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INFLUENCE OF IRRIGATION INTERVALS AND CHEMICAL FERTILIZATION ON SENNA (*Cassia acutifolia*, Delile) PLANTS:

I. EFFECT ON GROWTH AND POD PRODUCTION

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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 vegetative growth and production of pods in senna (*Cassia acutifolia*, Delile) plants.

Cassia acutifolia plants 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 feddan (P_0, P_1 and P_2, respectively) and K_2O at 25 kg/fed. (K_1). In addition, plants receiving no chemical fertilization ($N_0P_0K_0$) were used as the control.

Irrigation every 3 weeks gave the highest mean values for plant height, number of branches/plant, fresh and dry weights of leaves and stems/plant, whereas irrigation every 2 weeks gave the highest mean values for pods production (number of pods/plant, and the fresh and dry weights of pods/plant). All fertilization treatments promoted vegetative growth and pod production, with $N_2P_1K_1$ giving the tallest plants. Fertilization with $N_3P_2K_1$ gave the highest mean values for fresh and dry weights of leaves/plant, while the highest fresh and dry weights of stems/plant were obtained from plants fertilized with $N_3P_1K_1$ or $N_3P_2K_1$. On the other hand, $N_2P_2K_1$ gave the best pods production. Moreover, combining this treatment ($N_2P_2K_1$) with irrigation every 2 weeks gave a better production of pods, compared to any other combination of irrigation intervals and fertilization treatments, whereas the highest fresh and dry weights of leaves/plant were obtained with weekly irrigation + $N_3P_2K_1$. The highest fresh weight of stems/plant was obtained when irrigation every 3 weeks was combined with fertilization using $N_3P_1K_1$, while the highest dry weight of stems/plant was obtained when irrigation at 3 weeks was combined with fertilization using $N_3P_0K_1$, $N_3P_1K_1$ or $N_3P_2K_1$.

Keywords: Senna, *Cassia acutifolia*, fertilization, NPK, irrigation intervals.

INTRODUCTION

Senna plants (*Cassia acutifolia*, Delile), belonging to Family Caesalpiniaceae (Leguminosae), have been used since the ninth or tenth century by Arabian physicians who used both the leaves and the pods as a laxative. 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 (Trease and Evans, 1985).

Chemical fertilization is among the most important cultural practices affecting the growth and productivity of different medicinal plants. The beneficial effect of chemical fertilization (especially N and P fertilization) on the vegetative growth and pod production by senna plants has been demonstrated by a number of researchers, such as Ilangovan *et al.* (1989), Pareek *et al.* (1989) and Ismail (1995). Favourable responses by several other medicinal plants to chemical fertilization have also been reported by Shetty *et al.* (1990) on *Datura stramonium*, El-Ghadban (1994) on *Mentha viridis*, Jacoub (1995) on *Ocimum basilicum*, Kothari and Singh (1995) on *Mentha gracilis*, Tesi *et al.* (1995) on *Ocimum basilicum*, Kewala *et al.* (1996) on *Hyoscyamus species*, Jana and Varghese (1996) on *Catharanthus roseus*, Zheljazkov and Margina (1996) on mint, Kassem (1997) on *Rosmarinus officinalis*, El-Ghadban (1998) on spearmint and marjoram, Jacoub (1999) on sweet basil (*Ocimum basilicum*), and many others. However, the ability of the plants to benefit from the fertilization treatments depends to a large extent on the water content of the soil, which is considerably affected by the irrigation intervals.

Several researchers have investigated the effect of different irrigation intervals on the growth and productivity of a large variety of medicinal plants [Agina (1966) on *Pelargonium graveolens*, El-Hossary (1970) on *Saponaria officinalis*, Bisher (1972) on marjoram, Gherman (1979) on *Petroselenum cripsum*, Shalaby *et al.* (1982) on *Ammi visnaga*, Acosta and Lerch (1984) on *Datura candida*, Yaniv *et al.* (1984) on *Solanum khasianum*, Zambory and Tetenyi (1986) on peppermint, Hegde (1987) on *Capsicum annuum*], but relatively few scientists have looked into the relationship between the effects of fertilization and irrigation treatments on medicinal plants [Balbaa *et al.* (1971) on *Digitalis lanata*, Weglarz (1983) on caraway (*Carum Carvi* L.), Shoala (1992) on lemon grass (*Cymbopogon citrates*), Hammam (1996) on anise (*Pimpinella anisum*), Singh (1999, a) on *Cymbopogon flexuosus*, and Singh (1999, b) on geranium (*Pelargonium groveolens*)].

This study was conducted with the aim of determining the effects of irrigation intervals and chemical NPK fertilization treatments, as well as the interaction between these two factors, on the vegetative growth and the production of leaves and pods by senna (*Cassia acutifolia*, Delile) plants.

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.

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/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 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.

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)			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)		
N	P	K														
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		

At harvesting (on October 21st, 1997 and October 17th, 1998, in the first and second seasons, respectively), data were recorded on plant growth and yield characteristics, including plant height, number of branches/plant, fresh and dry weights of leaves and stems per plant, number of pods per plant, as well as the fresh and dry weights of pods per plant.

The dry weights of leaves, pods and stems were recorded after oven drying the different plant parts at 70° C till a constant weight was obtained.

The recorded data were statistically analysed, and the means were compared using the L.S.D. test at the 0.05 level as described by Snedecor and Cochran (1968).

RESULTS AND DISCUSSION

I- Vegetative growth

1. Plant height

The data presented in Table (2) showed that prolonging the irrigation intervals significantly increased senna plant height, i.e. the tallest plants were obtained with the longest irrigation intervals (3 weeks), followed by plants irrigated every 2 weeks, while the shortest plants in the two season were those irrigated at the shortest intervals (1 week).

Regarding the effect of fertilization, the data showed that fertilization treatments also had a significant effect on plant height in both seasons. In most cases, control plants were significantly shorter than those receiving the different fertilization treatments. The least effective chemical fertilization treatment was the addition of K alone with no N or P (i.e., the $N_0P_0K_1$ treatment). On the other hand, the most effective treatment in promoting plant height was the application of $N_2P_1K_1$, which gave significantly taller plants in both seasons than those obtained with most of the other treatments. Among the different N levels, plants receiving treatments which included the medium N fertilization rate (N_2) gave higher values in both seasons than those receiving any other N rate, regardless of the P fertilization rate. The effect of raising P fertilization rate depended on the rate of N fertilization that was applied. When no N was applied (N_0), or when N was applied at the lowest rate (N_1), raising the P rate resulted in a steady increase in plant height. On the other hand, when N was applied at the highest rate, raising the rate of P had an opposite effect, i.e. raising the P rate resulted in a steady reduction in plant height.

These results are in agreement with the findings of Kothari *et al.* (1987) on *Mentha arvensis*, Shetty *et al.* (1990) on *Datura stramonium*, El-Ghadban (1994) on *Mentha viridis*, Ismail (1995) on senna plants, Jacoub (1995) on sweet basil, Kothari and Singh (1995) on *Mentha gracilis*, Tesi *et al.* (1995) on *Ocimum basilicum*, Kewala *et al.* (1996) on *Hyoscyamus sp.*, Jana and Varghese (1996) on *Catharanthus roseus*, Zheljazkov and Margina (1996) on mint, Kassem (1997) on *Rosmarinus officinalis*, El-Ghadban (1998) on spearmint and marjoram, and Jacoub (1999) on sweet basil.

The data in Table (2) also showed that a significant interaction existed between the effects of irrigation intervals and fertilization treatments on the height of senna plants in both seasons. The tallest plants were those irrigated at the longest intervals (3 weeks) and fertilized with $N_2P_2K_1$ (in the first season) or $N_2P_1K_1$ (in the second season), whereas the shortest plants in both seasons were those irrigated at the shortest intervals (1 week) and receiving no fertilization.

2- Number of branches per plant

The results in Table (2) indicated that prolonging the irrigation intervals significantly increased the number of branches per plant. In both seasons, the highest number of branches were formed on plants irrigated at the longest intervals (3 weeks), followed by those irrigated every 2 weeks, whereas the lowest number of branches/plant were found on plants irrigated at the shortest intervals (1 week).

Table (2): Effect of irrigation intervals and chemical fertilization on plant height and the number of branches/plant in 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
	Plant height (cm)							
$N_0P_0K_0$	43.90	47.90	50.63	**47.48**	44.53	47.97	47.33	**46.61**
$N_0P_0K_1$	45.68	48.17	52.67	**48.84**	46.83	50.93	52.87	**50.21**
$N_0P_1K_1$	47.03	49.33	53.83	**50.07**	48.33	51.13	55.57	**51.68**
$N_0P_2K_1$	46.53	49.33	54.50	**50.12**	47.60	51.30	56.47	**51.79**
$N_1P_0K_1$	51.48	55.17	61.27	**55.97**	51.63	54.97	64.53	**57.04**
$N_1P_1K_1$	52.00	63.00	65.33	**60.11**	54.37	65.50	66.87	**62.24**
$N_1P_2K_1$	55.25	64.00	71.60	**63.62**	55.90	70.70	73.67	**66.76**
$N_2P_0K_1$	58.18	70.00	83.67	**70.61**	60.43	72.17	86.17	**72.92**
$N_2P_1K_1$	60.12	73.93	88.57	**74.21**	60.23	72.97	91.60	**74.93**
$N_2P_2K_1$	56.73	65.70	88.93	**68.79**	59.73	74.37	87.53	**73.88**
$N_3P_0K_1$	55.43	71.30	82.00	**69.58**	56.90	73.60	83.67	**71.39**
$N_3P_1K_1$	53.60	70.50	81.33	**68.48**	53.87	73.70	84.43	**70.67**
$N_3P_2K_1$	52.98	68.83	80.77	**67.53**	53.50	71.63	82.20	**69.11**
Means	**52.22**	**61.32**	**70.01**	---	**53.37**	**63.92**	**71.76**	---
LSD (0.05)								
I	**1.28**				**1.43**			
F	**2.66**				**2.97**			
I X F	**4.60**				**5.14**			
	Number of branches/plant							
$N_0P_0K_0$	4.60	5.33	5.73	**5.22**	5.20	6.00	6.00	**5.73**
$N_0P_0K_1$	4.80	5.73	5.80	**5.44**	5.20	6.27	6.33	**5.93**
$N_0P_1K_1$	4.93	5.37	6.23	**5.51**	5.27	6.30	7.00	**6.19**
$N_0P_2K_1$	5.00	5.60	7.17	**5.92**	5.00	6.30	7.60	**6.30**
$N_1P_0K_1$	6.17	7.27	10.83	**8.09**	5.50	7.63	11.83	**8.32**
$N_1P_1K_1$	6.43	7.33	11.40	**8.39**	6.23	7.90	12.40	**8.84**
$N_1P_2K_1$	7.80	7.80	13.77	**9.79**	8.20	8.50	15.70	**10.80**
$N_2P_0K_1$	8.33	8.63	14.83	**10.60**	8.63	9.13	15.73	**11.17**
$N_2P_1K_1$	8.50	8.63	15.80	**10.98**	8.57	9.23	17.03	**11.61**
$N_2P_2K_1$	8.47	9.33	17.53	**11.78**	8.90	9.73	18.60	**12.41**
$N_3P_0K_1$	9.10	10.33	13.40	**10.94**	9.63	11.00	16.13	**12.26**
$N_3P_1K_1$	9.33	11.63	12.40	**11.12**	9.83	12.57	13.90	**12.10**
$N_3P_2K_1$	9.33	12.33	11.37	**11.01**	10.10	13.03	14.07	**12.40**
Means	**7.14**	**8.10**	**11.25**	---	**7.41**	**8.74**	**12.49**	---
LSD (0.05)								
I	**0.41**				**0.39**			
F	**0.85**				**0.81**			
I X F	**1.48**				**1.40**			

* 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 data presented in Table (2) also showed that the different fertilization treatments had a generally favourable effect on the branching of senna plants. In both seasons, plants fertilized with $N_2P_2K_1$ had significantly more branches/plant than those found on plants receiving most of the other fertilization treatments, including the control. On the other hand, the least effective chemical fertilization treatment was the application of $N_0P_0K_1$, which gave an insignificantly higher number of branches than that formed on control plants. Similar increases in branching as a result of fertilization treatments were recorded by Oda (1972) on *Rosmarinus officinalis*, Ismail (1995) on senna plants, Jacoub (1995 and 1999) on *Ocimum basilicum*, Jana and Varghese (1996) on *Catharanthus roseus*, Zheljazkov and Margina (1996) on mint, and Kassem (1997) on *Rosmarinus officinalis*.

As the N rate was increased, the number of branches was increased. This was very clear when the N fertilization rate was raised from N_0 to N_1 or N_2, but when the N rate was increased from N_2 (especially when combined with P_2 and K_1) to N_3, the increase in the number of branches was less pronounced. In fact, no significant difference was obtained between the mean values recorded on plants fertilized with $N_2P_2K_1$, $N_3P_0K_1$, $N_3P_1K_1$ or $N_3P_2K_1$ (in both seasons).

The effect of phosphorus fertilization on branching depended on the rate of N fertilization. When no N was added (N_0), or when N was added at the low or medium rates (N_1 or N_2), the number of branches was increased steadily with raising the P rate. On the other hand, when N was added at the highest rate (N_3), raising the P fertilization rate only resulted in insignificant differences in the number of branches.

A significant interaction was obtained between the effects of irrigation intervals and fertilization treatments on the number of branches. The effect of fertilization on branching differed from one irrigation interval to the other. With irrigation at intervals of 1 or 2 weeks, raising the rate of N fertilization resulted in steady increases in the number of branches. Accordingly, when plants were irrigated weekly or every 2 weeks, fertilization treatments that included N_3 gave higher values than any other fertilization treatment (with lower N rates). On the other hand, when the plants were irrigated every 3 weeks, N fertilization was most effective when applied at the medium rate (N_2). Moreover, plants irrigated every 3 weeks and fertilized with $N_2P_2K_1$ had significantly more branches than those receiving any other combination of irrigation intervals and fertilization treatments.

3- Fresh and dry weights of leaves per plant

The data in Table (3) showed that irrigation intervals had a significant effect on the fresh and dry weights of leaves/plant. In both seasons, the longest irrigation intervals (3 weeks) gave the highest mean fresh and dry weights of leaves/plant, followed by irrigation every 1 week, whereas the lowest values were obtained from plants irrigated every 2 weeks.

The results recorded in the two seasons (Table 3) also showed that, in most cases, the different chemical fertilization treatments increased the recorded values significantly, compared to the control. Among the different fertilization treatments, the application of K with no N or P (i.e. the $N_0P_0K_1$ treatment) was the least effective treatment, giving significantly lower values than most of the other fertilization treatments.

Table (3): Effect of irrigation intervals and chemical fertilization on the fresh and dry weights of leaves/plant 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
	Fresh weight of leaves/plant (g)							
$N_0P_0K_0$	75.20	71.00	105.20	**83.80**	76.97	73.43	106.00	**85.48**
$N_0P_0K_1$	85.67	82.83	105.10	**91.21**	87.47	86.87	107.50	**93.93**
$N_0P_1K_1$	93.73	91.20	116.60	**100.50**	97.20	94.10	117.40	**102.90**
$N_0P_2K_1$	97.23	94.27	116.90	**102.80**	94.83	96.60	114.10	**101.80**
$N_1P_0K_1$	117.70	96.37	136.00	**116.70**	121.30	97.20	152.00	**123.50**
$N_1P_1K_1$	126.00	121.40	144.00	**130.50**	128.60	121.00	144.70	**131.40**
$N_1P_2K_1$	135.00	126.00	148.30	**136.40**	128.40	125.20	149.30	**134.30**
$N_2P_0K_1$	143.80	131.40	179.60	**151.60**	147.90	136.50	184.40	**156.30**
$N_2P_1K_1$	165.40	132.70	180.20	**159.40**	168.00	138.30	185.30	**163.90**
$N_2P_2K_1$	168.30	145.20	211.80	**175.10**	174.50	140.70	214.00	**176.40**
$N_3P_0K_1$	193.20	153.10	188.10	**178.10**	196.70	156.00	184.50	**179.10**
$N_3P_1K_1$	205.00	158.20	177.70	**180.30**	207.00	162.40	183.40	**184.30**
$N_3P_2K_1$	256.10	176.50	165.20	**199.30**	265.20	171.10	174.60	**203.60**
Means	**143.20**	**121.60**	**151.90**	---	**145.70**	**123.00**	**155.20**	---
LSD (0.05)								
I	0.82				1.70			
F	1.70				3.52			
I X F	2.95				6.10			
	Dry weight of leaves/plant (g)							
$N_0P_0K_0$	21.55	29.04	30.89	**27.16**	23.24	35.34	33.27	**30.62**
$N_0P_0K_1$	25.71	30.27	33.44	**29.81**	26.86	32.67	36.40	**31.98**
$N_0P_1K_1$	27.57	31.27	40.05	**32.97**	28.58	34.38	42.51	**35.15**
$N_0P_2K_1$	25.10	33.44	40.18	**32.91**	26.54	35.61	43.24	**35.13**
$N_1P_0K_1$	36.20	37.18	42.61	**38.66**	37.11	39.80	45.77	**40.89**
$N_1P_1K_1$	38.91	37.94	43.60	**40.15**	41.07	41.11	46.74	**42.97**
$N_1P_2K_1$	39.35	39.15	49.60	**42.70**	42.50	42.27	52.74	**45.84**
$N_2P_0K_1$	49.70	39.91	64.74	**51.45**	51.63	41.71	68.80	**54.05**
$N_2P_1K_1$	59.08	40.54	67.27	**55.63**	61.43	42.91	72.43	**58.92**
$N_2P_2K_1$	61.77	53.61	78.61	**64.66**	64.20	56.21	83.61	**68.01**
$N_3P_0K_1$	70.74	64.61	63.35	**66.23**	74.51	67.30	67.27	**69.70**
$N_3P_1K_1$	78.54	66.31	60.44	**68.43**	80.97	69.57	63.96	**71.50**
$N_3P_2K_1$	108.50	65.79	55.59	**76.64**	111.80	69.17	58.97	**79.99**
Means	**49.44**	**43.78**	**51.57**	---	**51.58**	**46.77**	**55.05**	---
LSD (0.05)								
I	1.60				1.77			
F	3.34				3.69			
I X F	5.78				6.39			

* 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 N and P fertilization, raising the application rates of N and/or P resulted in steady increases in the fresh and dry weights of leaves/plant (in most cases). Accordingly, combining the highest rate of these two nutrients (i.e. application of the $N_3P_2K_1$ treatment) gave the highest values in both seasons, followed by fertilization with $N_3P_1K_1$. The increases in the fresh weight of leaves as a result of chemical fertilization treatments is in agreement with the findings of Oda (1972) on sage plants, El-Badry and Hilal (1977) on peppermint, Ilangovan *et al.* (1989) on senna, Pareek *et al.* (1989) on senna (*Cassia angustifolia*), Shetty *et al.* (1990) on *Datura stramonium*, Ismail (1995) on senna, and Kassem (1997) on *Rosmarinus officinalis*.

A significant interaction was detected between the effects of irrigation intervals (1, 2 or 3 weeks) and chemical fertilization treatments on the fresh and dry weights of leaves/plant. In both seasons, the highest values were obtained from plants irrigated weekly and supplied with the highest fertilization level ($N_3P_2K_1$). The favourable effect of this treatment combination on the fresh and dry weights of leaves may be attributed to the high solubility of nutrients (due to the high water content of the soil, resulting from short irrigation intervals), which makes the nutrients - supplied by fertilization - available to the plant. Also, the availability of a sufficient water supply allows for photosynthesis to occur efficiently within the leaves, and the resulting carbohydrates contribute to the increase in the plant growth characteristics, including the fresh and dry weights of the leaves.

4- Fresh and dry weights of stems per plant

The data in Table (4) revealed that prolonging the irrigation intervals significantly increased the fresh and dry weights of stems/plant. In both seasons, plants irrigated every 3 weeks gave the greatest values, followed by those irrigated at 2-week intervals, while the shortest irrigation intervals (1 week) gave the lowest values.

The different fertilization treatments also proved to have a favourable effect on the mean fresh and dry weights of stems/plant. In most cases, the different fertilization treatments gave significantly heavier fresh and dry stems than the control. Moreover, the data presented in Table (4) show that, in most cases, the mean values showed a steady increase in response to raising the N and/or P fertilization rates (especially the N rate). Accordingly, the highest values were obtained from plants supplied with the highest N fertilization level, combined with any of the two P levels (i.e. plants fertilized with $N_3P_1K_1$ or $N_3P_2K_1$). In most cases, the differences between the mean values obtained from plants receiving these two treatments were insignificant. Similar increases in the fresh and dry weights of stems as a result of NPK fertilization treatments have been reported by Kassem (1997) on *Rosmarinus officinalis*, and El-Ghadban (1998) on spearmint (*Mentha viridis*) and marjoram (*Origanum majorana*).

A significant interaction between the effects of irrigation intervals and chemical fertilization treatments on the fresh and dry weights of stems/plant was obtained. In general, plants irrigated at the different intervals showed a steady increase in the fresh and dry weights of stems/plant with the increase in the rate of N fertilization. In both seasons, the highest fresh weight of

stems/plant was obtained from plants irrigated every 3 weeks and supplied with $N_3P_1K_1$. On the other hand, the highest dry weight of stems/plant was obtained from plants irrigated every 3 weeks and fertilized with $N_3P_0K_1$. However, the dry weight of stems of plants receiving this combination of treatments (irrigation every 3 weeks and fertilization with $N_3P_0K_1$) was not significantly different than that of plants irrigated at the same intervals (3 weeks) and fertilized using $N_3P_1K_1$ or $N_3P_2K_1$, i.e. the dry weight was most favourably influenced by combining the longest irrigation intervals (3 weeks) with the highest N fertilization level (N_3), regardless of the P fertilization level.

Table (4): Effect of irrigation intervals and chemical fertilization on the fresh and dry weights of stems/plant 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
	Fresh weight of stems/plant (g)							
$N_0P_0K_0$	135.10	145.50	165.90	**148.80**	139.40	149.90	171.00	**153.40**
$N_0P_0K_1$	142.50	149.00	167.10	**152.90**	144.60	151.80	171.80	**156.00**
$N_0P_1K_1$	144.70	150.90	171.60	**155.70**	148.80	153.30	173.80	**158.60**
$N_0P_2K_1$	148.20	156.10	170.70	**158.30**	151.40	158.80	174.40	**161.50**
$N_1P_0K_1$	205.80	200.80	257.50	**221.40**	210.20	207.00	262.10	**226.50**
$N_1P_1K_1$	226.40	221.10	265.80	**237.80**	229.40	224.40	268.00	**240.60**
$N_1P_2K_1$	228.30	224.20	263.40	**238.63**	233.20	226.30	270.30	**243.30**
$N_2P_0K_1$	242.00	240.10	308.50	**263.50**	246.30	246.10	310.70	**267.70**
$N_2P_1K_1$	245.20	248.70	336.30	**276.70**	250.90	250.50	374.80	**292.10**
$N_2P_2K_1$	252.10	269.90	372.90	**298.30**	255.80	275.50	379.10	**303.50**
$N_3P_0K_1$	275.00	291.40	384.00	**316.80**	278.60	294.30	389.30	**320.70**
$N_3P_1K_1$	278.60	288.60	400.10	**322.40**	283.40	293.40	412.20	**329.60**
$N_3P_2K_1$	291.60	287.40	386.00	**321.70**	297.60	296.10	374.30	**322.70**
Means	**216.60**	**221.00**	**280.80**	**---**	**220.70**	**225.20**	**287.10**	**---**
LSD (0.05)								
I	**4.29**				**0.89**			
F	**8.93**				**1.85**			
I X F	**15.46**				**3.98**			
	Dry weight of stems/plant (g)							
$N_0P_0K_0$	46.93	54.42	67.13	**56.16**	49.84	59.47	71.91	**60.40**
$N_0P_0K_1$	48.43	62.34	72.71	**61.16**	52.84	67.31	79.09	**66.41**
$N_0P_1K_1$	49.87	63.10	72.77	**61.92**	55.94	68.84	78.80	**67.86**
$N_0P_2K_1$	51.12	64.17	74.43	**63.24**	56.04	70.41	81.42	**69.29**
$N_1P_0K_1$	75.26	85.77	101.50	**87.52**	81.28	93.34	110.10	**94.91**
$N_1P_1K_1$	75.14	85.88	101.80	**87.62**	82.04	93.37	111.00	**95.48**
$N_1P_2K_1$	83.19	88.22	102.70	**91.36**	88.84	95.20	111.30	**98.45**
$N_2P_0K_1$	98.90	103.60	130.90	**111.10**	106.60	111.20	141.60	**119.80**
$N_2P_1K_1$	103.70	104.00	131.30	**113.00**	111.60	110.10	143.50	**121.70**
$N_2P_2K_1$	106.20	104.20	133.10	**114.50**	113.00	111.20	149.00	**124.40**
$N_3P_0K_1$	121.90	138.30	174.00	**144.70**	129.80	143.70	189.30	**154.30**
$N_3P_1K_1$	128.30	139.00	174.00	**147.10**	135.30	144.30	189.00	**156.20**
$N_3P_2K_1$	137.20	141.10	173.00	**150.40**	141.80	144.50	182.20	**156.20**
Means	**86.63**	**94.93**	**116.10**	**---**	**92.68**	**101.00**	**126.00**	**---**
LSD (0.05)								
I	**2.71**				**2.91**			
F	**5.64**				**6.06**			
I X F	**9.76**				**10.49**			

* 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- Pod production

1- Number of pods per plant

It is clear from the results recorded in the two seasons (Table 5) that, in general, moderate irrigation intervals (2 weeks) resulted in the highest number of pods/plant, followed by plants irrigated weekly. On the other hand, the longest irrigation intervals (3 weeks) gave the lowest values. This trend was similar to that reported by Hammam (1996) on anise (*Pimpinella anisum*) who found that short or moderate irrigation (every 2 or 4 weeks) resulted in a significantly higher fruit yield/plant, compared to irrigation every 6 weeks. Also, Mehboob *et al.* (1998) found that *Capsicum annuum* plants irrigated every 14 days gave a higher fruit yield, compared to those irrigated every 7 or 21 days.

Table (5): Effect of irrigation intervals and chemical fertilization on the number of pods/plant of senna (*Cassia acutifolia*, Delile) in the 1997 and 1998 seasons.

Fertilization treatments (F)*	Number of pods/plant							
	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
$N_0P_0K_0$	28.47	38.17	18.67	**28.43**	29.13	38.80	19.63	**29.19**
$N_0P_0K_1$	80.13	81.40	41.00	**67.51**	82.37	84.13	43.20	**69.90**
$N_0P_1K_1$	89.80	91.77	54.90	**78.82**	91.10	92.57	71.03	**84.90**
$N_0P_2K_1$	91.67	99.60	67.77	**86.34**	93.03	100.70	69.50	**87.73**
$N_1P_0K_1$	96.57	103.00	75.77	**91.79**	96.53	104.20	79.20	**93.32**
$N_1P_1K_1$	140.20	144.20	76.63	**120.30**	145.00	144.70	79.33	**123.00**
$N_1P_2K_1$	135.10	144.10	90.07	**123.10**	136.40	148.40	94.17	**126.30**
$N_2P_0K_1$	123.30	160.60	85.13	**126.00**	134.10	171.30	86.30	**130.60**
$N_2P_1K_1$	114.60	171.00	85.30	**123.60**	115.90	177.90	88.53	**127.40**
$N_2P_2K_1$	87.93	215.80	80.80	**128.20**	90.80	225.70	82.43	**133.60**
$N_3P_0K_1$	82.90	174.30	77.37	**111.50**	84.30	175.80	79.70	**113.30**
$N_3P_1K_1$	74.97	161.30	72.13	**102.80**	75.50	162.50	74.77	**104.30**
$N_3P_2K_1$	72.13	158.00	69.90	**100.00**	73.20	159.00	72.43	**101.50**
Means	**94.37**	**134.10**	**68.90**	---	**95.95**	**137.50**	**72.33**	---
LSD (0.05)								
I	**2.14**				**2.71**			
F	**4.46**				**5.64**			
I X F	**7.73**				**9.76**			

* 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 fertilization treatments on pods productivity of senna plants (*Cassia acutifolia*), the data in Table (5) showed that all the fertilization treatments increased the number of pods/plant significantly, compared to the control. In both seasons unfertilized control plants produced the fewest pods, whereas the highest number of pods was obtained from plants fertilized with $N_2P_2K_1$, followed by those fertilized with $N_2P_0K_1$. It can also be concluded from the data in Table (5) that the number of pods/plant was increased steadily by raising the rate of N fertilization up till the medium rate

(N_2), while a further increase in the N rate to the highest level (N_3) caused some reduction in the number of pods (compared to those produced with N_2). Also, when the plants received no N fertilization (N_0), or when they received the lowest N rate (N_1), the values increased steadily with raising the P fertilization rate. On the other hand, when N was applied at the highest rate (N_3), raising the P fertilization rate caused a steady reduction in the mean number of pods/plant. The increase in number of pods as a result of the different fertilization treatments is in agreement with the results reported by Pareek *et al.* (1989) on senna (*Cassia angustifolia*), and Fiad (1993) on caraway (*Carum carvi*).

A significant interaction was obtained in both seasons between the effects of irrigation intervals and chemical fertilization on the number of pods per plant in both seasons. In both seasons, the lowest number of pods was obtained from unfertilized plants that were irrigated every 3 weeks. On the other hand, the highest values were obtained from plants irrigated every 2 weeks and fertilized with $N_2P_2K_1$.

2- Fresh and dry weights of pods per plant

Data in Table (6) showed that, in both seasons, the highest mean fresh and dry weights of pods/plant were obtained from plants irrigated every 2 weeks, followed by plants irrigated weekly, whereas the lowest values were obtained from plants irrigated at the longest intervals (3 weeks). The increase in dry weight of pods as a result of moderate irrigation intervals (2 weeks) is in agreement with the findings of Hammam (1996) on ansie (*Pimpinella anisum*), and Mehboob *et al.* (1998) on *Capsicum annuum* plants. On the other hand, the reduction in the production of pods by senna plants irrigated at the longest intervals may be related to the promotion of vegetative growth that was observed with irrigation every 3 weeks. As previously mentioned, irrigation at the longest intervals gave the highest values for some vegetative growth parameters (plant height, number of branches/plant, fresh and dry weights of leaves/plant). This promotion of vegetative growth may have adversely affected the flowering of the plants and, consequently, the formation of pods.

The data in Table (6) also showed that all the chemical fertilization treatments gave significant increases in the recorded values, compared to the control. Even the least effective fertilization treatment ($N_0P_0K_1$) tripled the mean fresh weight of pods/plant, and more than doubled their dry weight, compared to the control. Moreover, the application of N and/or P fertilization caused further increases in the fresh and dry weights of pods/plant, with $N_2P_2K_1$ giving the highest values in both seasons. Plants receiving this treatment produced pods with a mean fresh weight that was about seven times higher than that of pods produced by control plants, while their mean dry weight was more than five times higher than that of the control. The increase in the fresh and dry weights of pods as a result of fertilization treatments is in agreement with the findings of Ilangovan *et al.* (1989), Pareek *et al.* (1989) and and Ismail (1995) on senna (*Cassia angustifolia*) plants. Also, an increase in the fruit yield of caraway (*Carum carvi*) plants receiving fertilization treatments has been reported by Fiad (1993).

Table (6): Effect of irrigation intervals and chemical fertilization on the fresh and dry weights of pods/plant 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
	Fresh weight of pods/plant (g)							
$N_0P_0K_0$	17.93	21.27	10.33	**16.51**	19.97	21.90	11.97	**17.94**
$N_0P_0K_1$	58.40	70.27	24.17	**50.94**	62.00	73.37	27.77	**54.38**
$N_0P_1K_1$	61.27	71.20	37.37	**56.61**	63.67	74.93	38.10	**58.90**
$N_0P_2K_1$	62.30	71.90	45.67	**59.96**	64.83	74.40	48.00	**62.41**
$N_1P_0K_1$	70.13	88.23	48.33	**68.90**	73.53	92.93	49.20	**71.89**
$N_1P_1K_1$	72.80	84.03	58.43	**71.76**	74.37	88.27	59.40	**74.01**
$N_1P_2K_1$	81.87	99.40	62.23	**81.17**	83.33	101.90	66.53	**83.93**
$N_2P_0K_1$	88.03	122.30	74.37	**94.90**	91.53	127.30	77.53	**98.78**
$N_2P_1K_1$	95.93	123.20	70.77	**96.62**	100.80	132.40	71.70	**101.60**
$N_2P_2K_1$	93.00	196.20	68.33	**119.20**	96.17	205.30	71.10	**124.20**
$N_3P_0K_1$	93.20	138.00	60.83	**97.66**	95.27	144.30	63.83	**101.10**
$N_3P_1K_1$	85.17	123.70	60.47	**89.79**	89.37	131.90	62.50	**94.60**
$N_3P_2K_1$	79.10	118.70	59.20	**85.66**	82.47	115.50	60.80	**86.27**
Means	**73.78**	**102.20**	**52.35**	**---**	**76.72**	**106.50**	**54.49**	**---**
LSD (0.05)								
I		**0.93**				**1.17**		
F		**1.93**				**2.43**		
I X F		**3.35**				**4.20**		
	Dry weight of pods/plant (g)							
$N_0P_0K_0$	9.32	9.47	5.24	**8.01**	10.35	11.18	6.68	**9.40**
$N_0P_0K_1$	23.84	27.87	10.72	**20.81**	25.07	28.96	12.01	**22.01**
$N_0P_1K_1$	26.24	26.97	12.87	**22.03**	27.63	30.48	13.89	**24.00**
$N_0P_2K_1$	29.63	32.24	15.74	**25.87**	30.52	33.41	16.31	**26.75**
$N_1P_0K_1$	31.64	41.55	18.92	**30.70**	33.14	43.04	20.31	**32.16**
$N_1P_1K_1$	34.70	40.97	20.31	**31.99**	32.67	42.44	21.71	**32.27**
$N_1P_2K_1$	37.34	43.93	19.91	**33.73**	38.55	45.13	21.41	**35.03**
$N_2P_0K_1$	40.94	45.66	32.20	**39.60**	43.07	48.49	34.73	**42.10**
$N_2P_1K_1$	44.94	46.00	24.91	**38.62**	40.54	49.29	27.68	**39.17**
$N_2P_2K_1$	41.94	69.55	24.07	**45.19**	45.06	71.65	27.11	**47.94**
$N_3P_0K_1$	42.18	60.22	23.76	**42.05**	45.26	58.77	25.24	**43.09**
$N_3P_1K_1$	41.54	57.54	24.61	**41.23**	44.91	59.94	27.70	**44.18**
$N_3P_2K_1$	37.58	41.54	24.22	**34.45**	40.64	44.74	27.24	**37.54**
Means	**33.99**	**41.81**	**19.81**	**---**	**35.18**	**43.99**	**21.69**	**---**
LSD (0.05)								
I		**1.10**				**1.30**		
F		**2.30**				**2.71**		
I X F		**3.98**				**4.69**		

* 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.

It is also clear from the data in Table (6) that a significant interaction was detected between the effects of irrigation intervals and chemical fertilization treatments on the fresh and dry weights of pods/plant. In both seasons, the effect of the different chemical fertilization treatments depended on the irrigation intervals that were used. With long irrigation intervals (3 weeks), the highest values were obtained from plants fertilized with $N_2P_0K_1$, but with short

irrigation intervals (1 week), the most effective fertilization treatment (in most cases) was $N_2P_1K_1$. On the other hand, when plants were irrigated at moderate intervals (2 weeks), the most effective fertilization treatment was $N_2P_2K_1$. In fact, this combination of treatments (irrigation every 2 weeks, and fertilization with $N_2P_2K_1$) gave the highest values recorded in both seasons, compared to those recorded with any other combination of irrigation intervals and fertilization treatments.

Recommendations: From the above results, it can be recommended that, for the highest yield of fresh or dry leaves, senna (*Cassia acutifolia*) plants should be irrigated weekly and fertilized with $N_3P_2K_1$. On the other hand, the best production of pods (in terms of number of pods/plant, as well as fresh and dry weights of pods/plant) can be achieved by irrigation every 2 weeks, combined with fertilization using $N_2P_2K_1$.

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تأثير فترات الرى و التسميد الكيماوى على نباتات السنامكى الإسكندرانى (*Cassia acutifolia*, Delile). أولاً: التأثير على النمو و إنتاج القرون

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

رويت نباتات السنامكى على فترات ١ أو ٢ أو ٣ أسابيع، و تم تسميدها كيماويا باستخدام 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 الفرسفور 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).

هذا و قد أعطى الرى كل ٣ أسابيع أعلى المتوسطات لصفات إرتفاع النبات و عدد الأفرع/نبات و الأوزان الطازجة و الجافة للأوراق و السيقان/نبات، فى حين أعطى الرى كل أسبوعين أعلى المتوسطات لإنتاج القرون (عدد القرون/نبات، و الأوزان الطازجة و الجافة للقرون/نبات). كذلك أدت جميع معاملات التسميد إلى زيادة النمو الخضرى و إنتاج القرون، و أعطى التسميد بإستخدام $N_2P_1K_1$ أطول النباتات، فى حين أعطى التسميد باستخدام $N_3P_2K_1$ أعلى المتوسطات للأوزان الطازجة و الجافة للأوراق/نبات، أما أعلى الأوزان الطازجة و الجافة للسيقان/نبات فتم الحصول عليها من النباتات المسمدة بواسطة $N_3P_1K_1$ أو $N_3P_2K_1$. و من جهة أخرى فقد أعطى التسميد بإستخدام $N_2P_2K_1$ أفضل إنتاج للقرون، كما أدى الجمع بين هذه المعاملة ($N_2P_2K_1$) و الرى كل أسبوعين إلى إعطاء أفضل النتائج من حيث إنتاج القرون، و ذلك بالمقارنة بجميع التباديل الأخرى من فترات الرى و معاملات التسميد، أما أعلى أوزان طازجة و جافة للأوراق/نبات فتم الحصول عليها عند الرى أسبوعيا مع التسميد بإستخدام $N_3P_2K_1$. و تم الحصول على أعلى وزن طازج للسيقان/نبات عند الجمع بين الرى كل ٣ أسابيع و التسميد بإستخدام $N_3P_1K_1$ ، فى حين تم الحصول على أعلى وزن جاف للسيقان/نبات عند الجمع بين الرى كل ٣ أسابيع و التسميد بإستخدام $N_3P_0K_1$ أو $N_3P_1K_1$ أو $N_3P_2K_1$.