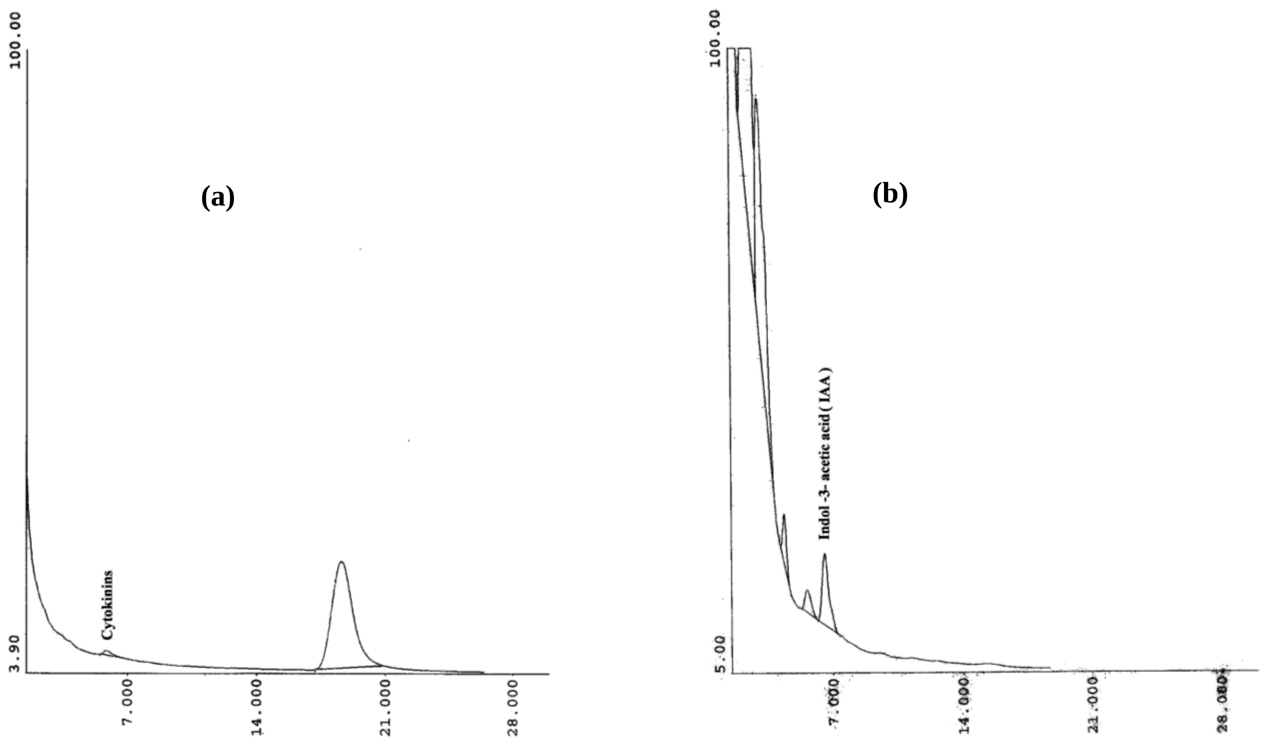
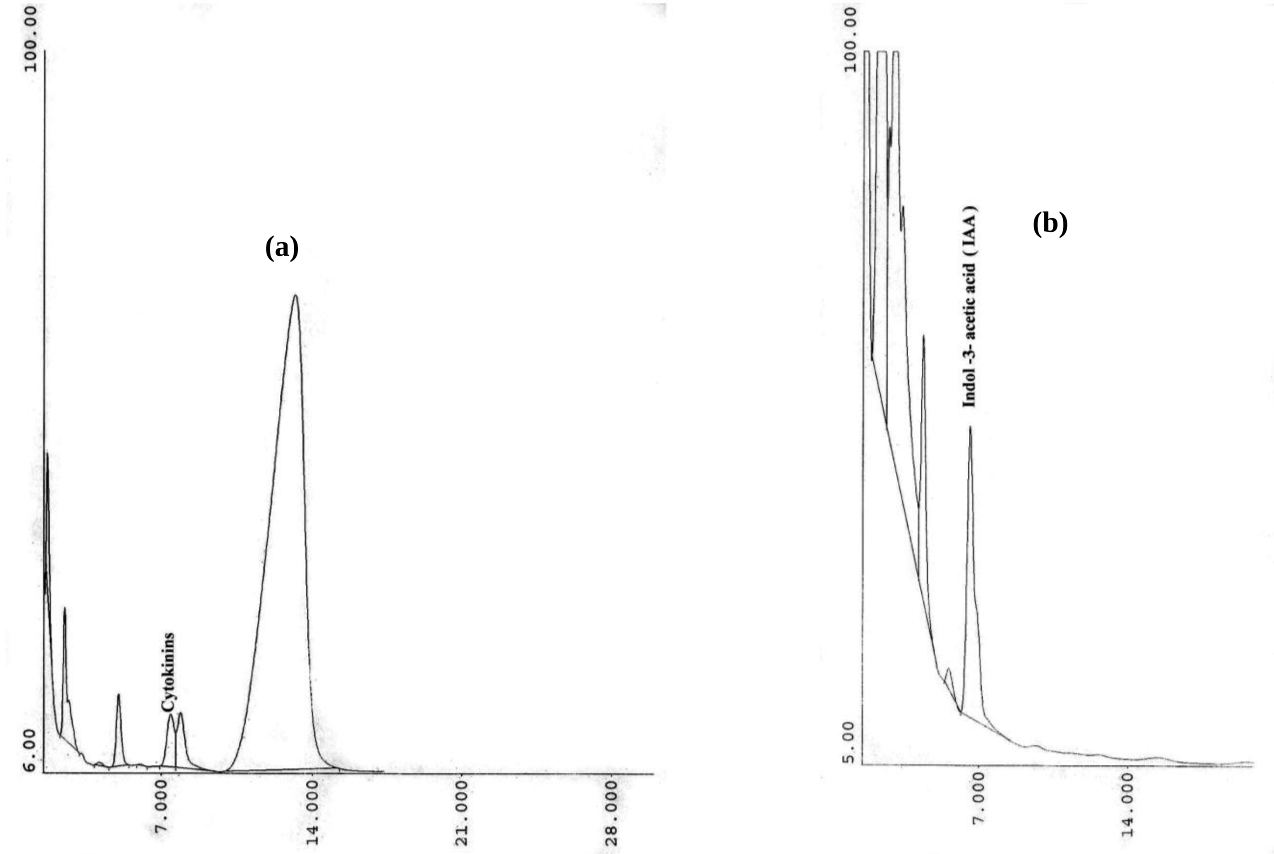


Fig. (37): Diagram indicating the effect of untreated treatment (i.e., control) on the endogenous (a) cytokinins and (b) IAA, GA3 and ABA in black cumin (*Nigella sativa* L.) roots at 66 days after sowing during 2004 season (µg/100 gm fresh weight).



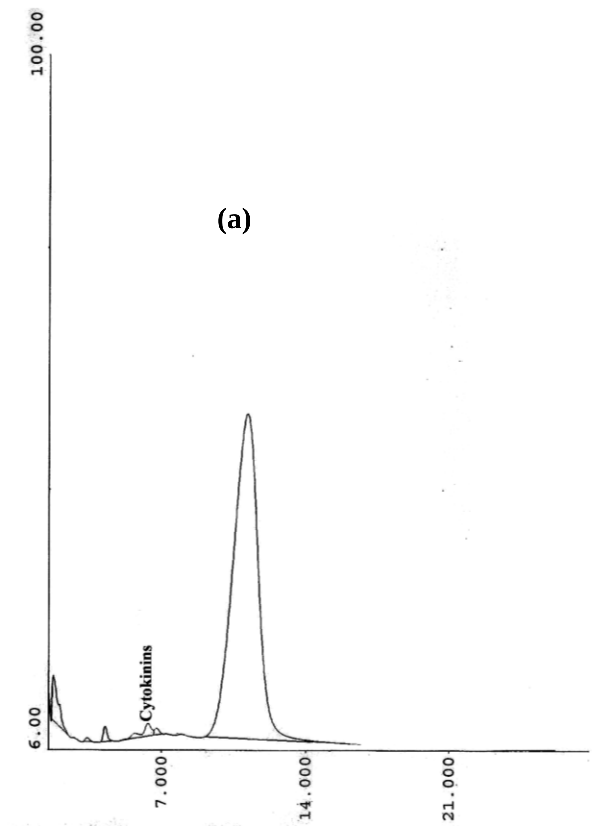
the endogenous amount of auxin in shoots with more fifty and fourty times than the control. Meanwhile, the treatment of Benzyladenine either when applied separately or when combined with each of boron and sulphur at 50 ppm for each; clearly decreased this content. In this respect, the severe reduction of endogenous auxin (0.223 μg/100 gm) existed with BA when used alone, yet, in combination with boron and sulphur it gave (2.424 μg/100 gm) nearly one third of control value (5.282 μg/100 gm) (Table 11 and Figs. 38-42).

As for the endogenous gibberellic acid (GA_3), it could be noticed that the only treatments of benzyl adenine (BA) at 25 ppm gave a detectable amounted of 2.213 μg/100 gm in roots of treated plants. Yet, either in roots or in shoots, the rest of treatments did not show any detectable amounts of this hormone (Table 11 and Figs. 33-37).

With regard to the third determined growth promoter cytokinins; clearly it could be noticed that its endogenous amount in the shoots decreased with different assigned treatments (Table 11 and Figs. 38-42). The highest reduction existed with BA + (B + S) (2.412 μg/100 gm) followed by BA alone (12.330 μg/100 gm) comparing with the value of control (64.486 μg/100 gm).

Meanwhile, in roots of treated plants, also endogenous cytokinins was decreased with the exogenous applied benzyl adenine, yet, each of NAA at 50 ppm and PP_{333} at ppm increased its amount. As for the growth inhibitor abscisic acid, clearly it could be noticed that, its amount was detected only in roots of plants treated with BA at 25 ppm (13.190 μg / 100 gm) and with PP_{333} at 1 ppm (0.177 μg / 100 gm). Meanwhile, the other two treatments

Fig. (38): Diagram indicating the effect of BA at 25 ppm treatment on the endogenous (a) cytokinins and (b) IAA, GA_3 & ABA in black cumin (*Nigella sativa* L.) shoots at 66 days after sowing during 2004 season (µg/100 gm fresh weight).



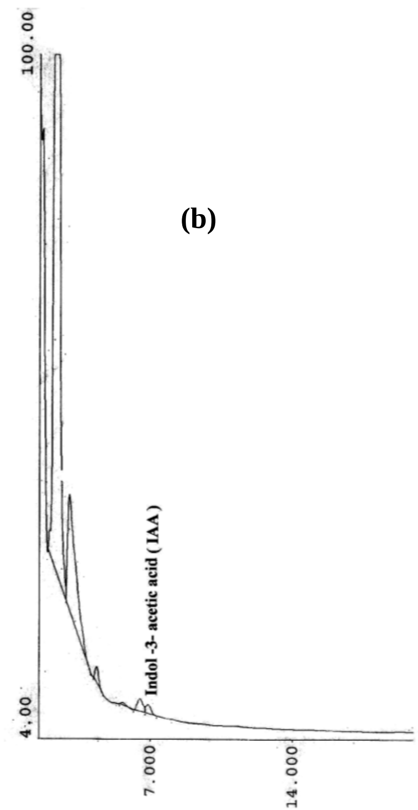


Fig. (39): Diagram indicating the effect of PP_{333} at 1 ppm treatment on the endogenous (a) cytokinins and (b) IAA, GA_3 & ABA in black cumin (*Nigella sativa* L.) shoots at 66 days after sowing during 2004 season (μg/100 gm fresh weight).

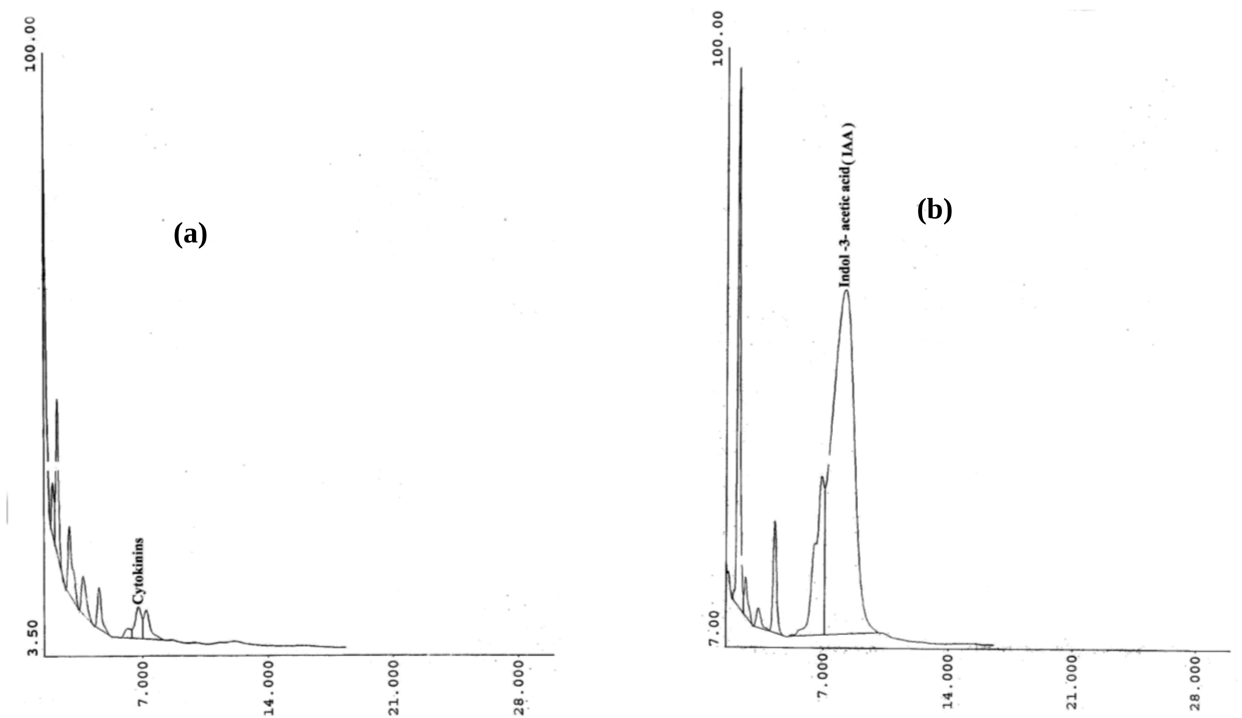
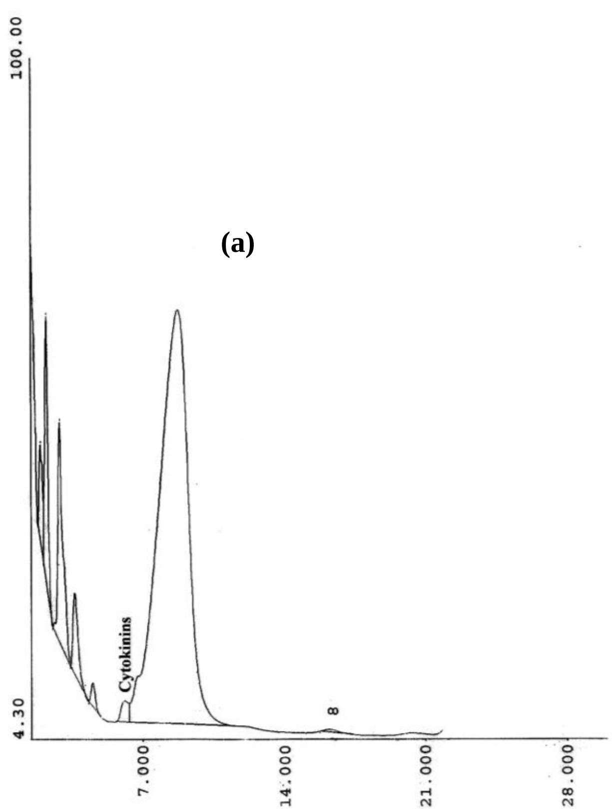
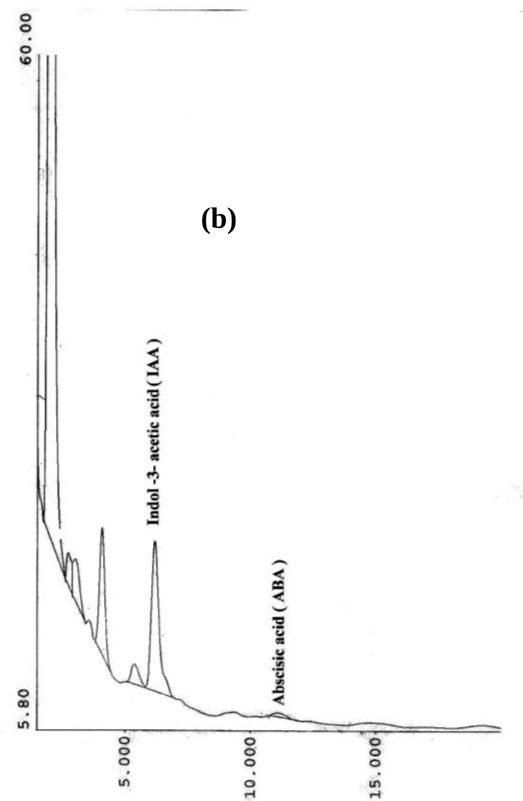


Fig. (42): Diagram indicating the effect of untreated treatment (i.e., control) on the endogenous (a) cytokinins and (b) IAA, GA3 and ABA in black cumin (*Nigella sativa* L.) shoots at 66 days after sowing during 2004 season (µg/100 gm fresh weight).





(i.e. NAA at 50 ppm and BA + (B+S)) as well as the control did not show any detectable amounts of endogenous abscisic acid, in their roots. Otherwise, in case of shoots the amount of 1.114 μg/100 gm was detected in shoots of treated plants with BA + (B+S) comparing with the only amounted of 1.023 μg/100 gm in case of control. Yet, the other treatments (i.e. BA, PP_{333} and NAA) did not show any detectable amounts of Abscisic acid in their roots.

Furthermore, when the determined hormones either growth promoters or inhibitors related together; this percentages between them could be having the main cause for any of vegetative or reproductive aspects obtained.

In general it could be concluded that, firstly, the exogenous application of benzyl adenine (one of the natural cytokinins) led to decrease the endogenous cytokinins specially in roots. Secondly, paclobutrazol the common antigibberellin exhibited to obvious effect that increases of endogenous cytokinins either ins hoots or in roots and the reduction of endogenous gibberellins or completely led to disappear it.

The above mentioned results has been previously recommend. Since, other studies reported the increase of endogenous cytokinins and reduction of endogenous gibberellin at the same time. Of these studies are **Bracale *et al.* (1988), Cohen *et al.* (1988), Weathenuax *et al.* (1996), Shinkle *et al.* (1998), Martinez-Garcia *et al.* (2000) and El-Desouky *et al.* (2005 a, b and c).**

II.7. Flowering:

As shown in Table (12) different applied treatments led to appear the first flower one or two days earlier than in control treatments. So, when these data related to the control (100%) are being less than one hundred.

Also, number of days required for first flower anthesis are being shortened with one, two or three days when compared with control. The only exception was that increasing of these days by only one day in case of pp_{333} at 1 ppm and the combination of B + S at 50 ppm for each as well as with two days in case of BA at 5 ppm + (B + S) at 50 ppm for each. These data are also being more evident when related to the control.

On the other hand, number of days required for first flower to reach its full anthesis were decreased. Reduction in days number reached about fifty or more in comparison to the control treatment. Here, it could be noticed that, e.g, K at 500 ppm, BA at 5 ppm and 25 ppm showed seven days meanwhile it was seventeen days in control treatments. The only exception was that slight retardation (one day) in case of NAA at 10 ppm.

Here, the above mentioned results are being of great interest because it included a change in plant maturity. In other meaning, it changed not only the time of flowering evocation but also probably photosynthates partitioning and allocation beside alteration of hormonal profile (as will mentioned later).

Other studies have been carried out interpreating some of the present study treatments. For example these results may be due to the function of boron in the promotion of IAA oxidase activity to

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prevent the accumulation of supra-optimal levels of endogenous IAA-Besides, boron is essential for the nucleic acid metabolism and incorporation of phosphorus into RNA and DNA leading to stimulation the initiation and development of florets on the spike **(Katalymow, 1969).** Similar results was obtained by **Marousky (1981)** on *Lilium longiflorum* plant.

These results may be due to that, at specific concentration of boron, it controls the phenols in cells as so prevent the damaging effect of phenols accumulation. Keeping the membrane in integrity state. Beside boron associated with protoplasmic membrane, reacting with the sugar molecule at this locus to form a complex, which then move through the membrane with a greater facility than the sugar molecule itself, leading to translocation of sugars which consequently increased the duration of flowers **(Gauch and Dugger, 1953).** These results are in agreement with those obtained by **Valk *et al.* (1991)** on tulip plant.

II.8. Fruiting:

II.8.1. Fruit setting:

Data in Table (13) clearly show that the most applied treatments decreased number of days required for setting the first fruit. The only exception was that BA at 25 ppm and BA at 5 ppm + (B + S each at 50 ppm) since they showed the same number of days for control. These results are being more obvious when related to the control. In this respect, all these treatments gave percentages less than the one hundred of control.

Also, it could be noticed that, NAA at 10 ppm and BA at 5ppm combined with each of boron and sulphur 50 ppm for each

Table (13): Effect of different applied treatments on fruit setting of black cumin (*Nigella sativa* L.) plants during 2003-2004 seasons.

Characters / Treatments (ppm)	No. of days required for complete 1st setted fruit	Earliness or retardness for complete 1st setted fruit (day)	% Relative to the control
Boron 50	7	+2	77.78
Boron 250	7	+2	77.78
Sulphar 50	7	+2	77.78
Sulphar 250	7	+2	77.78
K 100	8	+1	88.89
K 500	8	+1	88.89
BA 5	8	+1	88.89
BA 25	9	0	100.00
NAA 10	6	+3	66.67
NAA 50	8	+1	88.89
PP_{333} 1	8	+1	88.89
(B + S) 50 + 50	7	+2	77.78
BA + (B +S) 5 + (50+50)	5	+4	55.56
NAA + (B + S) 10 + (50 +50)	9	0	100.00
PP_{333} + (B + S) 1 + (50 + 50)	7	+2	77.78
BA + NAA + (B + S) 5+ 10+ (50 +50)	8	+1	88.89
Control	9	0	100.00

Mean value of 2003-2004 seasons.

were the most effective treatments for shortening that time required for first fruit setting. Values were 33.33 and 44.44% less than the control value with NAA at 10 ppm and BA at 5 ppm + (B+S each at 50 ppm), respectively.

In this respect, **Ahmed (1993)** reported that cycocel (like paclobutrazol) significantly increased the fruit number of Black cumin especially at the concentration of 500 ppm. Also, **Mousa *et al.* (2001)** reported that benzyladenine (BA) was the most effective treatment in increasing the number of capsules of Black cumin plants.

II.8.2. Fruits number:

Data in Table (14) clearly indicate that BA at 5 ppm, NAA at 10 ppm and PP_{333} at 1 ppm each combined with boron (50 ppm) and sulphur (50 ppm) gave high significant increase of fruit number and their dry weight. Meanwhile, boron at 50 ppm and PP_{333} at 1 ppm of the separated treatments (each alone) gave also high significant. Also, it could be noticed that each of sulphur, potassium and NAA in the two applied concentrations gave the smallest number of fruits and their weights as well. That was obvious in the two seasons of the present study. In this respect also it could be noticed that, these active treatments were preceded also with vigorous growth of both root and shoot systems. Since, different characteristics of root and shoot were improved under these treatments.

Here, of interest to note that these treatments improved vegetative, and root growths. That is being reflected also upon

Table (14): Effect of different applied treatments on fruits yield/plant of black cumin in pots at harvest time during 2003 and 2004.

Characters	Number of fruit/plant	Weight of fruit g/plant	Number of fruit/plant	Weight of fruit g/plant
Season / Treatments (ppm)	2003		2004	
Boron 50	14	1.73	13	1.56
Boron 250	7	1.23	7	1.12
Sulphar 50	6	1.54	7	1.53
Sulphar 250	5	1.20	5	1.14
K 100	8	1.12	6	1.10
K 500	6	1.23	8	1.14
BA 5	9	1.42	8	1.28
BA 25	9	1.36	9	1.40
NAA 10	6	1.31	8	1.46
NAA 50	6	0.82	6	0.87
PP_{333} 1	18	2.75	17	2.51
(B + S) 50 + 50	12	2.16	12	3.39
BA + (B +S) 5 + (50+50)	24	7.21	22	6.13
NAA + (B + S) 10 + (50 +50)	16	2.57	16	2.53
PP_{333} + (B + S) 1 + (50 + 50)	18	4.19	17	4.59
BA + NAA + (B+ S) 5+ 10+ (50 +50)	17	3.73	17	3.31
Control	7	1.31	6	0.79
L.S.D at 0.05	2.11	0.79	1.62	0.51
L.S.D at 0.01	2.91	1.09	2.23	0.70

flowering, thereby, final mature number of fruits was also significantly increased. In this respect, these data could be confirmed that these treatments improved photosynthesis and its efficiency as well. So, that is being reflected upon photosynthates translocation and partitioning as well. Thereby, a great part of biosynthesized materials are being allocated for fruits.

Also, other studies have been reported similar positive effects of some growth regulators including benzyleadenine upon the fruiting characteristics of *Nigella sativa*. They reported that cytokinins (as BA) appeared to play an important role in the regulation of cell division, differentiation and organogenesis in developing plant **(Skoog and Armstrong, 1970; Hall, 1973 and Youssif and Talaat, 1998).**

In addition, the positive effect of boron on the pod number per plant might owe much to its physiological role in the translocation of sugars and photosynthates in part tissues **(Marschner, 1986).** Similar results were reported by **Omar (1980), Huang *et al.* (1989), Ibrahim (1990), El-Said (1993)** and **Poulain and Al-Mohammad (1995)** on faba bean plants, and **Midan *et al.* (1982)** and **El-Mansi *et al.* (1990)** on pea plants.

II.8.3. Biological, economical yields and the harvest index:

Data in Table (15) clearly show that the all applied treatments increased the biological yield (i.e. dry weight of shoots and fruits) of black cumin during 2003 and 2004 seasons.

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In this respect, the treatment of BA at 5 ppm + (B + S each at 50 ppm) exhibited the highest biological yield that reached 10.38 and 8.20 g/plant with percentage of 434 and 431% in relative to the control during 2003 and 2004 seasons, respectively. Yet, sulphur at 250 ppm, boron at the two applied concentrations, K at 100 ppm and NAA at 50 ppm gave the lowest increase in this respect.

Regarding the economical yield per plant data clearly show that obvious high significant increase of this yield was existed with different applied treatments. These results are of great interest since increment of economic yield are being on the account of the biological one. That because percentages of economic yield relative to the control were higher more than of biological one. Increases of economic yield on the account of biological one could be pioneer result of the present study. Hence, increasing of economic yield (i.e. weight of dry seeds) could be reflected upon an increase of seed contents specially their oil content. So the present study strongly suggested that a number of the applied treatments practically could be used for the economic cultivation of black cumin plant. Of these treatments priority is being to BA at 5 ppm + (B + S each at 50 ppm), PP_{333} at 1 ppm + (B + S each at 50 ppm) and BA at 5 ppm + NAA at 10 ppm + (B+S each at 50 ppm) treatments.

Furthermore, the above mentioned results were clearly reflected on the calculated harvest index (i.e. the economic yield) divided by the biological one.

III- Field experiments:

In this part of the present study; two field experiments were carried out at the Hort. Experimental station, Dept. of Hort., Faculty of Agriculture at Moshtohor during the two successive seasons of 2003 and 2004.

These two experiments were assigned for the reproductive measurements and the chemical analysis of yielded fruits.

1- Number of capsules / plant:

Table (16) clearly show that the treatment of NAA at 50 ppm (during the two season) the only treatment that decreased the number of capsule per plant. Meanwhile, treatments of B at 250 ppm, sulphur at 50 and 250 ppm and K at 100 & 500 ppm either had no effect or insignificantly increased the number of capsule per plant. On the other hand the rest of treatments increased this number to reach in most cases the high level of significance. Here it could be noticed that BA at 5 ppm + (B + S each at 50 ppm) followed by NAA at 10 ppm + (B + S each at 50 ppm) treatments were superior in this respect.

2- Weight of intact capsule:

As shown in Table (16) different applied treatments increased the weight of intact capsule during first and second seasons. Weight increment of intact capsule was reached its maximum with BA at 5 ppm during first season and with BA at 25 ppm during the second season. Also, of interest to note that each of S at 50 ppm, the two K applied concentration, PP_{333} at 1 ppm, (B + S each at 50 ppm), BA at 5 ppm + (B + S), NAA at 10 ppm + (B+S

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each at 50 ppm), PP_{333} at 1 ppm + (B + S each at 50 ppm) and BA at 5 ppm + NAA at 10 ppm + (B+S each at 50 ppm) also reached the high level of significance that was true in both seasons. Moreover, it could be also, noticed that B at the two applied concentration was less effective in this respect during the two seasons of the present study.

In this respect, here also it could be noticed that (BA) or PP_{333} (the endogenouse estimated – cytokinin formation substance), both highly increased capsule weight. That it could be interpreted on the basis that cytokinin is recommended to induce sink capacity. Also, cytokinin is known to stimulate translocation of different assimilate from the source organs (leaves) to the sink ones (fruits).

3- Weight of seeds / capsule:

As shown in Table (16), it is more obvious that, increases of the intact capsule weight could be mainly attributed to the increases of their seeds. That, because seeds weight significantly was increased with different applied treatments during the two seasons of the present study. In this respect, BA at the two applied concentration during the two seasons gave the highest of seeds weight of reach the high level of significant. Also, PP_{333} and the mixture of BA at 5 ppm + (B+S each at 50 ppm) followed by K and BA at 5 ppm + NAA at 10 ppm + (B+S each at 50 ppm) were also increased seeds weight to reach the high level of significant.

According to the above mentioned results clearly to that increasing intact capsule is being due to their seeds not to the free capsule. Here, again we could conclude that the applied treatments improved its of photosynthate, translocation of different assimulate and the sink capacity as well. In other words, economic yield is being increased on the account of biological one. That is of great interest from the economical yield specially if that was accompanied with increase of oil yield as well mentioned letter.

4- Weight of empty capsule:

As shown in Table (16), empty capsule weight was decreased with different applied treatment. Reduction of empty-capsule weight reached to the middle of significant in some treatment (e.g. B at 50 ppm, BA at 5 ppm and the mixture of (B + S each at 50 ppm)) during the first and second seasons. So, comparing this aspect (empty – capsule weight) with each of intact capsule and seed weights clearly, we could concluded that the enhancement of black cumin growth was in favor of seeds yield (i.e. the economic part of yield).

5- Weight of capsules / plant:

Table (16), clearly show that different applied treatments increased weight of capsules per plant. But, here the only NAA at 50 ppm insignificantly increased this character. The rest of treatments increased this number significantly. Also, it could be noticed that BA at 5 ppm + (B + S each at 50 ppm) and PP_{333} at 1 ppm were superior in this respect.

6- Seeds number / capsule:

As shown in Table (16) clearly it could be noticed that during the two seasons of the present study different applied treatments significantly increased the number of seeds per capsule. Also, data clearly show that seeds number in different applied treatments increased to reach more than twice in control treatments. That means that seed yield could be also duplicated.

7- Weight of seeds per plant:

As shown in Table (16) different applied treatments significantly increased this weight to reach the high level of significance during 2003 and 2004 seasons. Also, it could be noticed that the combined treatments was more effective comparing with the separate ones. The only exception was that of BA at 5 ppm and PP_{333} at 1 ppm during 2003 season as well as PP_{333} at 1 ppm during 2004 season.

In this respect, also it could be noticed that boron at the two applied concentrations (i.e. 50 and 250 ppm) gave the lowest increase of seeds weight.

That means such treatments are of great interest from the economical view. Since that could be arise the yield / feddan from 280: 300 kg to3360: 3600 kg/feddan.

The above mentioned data clearly light that positive effective of different applied treatments upon vigour growth of black cumin, flowering, fruit setting and allocation of photo-assimilate towards the economic yield on the account of biological one.

In addition, the above mentioned results are being more evident when calculated as a percent of control. For example, in the second season the treatment of PP_{333} at 1 ppm + (B + S each at 50 ppm) gave a percentage of 479.1 and 600.47% during the two seasons, respectively comparing with a hundred for control. That means such treatment (PP_{333} at 1 ppm) + (B + S each at 50 ppm) gave weight of seeds more than 4 and 6 during 2003 and 2004 seasons, respectively times when compared with the control.

Fruit characteristics:

1) Weight of intact capsule:

Data in Table (17) clearly indicate that different applied treatments significantly increased the weight of intact capsule during the two seasons of the present study. In this respect most treatments exhibited the high level of significant especially that of BA at 25 ppm that gave 0.600 and 0.680 gm / capsule and boron + sulphur each at 50 ppm since it gave 0.600 and 0.580 gm per capsule during 2003 and 2004 seasons, respectively compared with 0.210 and 0.210 gm per capsule during the two seasons that in case of control treatment. On the other hand, the lowest increase was existed in case of boron at the two applied concentrations (i.e. 50 and 250 ppm) that was true in both seasons.s

In this respect, it could be mentioned that the obvious increase of capsule weight could be reflected upon also great increases of other seed characteristics including that of seeds weight. In other meaning, increase of economic part (i.e. seeds). That is of interest, because probability of oil increase also is being expected.

2) Seeds number per capsule:

As shown in Table (17) different applied treatments significantly increased seeds number / capsule. In general, seeds number per capsule nearly behaved as the same as capsule weight.

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Since, high level of significance also reached by the all applied treatments and the lowest increase existed in case of boron that exactly as it was in case of capsule weight. The above mentioned behaviour of obtained results existed in the two seasons of the present study.

Here, of interest to note that increases of capsule weight was accompanied with increases in the number of yielded seeds. So, as previously mentioned, these increases in weight of seeds and their number probably is being or it may accompanied with increases of oil yield (i.e. the economic part of this plant).

3) Weight of seeds / capsule:

Data in Table (17) clearly confirm that the weight of seeds per capsule behaved as the same as each of weight of intact capsule and the number of seeds as well.

In this respect all the applied treatments increased the weight of seeds per capsule to reach the high level of significance. These results are of great interest, since, increases in weight of seeds refers to that strict encouragement of minerals and photosynthates (i.e. protein, sugars and oils) translocation from source organs (i.e. roots and leaves) to sink ones (i.e. seeds). Furthermore, improvement of seeds characteristics are being preceded with vigorous growth in plants formed and carried such seeds.

4) Weight of empty capsule:

As shown in Table (17) the weight of empty capsule in most treatments was less than that of control. Here, it is more obvious that increasing of intact capsule weight was mainly in favor of the weight of economic part (i.e. weight of seeds).

5) Relation of seeds weight to the weight of empty capsule:

As shown in Table (17) nearly it could noticed that the above mentioned relation reached to 0.750 and 0.750 in 2003 and 2004 seasons in case of control treatment meanwhile, it was duplicated several time in case of other treatments. For example in case of BA at 5 ppm, BA at 25 ppm, PP_{333} at 1 ppm + (B + S each at 50 ppm), BA at 5 ppm + NAA at 10 ppm + (B + S each at 50 ppm), BA at 5 ppm + (B + S each at 50 ppm) and PP_{333} at 1 ppm, treatments it rose up to reach nearly about ten times more than that of control one. Also, in case of BA at 5 ppm it reached its maximum (8.000 gm) with increase percent of 1066% that means ten fold more than the control.

The above mentioned results are of great interest because increase of this percentage means that the seeds highly increased in their weight on the account of empty capsule weight. In other words that means that; the all applied treatments increased each of photosynthates and other nutrients translocation and their storage in seeds (i.e. the economic yield) was highly increased by different applied treatments. Of course, increasing of economic yield must be presented with each of vigorous growth of germinated seeds followed by improvement of growth during vegetative and flowering stages. That also should be accompanied with improvement both of photosynthates synthesis and their efficiently transport into seeds.

The above mentioned results also should be interpreted by the fact that all the applied treatments significantly increased the photosynthetic area (leaf area measurements) and their dry weight as well as increasing of photosynthetic pigments concentration in leaves of applied plants.

Also, of interest to note that the above mentioned results were nearly similar in 2003 and 2004 seasons.

Moreover, seeds weight when expressed relatively to the control the above mentioned conclusions are being more obvious. Since, e.g., this percentage was 1066% comparing with only 100%in case of control.

6) Weight of 100 seeds:

As shown in Table (17) different applied treatments increased the weight of 100 seeds to reach either the level of significance (5%) or even the high level (1%) in most cases during the two seasons. Also, it could be noticed that BA at 5 ppm alone or combined with boron and sulphur at 50 ppm for each and PP_{333} at 1 ppm + (B + S each at 50 ppm) gave the highest weight of 100 seeds during the two seasons. Meanwhile, the rest of different applied treatments also gave significantly increases in this respect. In addition, data when calculated as a percent of control are being more evident.

In general, the above mentioned data are in harmony with those obtained by **Mohamed (1997), Mohamed (1998), Khater *et al.* (1992), Osman (1979) and Khaled (2001).**

In addition, the increment in dry pod number and weight of seed yield / plant, due to applying P, B or GA_3 treatments, could be attributed to the more increases in vegetative growth characters, which might provide more green area and consequently, make more food supply for which dry matter content was a reliable index. In addition, it might be attributed to the more increase in pod setting percentage and reduction in abscission percentage, as well as the increase in seed number / pod, 100-seed weight and seed dry matter content. Moreover, review of literature showed positive correlation between seed yield and each of number of branches and pods / plant, number of seeds / pod, 100-seed weight and seed dry matter content **(El-Fieshawy and Fayed, 1990 and Etman, 1992).**

Capsule measurements:

1) Capsule diameter and length:

As shown in Table (18) capsule diameter was slightly decreased with boron, potassium at 500 ppm and NAA at 10 ppm during the first season. That was true also in the second season. Meanwhile the treatments of BA at 5 ppm, PP_{333} at 1 ppm, (B+S each at 50 ppm) mixture, and PP_{333} at 1 ppm + (B+S each at 50 ppm) mixture were obviously and high significantly increased capsule diameter. Also, it could be noticed the highest increase of capsule diameter existed in case of BA at 5 ppm combined with the mixture of boron and sulphur at 50 ppm for each.

On the other hand, as shown in Table (18) for capsule length the treatments of boron at the two applied concentrations as well as benzyl adenine also at the two applied concentrations and paclobutrazol are the only treatments showed less increase of capsule length. Meanwhile, sulphur at 50 and 250 ppm as well as potassium at the two applied concentrations NAA at 50 ppm, the mixture of boron and sulphur. BA at 5 ppm + (B + S each at 50 ppm) and NAA at 10 ppm +(B + S each at 50 ppm) were obviously

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increased capsule length to reach the high level of significance. Also, it could be noticed that NAA at 10 ppm combined with boron and sulphur at 50 ppm for each gave the highest increase of capsule length.

The above mentioned results could be reflect the common and recommended effects of these treatments especially those of the growth regulators benzyl adenine and paclobutrazol, since these regulators are commonly known to increase the transverse growth on the account of longitudinal one.

2) Capsule size:

Data in Table (18) clearly indicate that BA at 5 and 25 ppm; BA at 5 ppm + (boron + sulphur 50 ppm for each); PP_{333} at 1 ppm + (sulphur + boron at 50 ppm for each) and BA at 5 ppm + NAA at 10 ppm + (boron + sulphur at 50 ppm for each) significantly increased the size of intact capsules. Meanwhile, NAA at 50 and 10 ppm and boron at 250 ppm gave the lowest increase of this character. The above mentioned results were nearly the same in both seasons. Also, it could be noticed that such these positive treatments upon capsule size also were obviously and significantly affected many other vegetative and yield characteristics specially those of seeds weight / capsule and number of seeds/capsule as well as oil percentages (see Tables, 16, 17 & 19).

Moreover, this increase in capsule size are being reversed upon increase of seeds not to the free capsules.

3) Number of loculs:

As shown in Table (18) despite those genetically factors controlled the number of locules in fruit of any plant, but here, we could noticed that treatments of BA at 5 ppm + (B+S each at 50 ppm); PP_{333} at 1 ppm + (B+S each at 50 ppm) and BA at 5 ppm + NAA at 10 ppm + (B+S each at 50 ppm) increased this number in the two seasons as well as some other treatments but to less extend of increase.

Here, this number of locules already genetically is determined but the environmental conditions (including certain treatments) could be altered it. So, such positive treatments upon this character could be minimized the environmental effects. In other meaning; present treatments enhanced treated plants to normally express their genetic finger print, i.e. to reach the maximum normal number of locules.

4) Fruit shape index:

Data in Table (18) clearly show that in the two seasons treatments of sulphur at 50 and 250 ppm; K at 100 and 500 ppm and NAA at 10 and 50 ppm alone or in combination with B + S each at 50 ppm and B at 250 ppm significantly increased the fruit shape index. In other meaning these treatments either increased the fruit length on the account of their diameter or decreased fruit diameter itself. On the other hand treatments of BA at 5 and 25 ppm, paclobutrazol, BA at 5 ppm + (B+S each at 50 ppm) and PP_{333} at 1 ppm + (B+S each at 50 ppm) gave opposite effect, i.e. decreased the fruit shape index. In other meaning that effect is being either for reduction in fruit length or increase of fruit diameter. Meanwhile, other treatments increased this index but to less extent.

Moreover, the above mentioned results also are being more obvious when calculated relatively to the control (Table, 18).

5) Essential and fixed oils:

As shown in Table (19) it could be noticed that with no exception different applied treatments increased each of volatile and essential oils when compared with the control.

Also, it could be noticed that maximum increase of both oils (i.e. 1.43 for volatile and 34.91% for essential) existed with BA at 5 ppm. In addition, nearly this obvious increase of both oils also obtained with BA at 25 ppm, PP_{333} at 1 ppm, the mixture of boron and sulphur, BA at 5 ppm + (B + S each at 50 ppm) mixture, NAA at 10 ppm + (B+S each at 50 ppm) mixture, PP_{333} at 1 ppm + (B+S each at 50 ppm) mixture and BA at 5 ppm + NAA at 10 ppm + (B+S each at 50 ppm) mixture.

In this respect, the above mentioned results are considered of great interest, since the obtained increase of yielded oil by any of the applied treatments is one of the main goals of this study.

Here, also we could concluded that the vigorous growth obtained by such treatments also is being reflected upon many characteristics of yielded seeds. Of these, is that increase in seeds weight per plant (preceded with increase of seeds weight / capsule) (Tables, 16 & 17), increase of seeds weight on the account of free capsule weight (Table, 17) and all of that were ended with that increase of yielded oil.

Moreover, these results also confirm that the applied treatments are being improved each of minerals and photosynthates translocation from the site of their absorption (i.e. minerals by the roots) as well as the site of their synthesis (i.e. photosynthates in the leaves) to those sites function as sinks i.e., seeds.

Table (19): Effect of different applied treatments on oil fractions of black cumin (*Nigella sativa L.)* seeds (i.e. fixed, volatile & total oils).

Characters / Treatment (ppm)	% Fixed oil	Volatile oil (Essential oil)	% Total oil	R. Total oil to the control
Boron 50	31.50	1.05	32.55	105.07
Boron 250	31.53	1.01	32.54	105.04
Sulphar 50	31.65	1.07	32.72	105.62
Sulphar 250	31.82	1.08	32.90	106.20
K 100	32.39	1.30	33.69	108.75
K 500	32.63	1.30	33.93	109.52
BA 5	34.91	1.43	36.34	117.30
BA 25	34.46	1.32	35.78	115.49
NAA 10	32.82	1.14	33.96	109.62
NAA 50	32.97	1.25	34.22	110.46
PP_{333} 1	34.25	1.31	35.56	114.78
(B + S) 50 + 50	34.43	1.36	35.79	115.53
BA + (B +S) 5 + (50+50)	34.97	1.39	36.36	117.37
NAA + (B + S) 10 + (50 +50)	32.94	1.34	34.28	110.65
PP_{333} + (B + S) 1 + (50 + 50)	34.42	1.37	35.79	115.53
BA + NAA + (B + S) 5+ 10+ (50 +50)	34.74	1.28	36.02	116.27
Control	30.00	0.98	30.98	100.00

R. = relative total oil to the control.

Furthermore, other studies have been reported with Nigella plant brought nearly similar results to some of those obtained in the present study. However, was not as effective as earlier ones. In the 2nd cut, generally, GA and most MH treatments tended to decrease the volatile oil percent.

Both GA and MH were found to decrease the oil yield per mint plant for both cuts except for earlier sprays at the 2nd cut where all GA concentrations and the low MH concentrations in few cases were shown to increase the oil yield per plant. Accordingly, mint plants could be recommended for early spray with GA only in the 2nd cut.

In this respect, **Mahmoud (1980)** reported that the growth substances applied in the 1st cut were found to decrease the volatile oil percents immediately after the application to mint plants, yet a prominent increase was noticed at cutting. The latest spray, in this respect **Mostafa *et al.* (1996)** reported that the addition of boron at 270 ppm with any method combined with P_2O_5 at 300 ppm, gave the maximum increase in the essential oil percentage, compared with the other treatments. This increase may be due to increase number and/or gland size. Similar trend of results was cleared by **Sharga and Motial (1984)** on tuberose plant.

With regard to MH applications on geranium, a consistent decrease was recoded for all concentrations in both cuts.

In general, all the physiochemical properties of the essential oil (mint or geranium) were shown not to be affected by either GA or MH treatments with respect to the standard values. However, GA treatments appeared to improve slightly the menthol content of mint oil. Similarly, MH applied at its lowest concentration, showed the same effect.

It was also found that either GA or MH applications were found effective in improving the quality of geranium oils since total and free alc. percents (expressed in terms of geraniol) were increased reaching the maximum limits known by references.

Other studies have been carried out using Benzyl adenine (BA) and Gibberellic acid (GA_3) as foliar spray on black cumin plant. Of these studies are **Ahmed (1990)** who reported that BA at 20 ppm increased plant height, foliage weight, volatile oil yield and leaf content of nitrogen. Also, **Mousa *et al.* (2001)** showed that BA increased number of branches and capsules per plant, seed yield as well as fixed and volatile oil yields.

Also, as shown in Table (19) different applied treatments increased the percentage of total oil in black cumin seeds. The highest increase (36.02%) existed with BA at 5 ppm+ NAA at 10 ppm+ (B + S each at 50 ppm), BA at 5 ppm + (B + S each at 50 ppm) (36.36%) and BA at 5 ppm (36.34%) followed by each of BA at 25 pm, pp_{333} at 1 ppm, (B + S each at 50 ppm) and pp_{333} at 1 ppm + (B + S each at 50 ppm). Mean while, the lowest increase existed with each of B and S at the two applied concentration for each. The above mentioned results are being more obvious when related to the control value.

6) Chemical analysis:

Chemical composition of shoots and of defatted seeds:

As shown in Table (20) the all applied treatments obviously increased the nitrogen content in shoots of black cumin at 176 days after sowing when compared with the control value. In this respect boron at 50 ppm sulphur at 50 ppm and boron combined with sulphur at 50 ppm for each exhibited the highest value of nitrogen that reached 5.61%.

On the other hand, the lowest increase of nitrogen percentage existed with each of sulphur at 250 ppm and with K at 500 ppm.

The above mentioned results were complete correlated with the crude protein in the shoots. Since, the highest percentage was also obtained with boron at 50 ppm, and the lowest percentage of increase also existed with sulphur at 250 ppm and K at 500 ppm.

As for phosphorus and potassium in shoots of black cumin plant it could be noticed that each of them in most cases was increased.

With regard to NPK content in black cumin defated seeds clearly it could be noticed that different applied treatments increased the percentage of each of these elements (Table 21).

Also, crude protein percentage was increased with different applied treatments to reach its highest with BA at 5 ppm + NAA at 10 ppm + (B + S each at 50 ppm) followed by BA at the two applied concentrations. With regard to the total oil it could clearly be noticed that different applied treatments increased its content.

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Also, in this respect the treatment of BA at 5 ppm + NAA at 10 ppm + (B + S each at 50 ppm) exhibited its highest content. Meanwhile, B and S at the two applied concentrations gave the lowest increase of oil content.

On the other hand, carbohydrates content was behave conversely with the oil content. Meanwhile, the crude protein content in shoots was also increased with different applied treatments. In this respect, NAA at 10 ppm + (B + S each at 50 ppm) gave the highest of this content yet, S at 50 ppm and K at the two applied concentrations and B at 250 ppm gave the lowest increase in this content.