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INFLUENCE OF IRRIGATION INTERVALS AND CHEMICAL FERTILIZATION ON SENNA (*Cassia acutifolia,* Delile) PLANTS:
II.EFFECT ON CHEMICAL COMPOSITION AND PRODUCTION OF ACTIVE CONSTITUENTS

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ABSTRACT

This study was conducted at the Department of Ornamental Horticulture, Faculty of Agriculture Cairo University, Giza, and the Farm of Medicinal and Aromatic Plants, Faculty of Pharmacy, Cairo University, Giza, during the two successive seasons of 1997 and 1998, with the aim of investigating the effect of irrigation intervals and chemical NPK fertilization on the chemical composition and production of active constituents in senna (*Cassia acutifolia,* Delile) plants.

Cassia acutifolia were irrigated every 1, 2 or 3 weeks, and were supplied with chemical NPK fertilization using combinations of N at the rates of 0, 25, 50 or 75 kg/fed. (N_0, N_1, N_2 and N_3, respectively), P_2O_5 at 0, 25 or 50 kg/fed. (P_0, P_1 and P_2, respectively) and K at 25 kg/fed. (K_1). In addition, plants receiving no chemical fertilization ($N_0P_0K_0$) were used as the control.

The percentages of sennoside B in the leaves and pods were generally higher than those of sennoside A, and the percentages of both sennosides were higher in the pods than in the leaves. Irrigation every 3 weeks gave the highest means for percentages of total sennosides in leaves and pods, sennosides yield from leaves/plant, and percentages of sennosides A and B in glycosides extracted from leaves and pods, whereas irrigation every 2 weeks gave the highest sennosides yield from pods/plant and the highest total sennosides yield (from leaves + pods)/plant, as well as the highest percentages of N, P and K in the leaves and stems. On the other hand, the highest contents of leaf pigments (chlorophyll a, b and carotenoids) were obtained with weekly irrigation. In general, the different fertilization treatments decreased the total percentages of sennosides, as well as the percentages of sennosides A and B in leaves and pods, but increased the sennosides yield from leaves/plant and pods/plant (with $N_2P_2K_1$ giving the highest values), the leaf pigments content, as well as the N, P and K contents in leaves and stems (with $N_3P_2K_1$ giving the highest values for these characteristics). For each of the different characteristics that were studied, the highest values were obtained when the best irrigation interval for the studied characteristic was combined with using the best fertilization treatment.

Keywords: Senna, *Cassia acutifolia*, fertilization, NPK, irrigation intervals, sennoside, chlorophyll, carotenoids, nutrients.

INTRODUCTION

Arabian physicians have used both the leaves and pods of Alexandrian senna plants [*Cassia acutifolia*, Delile; Family: Caesalpiniaceae (Leguminosae)] as a laxative since the ninth or tenth century. Senna stimulates the muscular coat of the intestine and produces purgation, which is not followed, as is commonly the case, by constipation; it is therefore one of the most useful purgatives, especially in cases of habitual constipation. Despite the availability of a number of synthetics, sennoside preparations remain among the most important pharmaceutical laxatives (Trease and Evans, 1985).

The leaves and pods of Alexandrian senna contain anthracene derivatives and dianthrone derivatives of rhein, including anthraquinone glycosides, which have been shown to be the major active constituents. The two most important glycosides are named as sennoside A and sennoside B. A third active glycoside is probably derived from the anthranol of aloe-emodin and exerts a powerful synergistic effect upon the activity of the two sennosides. The commercial leaves contain about 2 to 3 % of the two sennosides and about 0.2 to 0.4 % of the third glycoside (Balbaa *et al.*, 1976).

Chemical fertilization is one of the most important cultural practices affecting the production of active constituents in medicinal plants. In most cases, fertilization treatments were found to cause increases in the production of different medicinally active constituents, including alkaloids [Mallick *et al.* (1989) on *Cephaelis ipecacuanha*, Shetty *et al.* (1990) on *Datura stramonium*, Lim *et al.* (1991) on *Nicotiana tabacum*, Jana and Varghese (1996) and Shylaja *et al.* (1998) on *Catharanthus roseus*], ascorbic acid and capsaicin [Mary and Balakrishnan (1990) on *Capsicum annuum*], vinblastine [Yanishevskli and Dzhaparidze (1990) on *Catharanthus roseus*], and hyoscyamine [Kewala *et al.* (1996) on *Hyoscyamus muticus*]. However, studies conducted to investigate the effect of chemical fertilization on the sennosides content of senna plants have yielded varying results. For example, Pareek *et al.* (1983, b) found that the highest sennoside yield of *Cassia angustifolia* plants was obtained with application of 50 kg N/ha., but in a later study, Pareek *et al.* (1989) showed that when *C. angustifolia* plants were supplied with nitrogen at 30, 45 and 60 kg/ha, the total sennosides concentration in the leaves and pods remained unchanged. In another study, Ilangovan and Subbia (1991) supplied senna (*C. angustifolia*) plants with N and P each at 0, 50 or 100 kg/ha, and K at 20 kg/ha. They found that using N increased pod sennoside content but had no appreciable effect on the sennoside content in leaves, and that leaf sennosides content increased with raising P application rate.

Chemical fertilization also has a considerable effect on other plant chemical components, including leaf pigments (chlorophyll a, b and carotenoids), carbohydrates, proteins and nutrients [Lamarre (1983) on tobacco, Kharwara *et al.* (1986) on opium poppy, Jacoub (1995) on *Ocimum basilicum*, El-Ghadban (1998) on *Origanum majorana*, and Jacoub (1999) on *Thymus vulgaris*].

The active components of medicinal plants are also markedly affected by the intervals at which they are irrigated. This has been shown in studies conducted by Acosta and Lerch (1984) on *Datura candida*, Zarad and Laila (1994) on white squill (*Urginea maritima* L.), Christiansen *et al.* (1997) on lupin (*Lupinus angustifolius* L.), and Sidky and El-Mergawi (1997) on

Ambrosia maritima. Irrigation intervals also affect the contents of other plant chemical components, including proteins [Khashmelmous (1984) on coriander], nutrients and carbohydrates [Shoala (1992) on lemon grass (*Cymbopogon citratus*), Zarad and Laila (1994) on *Urginea maritima* L., Hammam (1996) on anise], and leaf pigments [Hammam (1996) on anise].

This study was conducted with the aim of investigating the effect of different NPK fertilization treatments and irrigation intervals, as well as the interaction between these two factors, on the production of active components and the chemical composition of Alexandrian senna (*Cassia acutifolia*) plants grown under Egyptian conditions.

MATERIALS AND METHODS

This study was conducted at the Department of Ornamental Horticulture, Faculty of Agriculture Cairo University, Giza, and the Farm of Medicinal and Aromatic Plants, Faculty of Pharmacy, Cairo University, Giza, during the two successive seasons of 1997 and 1998, with the aim of investigating the effect of irrigation intervals and chemical NPK fertilization on the vegetative growth and yield of senna (*Cassia acutifolia*, Delile) plants.

The experimental area was divided into plots (2.5 X 2.0 m) with 3 rows/plot, at a distance of 60 cm between rows. Between every two plots, there was a ridge 50 cm wide. Seeds of senna (*Cassia acutifolia*, Delile) were sown on May 15th, 1997 and May 10th, 1998 (in the first and second seasons, respectively) on one side of the rows, in hills 40 cm apart. The physical and chemical properties of the soil of the experimental area are shown in Table (1). After sowing the seeds, the plots were regularly irrigated every 7 days till seed germination. The seedlings were then thinned to 1 plant/hill, with a total of 15 plants/plot.

Table (1): Physical and chemical properties of the experimental soil.

I-Physical analysis				
Clay	Silt	Sand	Gravel	Texture
27.50%	8.32%	61.93%	2.25%	Sandy clay

II- Chemical analysis: Total nutrients content (ppm) N	P	K	Organic matter (%)	$CaCo_3$ (%)	pH	EC (dS/m)	Ca^{++} (meq/l)	Mg^{++} (meq/L)	Na^{+} (meq/L)	K^{+} (meq/L)	CO_3^{--} (meq/L)	HCO_3^{-} (meq/L)	Cl^{-} (meq/L)	SO_4^{--} (meq/L)
2.02	26.51	530	1.72	3.20	7.54	3.1	18.1	6.5	11.1	1.3	-	7.0	13.5	16.5

The layout of this experiment was a split-plot design, with the main plots arranged in a randomized complete blocks design, with 3 replicates. The main plots were assigned to irrigation intervals (3 intervals), while the sub-plots were assigned to chemical fertilization treatments (13 treatments, including the control).

The irrigation treatments (viz. irrigation every 1, 2 or 3 weeks) were initiated on July 3rd, 1997 and July 10th, 1998, in the 1st and 2nd seasons, respectively. The chemical NPK fertilization treatments were combinations of N at the rates of 0, 25, 50 or 75 kg/fed. (N_0, N_1, N_2 and N_3, respectively), P_2O_5

at 0, 25 or 50 kg feddan (P_0, P_1 and P_2, respectively) and K at 25 kg/fed. (K_1). In addition, plants receiving no chemical fertilization ($N_0P_0K_0$) were used as the control.

The three nutrients (N, P and K) were supplied using ammonium sulphate (20.5%N), calcium superphosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O). The calcium superphosphate was incorporated into the soil prior to planting (during soil preparation), while the nitrogenous fertilizer was divided into three equal doses, added on 3rd July, 24th July and 14th August in both seasons, whereas potassium sulphate was divided into 2 equal doses, applied on 3rd July and 24th July in both seasons.

At harvesting (on October 21st, 1997 and October 17th, 1998, in the first and second seasons, respectively), samples of leaves and pods were collected, and their sennosides contents were separated, and HPLC analysis was then carried out to determine the sennosides A and B contents, according to the method described by Ohshima and Takahashi (1983). *Cassia acutifolia* contains partially purified natural complexes of anthraquinone glycosides, which are isolated as calcium salts. They contain not less than 90% of sennosides, calculated on the dry weight basis (Wagner and Blaat, 1996).

Also, samples of fresh leaves were chemically analysed to determine their pigments [chlorophyll "a", chlorophyll "b", total chlorophyll (a+b) and carotenoids] content, using the method described by Saric *et al.* (1967). In addition, dry leaf and stem samples were digested for extraction of nutrients (using the method described by Piper, 1947), then the extracts were chemically analysed to determine their contents of N (using the modified micro-Kjeldahl methos, as described by Pregl, 1945), P (colourimetrically, using the method outlined by Troug and Mayer, 1939) and K (using an atomic absorption flame emission spectrophotometer (manufactured by Shimadzu, Japan), as mentioned by Salem (1984).

RESULTS AND DISCUSSION

I- Sennosides production

1- Total sennosides percentages in leaves and pods

The results recorded in two seasons (Table 2) show that in both seasons, prolonging the irrigation intervals (i.e., increasing the water stress) resulted in steady increases in the total sennosides percentages in senna leaves and pods. Accordingly, the shortest irrigation intervals (1 week) gave the lowest sennosides percentages in both seasons, followed by irrigation every 2 weeks, whereas the longest irrigation intervals (3 weeks) gave the highest values.

Regarding the effect of chemical fertilization treatments, the results presented in Table (2) show that most of the treatments reduced the total sennosides content in senna leaves and pods. In both seasons, only two treatments ($N_0P_0K_1$ and $N_0P_1K_1$) increased the total sennosides percentage in the leaves, compared to the control. The total sennosides percentage in the pods was also increased by these two treatments, and by fertilization using $N_0P_2K_1$ (compared to the control).

Table (2): Effect of irrigation intervals and chemical fertilization on the total sennosides content (%) in leaves and pods of senna (*Cassia acutifolia*, Delile) in the 1997 and 1998 seasons.

Fertilization treatments (F)*	First season (1997)				Second season (1998)			
	Irrigation intervals (I)				Irrigation intervals (I)			
	1 week	2 weeks	3 weeks	Means	1 week	2 weeks	3 weeks	Means
	Total sennosides content (%) in leaves							
$N_0P_0K_0$	2.00	2.41	2.88	**2.43**	1.98	2.36	2.90	**2.41**
$N_0P_0K_1$	2.06	2.45	2.98	**2.50**	2.00	2.47	3.00	**2.49**
$N_0P_1K_1$	2.11	2.59	3.00	**2.57**	2.07	2.61	3.02	**2.57**
$N_0P_2K_1$	1.97	2.40	2.82	**2.40**	1.91	2.41	2.79	**2.37**
$N_1P_0K_1$	1.78	2.40	2.81	**2.28**	1.77	2.40	2.78	**2.28**
$N_1P_1K_1$	1.82	2.36	2.72	**2.27**	1.80	2.30	2.68	**2.24**
$N_1P_2K_1$	1.87	2.30	2.75	**2.33**	1.82	2.32	2.82	**2.30**
$N_2P_0K_1$	1.75	2.31	2.74	**2.30**	1.71	2.27	2.71	**2.25**
$N_2P_1K_1$	1.68	2.29	2.62	**2.20**	1.70	2.24	2.60	**2.18**
$N_2P_2K_1$	1.71	2.27	2.70	**2.26**	1.70	2.23	2.73	**2.28**
$N_3P_0K_1$	1.66	2.30	2.60	**2.19**	1.63	2.31	2.71	**2.22**
$N_3P_1K_1$	1.60	2.22	2.51	**2.11**	1.54	2.20	2.50	**2.08**
$N_3P_2K_1$	1.50	2.09	2.00	**1.86**	1.51	2.10	1.98	**1.86**
Means	**1.81**	**2.34**	**2.70**	---	1.78	**2.32**	**2.71**	---
	Total sennosides content (%) in pods							
$N_0P_0K_0$	2.71	3.00	4.71	**3.47**	2.73	3.00	4.70	**3.48**
$N_0P_0K_1$	2.80	3.50	4.84	**3.71**	2.84	3.55	4.82	**3.74**
$N_0P_1K_1$	2.89	3.54	5.00	**3.81**	2.90	3.60	4.97	**3.82**
$N_0P_2K_1$	2.60	3.84	4.72	**3.59**	2.63	3.50	4.69	**3.57**
$N_1P_0K_1$	2.40	3.46	4.35	**3.29**	2.42	3.40	4.32	**3.31**
$N_1P_1K_1$	2.40	3.27	4.31	**3.31**	2.39	3.31	4.29	**3.31**
$N_1P_2K_1$	2.40	3.25	4.37	**3.35**	2.38	3.24	4.40	**3.36**
$N_2P_0K_1$	2.35	3.24	4.27	**3.37**	2.33	3.24	4.30	**3.38**
$N_2P_1K_1$	2.30	3.20	4.10	**3.22**	2.28	3.22	4.00	**3.17**
$N_2P_2K_1$	2.30	3.15	4.07	**3.20**	2.27	3.20	4.01	**3.17**
$N_3P_0K_1$	2.23	3.13	3.79	**3.06**	2.20	3.17	3.80	**3.06**
$N_3P_1K_1$	2.20	3.09	3.98	**3.08**	2.18	3.02	4.00	**3.06**
$N_3P_2K_1$	2.00	3.06	3.86	**2.98**	1.97	3.00	3.68	**2.89**
Means	**2.43**	**3.26**	**4.34**	---	**2.42**	**3.27**	**4.31**	---

*** N_0, N_1, N_2 and N_3 = N at 0, 25, 50 and 75 kg/fed., respectively.**
P_0, P_1 and P_2 = P_2O_5 at 0, 25 and 50 kg/fed., respectively.
K_0 and K_1 = K_2O at 0 and 25 kg/fed., respectively.

In both seasons, plants fertilized with $N_0P_1K_1$ had the highest percentages of total sennosides in their leaves and pods, compared to those of plants receiving any other treatment. A similar conclusion was reached by Ilangovan and Subbia (1991) on senna (*Cassia angustifolia*) plants. On the other hand, most of the other fertilization treatments gave lower values than the control. Moreover, the recorded values tended to decrease steadily with raising the fertilization rate. In fact, the lowest mean values recorded in the two seasons were obtained from plants receiving the highest fertilization level ($N_3P_2K_1$).

The reduction of the sennosides content as a result of NPK fertilization is in agreement with the findings of Son *et al.* (1998) on *Ginkgo biloba*.

Regarding the interaction between the effects of irrigation intervals and fertilization treatments, the data in Table (2) showed that combining irrigation every 3 weeks with fertilization using $N_0P_1K_1$ gave the highest sennosides content in leaves and pods, compared to any other combination of treatments. On the other hand, the lowest values were obtained in the leaves of plants irrigated weekly and receiving the highest fertilization level ($N_3P_2K_1$).

2- Total sennosides yield

a- From leaves per plant

The results recorded in the two seasons (Table 3) show that prolonging the irrigation intervals increased the sennoside yield steadily. Accordingly, the longest irrigation intervals (3 weeks) gave the highest mean sennoside yields, followed by irrigation every 2 weeks, whereas weekly irrigation gave the lowest sennoside yields (in both seasons).

Regarding the effect of the chemical fertilization treatments, the data recorded in the two seasons (Table 3) show that all of the chemical fertilization treatments increased the sennosides yield from leaves/plant, compared to the control. A similar increase in the sennosides yield of *Cassia angustifolia* as a result of N fertilization was obtained by Pareek *et al.* (1983, b). In both seasons, the highest values were obtained from plants fertilized with $N_2P_2K_1$. On the other hand, the least effective fertilization treatment for increasing the sennosides yield from leaves/plant was ($N_0P_0K_1$). The favourable effect of the different fertilization treatment on the total sennosides yield from leaves/plant can be attributed to the effect of fertilization on the dry weights of leaves, and not to an increase in the sennosides percentage in the leaves, since (as previously mentioned), most of the fertilization treatments reduced the percentage of total sennosides in the leaves.

Regarding the interaction between the effects of irrigation intervals and chemical fertilization treatments on the sennosides yield from leaves/plant, the data in Table (3) showed that in both seasons, plants irrigated every 3 weeks and fertilized with $N_2P_2K_1$ gave the highest values, compared to those obtained from plants receiving any other combination of treatments. On the other hand, the lowest values were obtained from unfertilized plants ($N_0P_0K_0$) that were irrigated weekly.

b- From pods per plant

The results recorded in the two seasons (Table 3) show that the total sennosides yield of pods/plant was considerably affected by irrigation intervals. The highest values were obtained from plants irrigated every 2 weeks, followed by plants irrigated every 3 weeks, whereas the lowest values were obtained from plants irrigated weekly (the shortest irrigation interval).

Table (3): Effect of irrigation intervals and chemical fertilization on the sennosides yield (%) in leaves and pods/plant, and total sennosides yield (in pods+leaves)/plant of senna (*Cassia acutifolia*, Delile) in the 1997 and 1998 seasons.

Fertilization treatments (F)*	Total sennosides yield in leaves (g/plant)				Total sennosides yield in pods (g/plant)				Total sennosides yield in leaves+pods (g/plant)			
	Irrigation intervals (I)				Irrigation intervals (I)				Irrigation intervals (I)			
	1 week	2 weeks	3 weeks	Means	1 week	2 weeks	3 weeks	Means	1 week	2 weeks	3 weeks	Means
	First season (1997)											
$N_0P_0K_0$	0.43	0.70	0.89	0.67	0.25	0.28	0.25	0.26	0.68	0.98	1.14	0.93
$N_0P_0K_1$	0.53	0.74	1.00	0.76	0.67	0.98	0.52	0.72	1.20	1.72	1.52	1.48
$N_0P_1K_1$	0.58	0.81	1.20	0.86	0.76	0.95	0.64	0.78	1.34	1.76	1.84	1.65
$N_0P_2K_1$	0.49	0.80	1.13	0.81	0.77	1.24	0.74	0.92	1.26	2.04	1.87	1.72
$N_1P_0K_1$	0.64	0.89	1.20	0.91	0.76	1.44	0.82	1.01	1.40	2.33	2.02	1.92
$N_1P_1K_1$	0.71	0.90	1.19	0.93	0.83	1.34	0.88	1.02	1.54	2.24	2.07	1.95
$N_1P_2K_1$	0.74	0.90	1.36	1.00	0.90	1.33	0.87	1.03	1.64	2.23	2.14	2.00
$N_2P_0K_1$	0.87	0.92	1.77	1.19	0.96	1.48	1.37	1.27	1.83	2.40	3.14	2.46
$N_2P_1K_1$	0.99	0.93	1.76	1.23	1.03	1.47	1.02	1.17	2.02	2.40	2.78	2.40
$N_2P_2K_1$	1.06	1.22	2.12	1.47	0.96	2.19	0.98	1.38	2.02	3.41	3.10	2.84
$N_3P_0K_1$	1.17	1.49	1.65	1.44	0.94	1.88	0.90	1.37	2.11	3.37	2.55	2.68
$N_3P_1K_1$	1.26	1.47	1.52	1.42	0.91	1.78	0.98	1.22	2.17	3.25	2.50	2.64
$N_3P_2K_1$	1.63	1.38	1.11	1.37	0.75	1.27	0.93	0.98	2.38	2.65	2.04	2.36
Means	0.85	1.01	1.38	---	0.81	1.36	0.84	---	1.66	2.37	2.21	---
	Second season (1998)											
$N_0P_0K_0$	0.46	0.83	0.96	0.75	0.28	0.34	0.31	0.31	0.74	1.17	1.27	1.06
$N_0P_0K_1$	0.54	0.81	1.09	0.81	0.71	1.03	0.58	0.77	1.25	1.84	1.67	1.59
$N_0P_1K_1$	0.59	0.90	1.28	0.92	0.80	1.10	0.69	0.86	1.39	2.00	1.97	1.79
$N_0P_2K_1$	0.51	0.86	1.21	0.86	0.80	1.17	0.74	0.90	1.31	2.03	1.95	1.76
$N_1P_0K_1$	0.66	0.96	1.27	0.96	0.80	1.46	0.88	1.05	1.46	2.42	2.15	2.01
$N_1P_1K_1$	0.74	0.95	1.25	0.98	0.78	1.40	0.93	1.04	1.52	2.35	2.18	2.02
$N_1P_2K_1$	0.77	0.98	1.49	1.08	0.92	1.46	0.94	1.11	1.69	2.44	2.43	2.19
$N_2P_0K_1$	0.88	0.95	1.86	1.23	1.00	1.57	1.49	1.35	1.88	2.52	3.35	2.58
$N_2P_1K_1$	1.04	0.96	1.88	1.29	0.92	1.59	1.11	1.21	1.96	2.55	2.99	2.50
$N_2P_2K_1$	1.09	1.25	2.28	1.54	1.02	2.29	1.09	1.47	2.11	3.54	3.37	3.01
$N_3P_0K_1$	1.21	1.55	1.82	1.53	1.00	1.86	0.96	1.27	2.21	3.41	2.78	2.80
$N_3P_1K_1$	1.25	1.53	1.60	1.46	0.98	1.81	1.11	1.30	2.23	3.34	2.71	2.76
$N_3P_2K_1$	1.69	1.45	1.17	1.44	0.80	1.34	1.00	1.05	2.49	2.79	2.17	2.28
Means	0.88	1.08	1.47	---	0.83	1.42	0.91	---	1.71	2.50	2.38	---

* N_0, N_1, N_2 and N_3 = N at 0, 25, 50 and 75 kg/fed., respectively.
P_0, P_1 and P_2 = P_2O_5 at 0, 25 and 50 kg/fed., respectively.
K_0 and K_1 = K_2O at 0 and 25 kg/fed., respectively.

Regarding the effect of chemical fertilization treatments on the sennosides yield of pods, the data in Table (3) showed that all the chemical fertilization treatments increased the recorded values, compared to the control. The highest values were obtained from plants fertilized with $N_2P_2K_1$, while the least effective treatment was $N_0P_0K_1$.

The data presented in Table (3) also showed that the interaction between the effects of the irrigation intervals and the fertilizations treatments resulted in considerable differences between the values obtained with the different treatment combinations. In both seasons, the highest values were obtained in plants fertilized with $N_2P_2K_1$ and irrigated every 2 weeks.

c- From (leaves + pods) per plant

The results recorded in the two seasons (Table 3) show that in both seasons, plants irrigated every 2 weeks gave the highest sennosides yield, followed by plants irrigated every 3 weeks, whereas plants irrigated weekly gave the lowest sennosides yield.

The data in Table (3) also showed that plants receiving the different fertilization treatments gave higher sennosides yields than the unfertilized control plants. The least effective treatment in this respect was the application of K only ($N_0P_0K_1$), whereas the highest values were obtained from plants fertilized with $N_2P_2K_1$. The increase in the sennosides yield of fertilized plants (compared to the control) is in agreement with the findings of Pareek *et al.* (1983, b) on senna (*Cassia angustifolia*) plants.

Regarding the effect of different combinations of irrigation intervals and fertilization treatments on the sennosides yield/plant, the results presented in Table (3) showed that the highest values were obtained from plants fertilized with $N_2P_2K_1$ and irrigated every 2 weeks, followed by plants irrigated at the same intervals (2 weeks) and fertilized with $N_3P_0K_1$. On the other hand, the lowest values recorded in both seasons were obtained from unfertilized plants ($N_0P_0K_0$) that were irrigated weekly.

3- HPLC analysis of sennosides

The data presented in Table (4) and Fig. (1) show that the sennosides A and B were the main components of the glycosides extracted from the leaves and pods of senna (*Cassia acutifolia*) plants. In general, the sennoside B percentages in the leaves and pods were higher than the sennoside A percentages, and the pods had higher contents of both sennosides (A and B) than the leaves.

The data in Table (4) also revealed that prolonging the irrigation intervals increased the percentages of sennosides A and B in glycosides extracted from leaves and pods, with the longest irrigation intervals (3 weeks) giving the highest values. On the other hand, chemical fertilization treatments decreased the sennoside A and B percentages in both leaves and pods, with control plants giving the highest values, whereas fertilization with ($N_3P_2K_1$) gave the lowest values.

Regarding the effect of different combinations of irrigation intervals and fertilization treatments, the data in Table (4) and Fig. (1) showed that the highest percentages of sennosides A and B in the leaves and pods were obtained from unfertilized plants ($N_0P_0K_0$) that were irrigated every 3 weeks, whereas the lowest values were obtained when the highest fertilization rate ($N_3P_2K_1$) was combined with weekly irrigation.

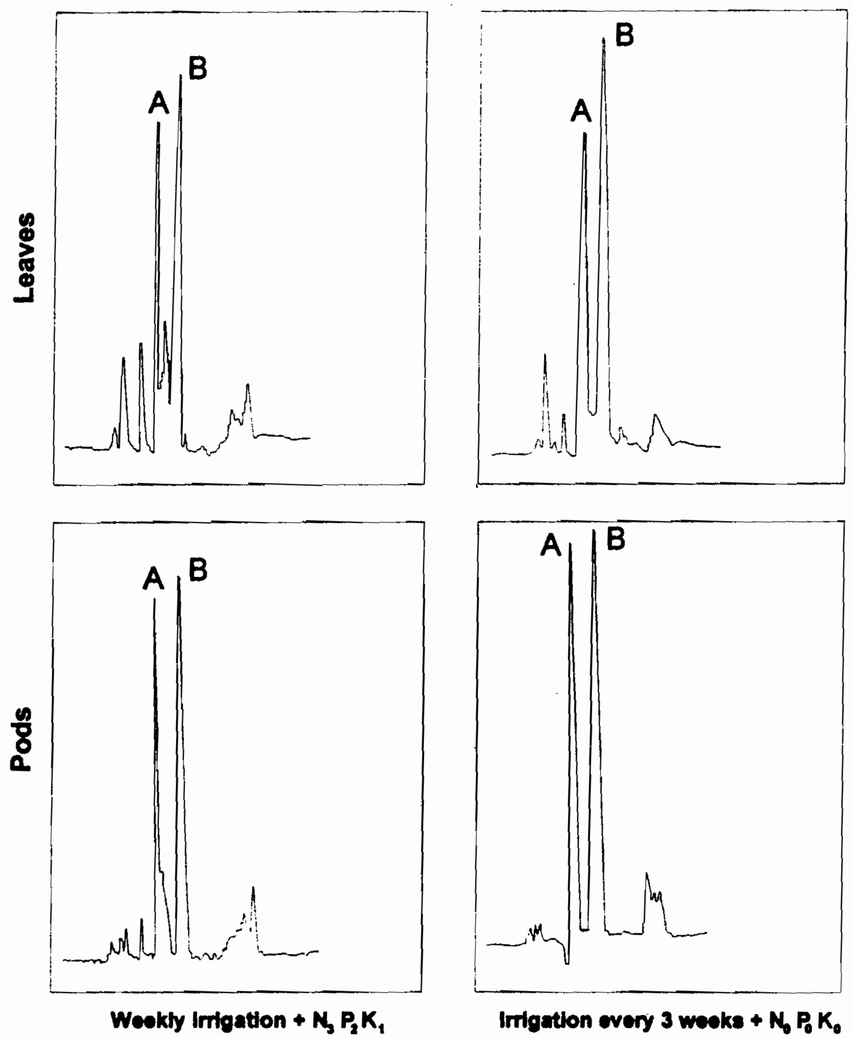

Fig. (1): HPLC analysis of glycosides extracted from leaves and pods of senna (*Cassia acutifolia*, Delile) plants irrigated weekly and fertilized with $N_3P_2K_1$, or irrigated every 3 weeks and receiving no fertilization ($N_0P_0K_0$).

Table (4): Effect of irrigation intervals and chemical fertilization on the sennosides A and B percentages in the glycosides extracted from leaves and pods of senna (*Cassia acutifolia*, Delile).

Fertilization treatments (F)*	Sennosides "A" content (%)				Sennosides "B" content (%)			
	Irrigation intervals (I)				Irrigation intervals (I)			
	1 week	2 weeks	3 weeks	Means	1 week	2 weeks	3 weeks	Means
	In leaves							
$N_0P_0K_0$	12.31	13.90	14.40	**13.54**	36.30	41.10	43.00	40.13
$N_1P_1K_1$	11.44	12.50	14.00	**12.65**	35.12	40.50	42.14	39.25
$N_2P_2K_1$	10.21	11.70	12.31	**11.41**	33.71	39.78	40.60	38.03
$N_3P_2K_1$	9.29	10.30	11.22	**10.27**	29.98	32.90	34.51	32.46
Means	**10.81**	**12.10**	**12.98**	---	**33.78**	**38.57**	**40.06**	---
	In pods							
$N_0P_0K_0$	16.31	17.46	18.51	**17.43**	45.34	47.71	50.00	47.68
$N_1P_1K_1$	15.11	16.33	17.10	**16.18**	43.30	44.30	49.00	45.53
$N_2P_2K_1$	14.00	15.00	16.60	**15.20**	42.01	43.00	46.31	43.77
$N_3P_2K_1$	12.45	13.31	14.23	**13.33**	36.15	40.20	41.16	39.17
Means	**14.47**	**15.53**	**16.61**	---	**41.70**	**43.80**	**46.62**	---

* N_0, N_1, N_2 and N_3 = N at 0, 25, 50 and 75 kg/fed., respectively.
P_0, P_1 and P_2 = P_2O_5 at 0, 25 and 50 kg/fed., respectively.
K_0 and K_1 = K_2O at 0 and 25 kg/fed., respectively.

II- Chemical compsition

1- Leaf pigments content

a- Chlorophylls "a" and "b" contents

Chemical analysis of the fresh leaves revealed that prolonging the irrigation intervals resulted in a steady reduction in the chlorophyll "a" and chlorophyll "b" contents (Table 5). Plants irrigated at the shortest intervals (1 week) gave the highest mean values in both seasons, whereas plants irrigated at the longest intervals (3 week) gave the lowest values.

The data in Table (5) also show that chemical fertilization had a generally favourable effect on the synthesis and accumulation of chlorophyll "a" and chlorophyll "b" in leaves of senna (*Cassia acutifolia*) plants. In most cases, the different fertilization treatments increased the chlorophyll "a" and chlorophyll "b" contents (compared to the control), with $N_3P_2K_1$ giving the highest mean values. Similar increases in the chlorophyll "a" and chlorophyll "b" contents as a result of fertilization treatments have been reported by Jacoub (1995) on sweet basil (*Ocimum basilicum*), and El-Ghadban (1998) on spearmint. The increase in the contents of chlorophyll "a" and chlorophyll "b" in the leaves of fertilized plants may explain the increase in the total sennosides yield, since the increase in the content of leaf pigments indicates that photosynthesis occurred a higher rate in fertilized plants than in the unfertilized control ($N_0P_0K_0$). This increase in the photosynthetic rate led to a significant promotion in vegetative growth characteristics (including the fresh and dry weights of leaves) and pod production (in terms of number of pods, and the fresh and dry weights of pods/plant), as mentioned in Part I of this study. As a result of this promotion in the yields of leaves and pods/plant, the sennosides yield/plant was increased (despite the reduction in the sennosides percentage in the leaves and pods as a result of the fertilization treatments).

Table (5): Effect of irrigation intervals and chemical fertilization on the contents of chlorophyll "a", chlorophyll "b" and carotenoids in leaves of senna (*Cassia acutifolia*, Delile) in the 1997 and 1998 seasons.

Fertilization treatments (F)*	Chlorophyll "a" content (mg/g fresh matter)				Chlorophyll "b" content (mg/g fresh matter)				Carotenoids content (mg/g fresh matter)			
	Irrigation intervals (I)				Irrigation intervals (I)				Irrigation intervals (I)			
	1 week	2 weeks	3 weeks	Means	1 week	2 weeks	3 weeks	Means	1 week	2 weeks	3 weeks	Means
	First season (1997)											
$N_0P_0K_0$	0.934	0.930	0.802	0.890	0.453	0.499	0.399	0.450	0.482	0.320	0.382	0.395
$N_0P_0K_1$	1.217	1.175	0.931	1.108	0.666	0.700	0.413	0.593	0.518	0.366	0.388	0.424
$N_0P_1K_1$	1.254	1.191	1.095	1.180	0.695	0.750	0.409	0.618	0.653	0.408	0.441	0.501
$N_0P_2K_1$	1.344	1.203	1.134	1.227	0.702	0.745	0.619	0.689	0.645	0.408	0.425	0.493
$N_1P_0K_1$	1.738	1.325	1.202	1.422	0.569	0.713	0.630	0.637	0.721	0.617	0.453	0.597
$N_1P_1K_1$	1.772	1.372	1.374	1.506	0.605	0.717	0.690	0.671	0.703	0.663	0.458	0.608
$N_1P_2K_1$	1.784	1.396	1.495	1.558	0.600	0.732	0.730	0.687	0.759	0.652	0.477	0.629
$N_2P_0K_1$	1.821	1.564	1.563	1.649	0.582	0.704	0.731	0.672	0.766	0.673	0.460	0.633
$N_2P_1K_1$	1.857	1.587	1.734	1.726	0.592	0.719	0.750	0.687	0.742	0.721	0.466	0.643
$N_2P_2K_1$	1.838	1.585	1.733	1.719	0.714	0.773	0.776	0.754	0.773	0.766	0.459	0.666
$N_3P_0K_1$	1.878	1.679	1.732	1.763	0.895	0.807	0.803	0.835	0.772	0.820	0.511	0.701
$N_3P_1K_1$	1.840	1.847	1.804	1.830	0.940	0.806	0.895	0.880	1.710	0.775	0.523	1.003
$N_3P_2K_1$	1.910	1.894	1.805	1.870	1.573	0.833	0.768	1.058	0.876	0.961	0.735	0.612
Means	1.630	1.442	1.416	---	0.737	0.730	0.663	---	0.778	0.627	0.475	---
	Second season (1998)											
$N_0P_0K_0$	0.894	0.881	0.800	0.858	0.333	0.398	0.594	0.442	0.366	0.220	0.360	0.315
$N_0P_0K_1$	1.111	0.940	0.944	0.998	0.463	0.470	0.510	0.481	0.519	0.260	0.371	0.383
$N_0P_1K_1$	1.041	0.960	0.800	0.934	0.471	0.510	0.300	0.427	0.612	0.374	0.406	0.464
$N_0P_2K_1$	1.240	1.110	0.900	1.083	0.503	0.530	0.466	0.500	0.640	0.399	0.420	0.486
$N_1P_0K_1$	1.527	1.200	1.102	1.279	0.355	0.500	0.481	0.445	0.700	0.590	0.440	0.577
$N_1P_1K_1$	1.561	1.160	1.160	1.294	0.398	0.496	0.480	0.458	0.699	0.613	0.460	0.591
$N_1P_2K_1$	1.601	1.170	1.234	1.335	0.399	0.499	0.494	0.464	0.730	0.640	0.460	0.610
$N_2P_0K_1$	1.610	1.303	1.254	1.389	0.411	0.533	0.500	0.481	0.730	0.660	0.450	0.613
$N_2P_1K_1$	1.655	1.303	1.433	1.464	0.390	0.541	0.456	0.462	0.721	0.690	0.470	0.627
$N_2P_2K_1$	1.641	1.374	1.422	1.479	0.520	0.580	0.399	0.500	0.750	0.700	0.470	0.640
$N_3P_0K_1$	1.666	1.345	1.422	1.478	0.630	0.584	0.499	0.571	0.730	0.740	0.500	0.657
$N_3P_1K_1$	1.600	1.543	1.503	1.549	0.750	0.600	0.400	0.583	0.986	0.740	0.695	0.807
$N_3P_2K_1$	1.700	1.681	1.605	1.662	1.399	0.640	0.444	0.828	1.101	0.890	0.700	0.897
Means	1.450	1.228	1.198	---	0.540	0.529	0.463	---	0.715	0.578	0.477	---

*** N_0, N_1, N_2 and N_3 = N at 0, 25, 50 and 75 kg/fed., respectively.**
P_0, P_1 and P_2 = P_2O_5 at 0, 25 and 50 kg/fed., respectively.
K_0 and K_1 = K_2O at 0 and 25 kg/fed., respectively.

Regarding the effect of different combinations of irrigation intervals and fertilization treatments on the chlorophyll "a" and chlorophyll "b" contents, the data in Table (5) show that in both seasons, plants irrigated weekly and supplied with $N_3P_2K_1$ had higher chlorophyll "a" and chlorophyll "b" contents, compared to plants receiving any other treatment combination. On the other hand, the lowest chlorophyll "a" content (in both seasons) was obtained from unfertilized plants ($N_0P_0K_0$) that were irrigated every 3 weeks. A similar trend was observed for the chlorophyll "b" content in the first season (i.e. the lowest value was obtained from unfertilized plants irrigated every 3 weeks), but in the second season, the lowest chlorophyll "b" content was obtained from plants that were fertilized with $N_0P_1K_1$ and irrigated every 3 weeks.

b- Carotenoids content

The content of carotenoids in the leaves of senna plants (*Cassia acutifolia*) were generally affected in the same way as chlorophyll by the different irrigation intervals and fertilization treatments (Table 5). In both seasons, it was found that prolonging the irrigation intervals reduced the carotenoids content steadily, i.e., the shortest intervals (1 week) gave the highest values, while the longest intervals (3 weeks) gave the lowest values.

Results recorded in the two seasons (Table 5) also show that plants receiving the different chemical fertilization treatments had higher carotenoid contents than the control. In general, raising the rate of N fertilization from N_0 to N_1, N_2 or N_3 resulted in a steady increase in the carotenoids content, regardless of the P or K rates applied. The highest carotenoids contents were obtained from plants fertilized with $N_3P_1K_1$ (in the first season) or $N_3P_2K_1$ (in the second season), whereas fertilization with $N_0P_0K_1$ gave the lowest mean values in both seasons, compared to all other fertilization treatments. The increase in the carotenoids content as a result of fertilization is in agreement with the results obtained by Jacoub (1995) on sweet basil (*Ocimum basilicum*), and El-Ghadban (1998) on spearmint.

Regarding the effect of different combinations of irrigation intervals and chemical fertilization treatments on the carotenoids content, the data in Table 5) showed that in the first season, the highest value was obtained from plants irrigated weekly and fertilized with $N_3P_1K_1$, whereas in the second season, the highest value was obtained from plants irrigated weekly and fertilized with $N_3P_2K_1$. On the other hand, the lowest values recorded in the two seasons were obtained from unfertilized plants ($N_0P_0K_0$) irrigated every 2 weeks.

2- Contents of nutrients (N, P and K) in leaves and stems

The data recorded in the two seasons show that in both seasons, irrigation at the medium intervals (2 weeks) gave the highest N, P and K contents in the leaves (Table 6) and the stems (Table 7), whereas the lowest values were found in plants irrigated at the longest intervals (3 weeks). The above results are logical, since the short or moderate water irrigation intervals ensure a relatively high water content in the soil, which dissolves the different nutrients and enables the plants to absorb them. On the other hand, long irrigation intervals decreased the available water content. Consequently, the nutrients that were found in the soil, or which were added by fertilization, remained un-dissolved and were not taken up readily by the plants. A similar result has been reported by Shoala (1992) on *Cymbopogon citratus*.

Regarding the effect of chemical fertilization treatments on the N, P and K contents in the leaves and stems, the recorded results (Tables 6 and 7) show that plants receiving the different chemical fertilization treatments had higher N contents than unfertilized control plants. It is also clear that, in most cases, raising the rate of N and/or P fertilization resulted in a steady increase in the recorded values. Accordingly, fertilization with the highest fertilization level ($N_3P_2K_1$) was the most effective treatment for increasing the contents of N, P and K in the leaves and stems, whereas the lowest values were obtained from plants supplied with K only ($N_0P_0K_1$). The increase in the N, P and K contents of leaves as a result of fertilization treatments is in agreement with the findings of Tonello *et al.* (1982) and Lamarre (1983) on tobacco, Pareek *et al.* (1983, a) on *Cymbopogon martinii*, Lim *et al.* (1991) on *Nicotiana tabacum*, Jacoub (1995 and 1999) on *Ocimum basilicum* and *Thymus vulgaris*, and El-Ghadban (1998) on marjoram and spearmint.

Table (6): Effect of irrigation intervals and chemical fertilization on the N, P and K contents in leaves of senna (*Cassia acutifolia*, Delile) plants in the 1997 and 1998 seasons.

Fertilization treatments (F)*	N content (% of dry matter)				P content (% of dry matter)				K content (% of dry matter)			
	Irrigation intervals (I)				Irrigation intervals (I)				Irrigation intervals (I)			
	1 week	2 weeks	3 weeks	Means	1 week	2 weeks	3 weeks	Means	1 week	2 weeks	3 weeks	Means
	First season (1997)											
$N_0P_0K_0$	1.30	1.40	1.19	**1.30**	0.40	0.61	0.36	**0.46**	1.10	1.29	1.00	**1.13**
$N_0P_0K_1$	1.31	1.40	1.22	**1.31**	0.42	0.61	0.37	**0.47**	1.14	1.30	1.00	**1.15**
$N_0P_1K_1$	1.35	1.43	1.22	**1.33**	0.51	0.63	0.38	**0.51**	1.16	1.30	1.03	**1.16**
$N_0P_2K_1$	1.36	4.50	1.30	**1.39**	0.52	0.64	0.41	**0.52**	1.17	1.31	1.10	**1.19**
$N_1P_0K_1$	1.67	1.90	1.51	**1.69**	0.41	0.61	0.38	**0.47**	1.35	1.60	1.30	**1.42**
$N_1P_1K_1$	1.80	1.92	1.61	**1.78**	0.56	0.64	0.43	**0.52**	1.38	1.60	1.31	**1.43**
$N_1P_2K_1$	1.84	2.35	1.73	**1.97**	0.53	0.66	0.46	**0.55**	1.49	1.65	1.42	**1.52**
$N_2P_0K_1$	2.31	2.70	2.00	**2.34**	0.55	0.65	0.50	**0.57**	1.69	2.00	1.61	**1.77**
$N_2P_1K_1$	2.51	2.76	2.01	**2.43**	0.61	0.68	0.53	**0.61**	1.85	2.26	1.73	**1.95**
$N_2P_2K_1$	2.63	3.01	2.41	**2.68**	0.63	0.68	0.56	**0.62**	2.10	2.43	1.75	**2.09**
$N_3P_0K_1$	3.31	3.79	3.11	**3.40**	0.61	0.69	0.58	**0.63**	2.10	2.53	1.98	**2.20**
$N_3P_1K_1$	3.42	4.31	3.10	**3.61**	0.62	0.70	0.58	**0.63**	2.22	2.70	2.00	**2.31**
$N_3P_2K_1$	3.78	4.41	3.09	**3.76**	0.66	0.71	0.60	**0.66**	2.69	3.30	2.49	**2.83**
Means	**2.20**	**2.53**	**1.96**	---	**0.54**	**0.65**	**0.47**	---	**1.65**	**1.94**	**1.52**	---
	Second season (1998)											
$N_0P_0K_0$	1.33	1.50	1.21	**1.35**	0.42	0.60	0.38	**0.47**	1.20	1.30	1.13	**1.21**
$N_0P_0K_1$	1.34	1.51	1.33	**1.39**	0.43	0.62	0.38	**0.48**	1.26	1.32	1.14	**1.24**
$N_0P_1K_1$	1.45	1.53	1.34	**1.44**	0.52	0.64	0.39	**0.52**	1.23	1.33	1.15	**1.24**
$N_0P_2K_1$	1.45	1.55	1.41	**1.47**	0.53	0.65	0.42	**0.53**	1.24	1.34	1.16	**1.25**
$N_1P_0K_1$	1.77	1.94	1.60	**1.77**	0.43	0.62	0.39	**0.48**	1.39	1.64	1.37	**1.47**
$N_1P_1K_1$	1.91	2.00	1.70	**1.87**	0.51	0.64	0.44	**0.53**	1.47	1.67	1.41	**1.52**
$N_1P_2K_1$	1.94	2.46	1.80	**2.07**	0.54	0.65	0.47	**0.55**	1.56	1.69	1.43	**1.56**
$N_2P_0K_1$	2.40	2.81	2.02	**2.41**	0.57	0.66	0.49	**0.57**	1.79	2.11	1.63	**1.84**
$N_2P_1K_1$	2.61	2.88	2.12	**2.54**	0.62	0.67	0.54	**0.61**	1.88	2.41	1.85	**2.05**
$N_2P_2K_1$	2.72	3.21	2.50	**2.81**	0.62	0.68	0.57	**0.62**	2.11	2.51	1.86	**2.16**
$N_3P_0K_1$	3.42	3.99	3.30	**3.57**	0.64	0.69	0.58	**0.64**	2.34	2.65	2.10	**2.36**
$N_3P_1K_1$	3.52	4.46	3.20	**3.73**	0.65	0.72	0.59	**0.65**	2.41	2.76	2.07	**2.41**
$N_3P_2K_1$	3.89	4.52	3.19	**3.87**	0.67	0.73	0.62	**0.67**	2.81	3.03	2.31	**2.72**
Means	**2.29**	**2.64**	**2.06**	---	**0.55**	**0.66**	**0.48**	---	**1.75**	**1.98**	**1.59**	---

*** N_0, N_1, N_2 and N_3 = N at 0, 25, 50 and 75 kg/fed., respectively.**
P_0, P_1 and P_2 = P_2O_5 at 0, 25 and 50 kg/fed., respectively.
K_0 and K_1 = K_2O at 0 and 25 kg/fed., respectively.

The interaction between the effects of irrigation intervals and chemical fertilization treatments resulted in large variations in the contents of N, P and K in the leaves and stems of senna plants. In both seasons, the highest values were obtained from plants irrigated every 2 weeks and supplied with the highest fertilization level ($N_3P_2K_1$), whereas the lowest values were obtained from the leaves of unfertilized plants ($N_0P_0K_0$) that were irrigated every 3 weeks. The remarkably high concentrations of the three nutrients in the leaves and stems of plants irrigated every 2 weeks and supplied with relatively high fertilization levels may be explained by the presence of sufficient water in the soil to dissolve the added fertilizers and make them available to the plants. Under such conditions, maximum absorption of nutrients occurred, and the N, P and K taken up by the plant were accumulated in the plant organs. Under short irrigation intervals (weekly irrigation), a slight reduction in the nutrient contents was observed, which may be attributed to the excessive amounts of water in the soil, leading to the leaching of the nutrients, and a reduction in their uptake by the plants.

Table (7): Effect of irrigation intervals and chemical fertilization on the N, P and K contents in stems of senna (*Cassia acutifolia*, Delile) plants in the 1997 and 1998 seasons.

Fertilization treatments (F)*	N content (% of dry matter)				P content (% of dry matter)				K content (% of dry matter)			
	Irrigation intervals (I)				Irrigation intervals (I)				Irrigation intervals (I)			
	1 week	2 weeks	3 weeks	Means	1 week	2 weeks	3 weeks	Means	1 week	2 weeks	3 weeks	Means
	First season (1997)											
$N_0P_0K_0$	1.10	1.21	1.00	1.10	0.31	0.50	0.30	0.37	1.21	1.31	1.04	1.19
$N_0P_0K_1$	1.11	1.24	1.00	1.12	0.32	0.52	0.31	0.38	1.23	1.32	1.05	1.20
$N_0P_1K_1$	1.20	1.30	1.11	1.20	0.40	0.53	0.38	0.44	1.25	1.32	1.06	1.21
$N_0P_2K_1$	1.26	1.31	1.21	1.26	0.45	0.54	0.43	0.47	1.25	1.35	1.06	1.22
$N_1P_0K_1$	1.56	1.67	1.45	1.56	0.33	0.51	0.32	0.39	1.45	1.60	1.40	1.48
$N_1P_1K_1$	1.70	1.82	1.60	1.71	0.41	0.54	0.40	0.45	1.47	1.62	1.43	1.51
$N_1P_2K_1$	1.70	1.83	1.62	1.72	0.43	0.56	0.42	0.47	1.85	1.67	1.50	1.58
$N_2P_0K_1$	2.20	2.60	2.00	2.27	0.45	0.55	0.44	0.48	1.79	2.01	1.70	1.83
$N_2P_1K_1$	2.41	2.63	2.33	2.46	0.47	0.56	0.44	0.49	1.93	2.31	1.83	2.02
$N_2P_2K_1$	2.51	2.66	2.52	2.56	0.50	0.57	0.46	0.51	1.99	2.53	1.83	2.12
$N_3P_0K_1$	3.10	3.40	3.10	3.20	0.51	0.58	0.48	0.52	2.11	2.63	2.00	2.25
$N_3P_1K_1$	3.14	3.61	2.90	3.22	0.53	0.60	0.51	0.55	2.32	2.74	2.10	2.39
$N_3P_2K_1$	3.39	3.79	2.90	3.36	0.55	0.62	0.51	0.56	2.79	3.40	2.51	2.90
Means	2.03	2.24	1.90	---	0.44	0.55	0.42	---	1.72	1.99	1.58	---
	Second season (1998)											
$N_0P_0K_0$	1.11	1.30	1.02	1.14	0.33	0.49	0.31	0.38	1.22	1.33	1.14	1.23
$N_0P_0K_1$	1.20	1.30	1.03	1.18	0.34	0.53	0.32	0.40	1.30	1.35	1.15	1.27
$N_0P_1K_1$	1.30	1.31	1.28	1.30	0.41	0.54	0.39	0.45	1.31	1.36	1.16	1.28
$N_0P_2K_1$	1.30	1.33	1.28	1.30	0.46	0.55	0.44	0.48	1.32	1.37	1.17	1.29
$N_1P_0K_1$	1.67	1.77	1.58	1.67	0.35	0.52	0.33	0.40	1.47	1.71	1.39	1.52
$N_1P_1K_1$	1.71	1.93	1.62	1.75	0.43	0.56	0.41	0.47	1.57	1.73	1.50	1.60
$N_1P_2K_1$	1.73	1.94	1.64	1.77	0.43	0.57	0.44	0.48	1.59	1.77	1.51	1.62
$N_2P_0K_1$	2.31	2.74	2.30	2.45	0.47	0.57	0.48	0.51	1.89	2.21	1.73	1.94
$N_2P_1K_1$	2.43	2.77	2.40	2.53	0.48	0.58	0.43	0.50	1.99	2.61	1.94	2.18
$N_2P_2K_1$	2.49	2.79	2.46	2.58	0.51	0.59	0.45	0.52	2.22	2.64	1.95	2.27
$N_3P_0K_1$	3.31	3.53	3.00	3.28	0.52	0.60	0.49	0.54	2.44	2.74	2.12	2.43
$N_3P_1K_1$	3.21	3.73	3.00	3.31	0.53	0.62	0.52	0.56	2.51	2.85	2.09	2.48
$N_3P_2K_1$	3.50	3.78	2.96	3.41	0.56	0.64	0.52	0.57	2.91	3.10	2.40	2.81
Means	2.10	2.32	1.97	---	0.45	0.57	0.43	---	1.82	2.06	1.64	---

* N_0, N_1, N_2 and N_3 = N at 0, 25, 50 and 75 kg/fed., respectively.
P_0, P_1 and P_2 = P_2O_5 at 0, 25 and 50 kg/fed., respectively.
K_0 and K_1 = K_2O at 0 and 25 kg/fed., respectively.

Recommendations: From the above results, it can be recommended that senna (*Cassia acutifolia*, Delile) plants should be irrigated every 2 weeks and fertilized with $N_2P_2K_1$. This combination of irrigation and fertilization treatments gave the highest yield of sennosides from pods/plant, and the highest total sennosides (A + B) yield/plant. However, for the highest sennosides quality (i.e. the highest percentages of sennosides A and B), the plants should be irrigated every 3 weeks, and should not be fertilized at all ($N_0P_0K_0$).

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تأثير فترات الري و التسميد الكيماوى على نباتات السنامكي الإسكندراني (*Cassia acutifolia*, Delile). ثانياً: التأثير على التركيب الكيميائي و إنتاج المكونات الفعالة

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أجريت هذه الدراسة بقسم بساتين الزينة، كلية الزراعة، جامعة القاهرة، الجيزة، و مزرعة النباتات الطبية والعطرية، كلية الصيدلة، جامعة القاهرة، الجيزة، خلال الموسمين المتتاليين ١٩٩٧ و ١٩٩٨، و ذلك بهدف دراسة تأثير فترات الرى و التسميد الكيماوى (NPK) على التركيب الكيميائى و إنتاج المكونات الفعالة فى نباتات السنامكى الإسكندرانى (*Cassia acutifolia*, Delile).

رويت نباتات السنامكى على فترات ١ أو ٢ أو ٣ أسابيع، و تم تسميدها كيماوياً بإستخدام توليفات من النتروجين بمعدلات صفر أو ٢٥ أو ٥٠ أو ٧٥ كجم/فدان (يشار إليها بالمعاملات N_0 و N_1 و N_2 و N_3 على التوالى)، و الفوسفور بمعدلات صفر أو ٢٥ أو ٥٠ كجم فو٢أ٥/فدان (يشار إليها بالمعاملات P_0 و P_1 و P_2 على التوالى)، و البوتاسيوم بمعدل ٢٥ كجم بو٢أ/فدان (يشار إليه بالمعاملة K_1). و بالإضافة إلى المعاملات السابقة فقد تم إستخدام نباتات غير مسمدة ($N_0P_0K_0$) كنباتات المقارنة (الكنترول).

و بصفة عامة كانت النسبة المئوية للسينوسيد B فى الأوراق و القرون أعلى من نسبة السينوسيد A، و كانت النسبة المئوية لكل من سينوسيد A و سينوسيد B أعلى فى القرون عنها فى الأوراق. هذا و قد أعطى الرى كل ٣ أسابيع أعلى المتوسطات للنسب المئوية للسينوسيدات الكلية فى الأوراق و القرون، و لمحصول السينوسيدات من الأوراق/نبات، و للنسب المئوية للسينوسيدات A و B فى الجليكوسيدات المستخلصة من الأوراق و القرون، فى حين أعطى الرى كل أسبوعين أعلى محصول سينوسيدات من القرون/نبات، و أعلى محصول كلى (من الأوراق + القرون)/نبات، و كذلك أعلى نسب مئوية من النتروجين و الفوسفور و البوتاسيوم فى الأوراق و السيقان. و من جهة أخرى فقد تم الحصول على أعلى محتوى من الصبغات (كلوروفيل أ و ب و كاروتينويدات) عند الرى أسبوعيا. و بصفة عامة فإن المعاملات السمادية المختلفة قللت النسب المئوية الإجمالية للسينوسيدات، و كذلك النسب المئوية للسينوسيدات A و B ، فى الأوراق و القرون، إلا أنها زادت محصول السينوسيدات من الأوراق/نبات و من القرون/نبات (حيث أعطت المعاملة $N_2P_2K_1$ أعلى القيم)، و محتوى الصبغات فى الأوراق، و كذلك محتوى النتروجين والفوسفور و البوتاسيوم فى الأوراق و السيقان (حيث أعطت المعاملة $N_3P_2K_1$ أعلى القيم لهذه الصفات). هذا و تم الحصول على أعلى القيم لكل من الصفات المختلفة عند الجمع ما بين أفضل فترة رى للصفة وإستخدام أفضل معاملة سمادية.