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STUDIES ON THE EFFECT OF IRRIGATION INTERVALS, BIO AND CHEMICAL FERTILIZATION ON ROSELLE PLANT PRODUCTIVITY

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ABSTRACT

Two field experiments were carried out at the Experimental Farm of Faculty of Agriculture, Ain Shams University, Egypt during the two seasons of 1999 and 2000 to investigate the effect of irrigation intervals and different fertilization sources on the growth, yield and chemical constituents of roselle plants. Three irrigation intervals, i.e. irrigation every 1, 2 and 3 weeks were applied in combination with 4 mixtures of chemical and bio-fertilizers which were as follows:

1. Full dose of NPK-recommended rate : 150 kg/fed. ammonium sulphate (20.5%) + 200 kg/fed. calcium superphosphate (15.5%) + 150 kg/fed. potassium sulphate (48%).
2. 50% NPK-recommended rate + 4 kg/fed. biogen.
3. 50% NPK-recommended rate + 4 kg/fed. phosphorin.
4. 50% NPK-recommended rate + 4 kg/fed. biogen + 4 kg/fed. phosphorin.

The obtained results indicated that, the treatment irrigated every 1 week and fertilized with 50% NPK-recommended rate + biogen + phosphorin produced the highest values of plant height, number of branches and fruits/plant, fresh weights of fruits and sepals g/plant, sepals dry weight (g/plant or kg/fed.), seed yield (g/plant or ton/fed.), anthocyanin content as well as N, P and K contents in both seasons. The lowest pH values (which caused the highest acidity), the highest T.S.S and fixed oil percentages were obtained from the treatment irrigated every 3 weeks and fertilized with half dose of NPK-recommended rate combined with both biofertilizers in both seasons. The treatment irrigated every 2 weeks and fertilized with 50% NPK-recommended rate combined with both biofertilizers produced the highest fixed oil yield g/plant and kg/fed. in both seasons.

INTRODUCTION

Roselle plant (*Hibiscus sabdariffa*, L.) is a subtropical plant that belongs to family Malvaceae and is known in Egypt as karkade. Epicalyxes and calyxes are the main parts used for producing soft hot and cold red drink which is used as antihypertension and cardiotunic without producing side effects as well as extracting the natural coloring pigment (anthocyanin) which is used in food industries and cosmetics (Diab, 1968). Furthermore, fixed oil of roselle seeds has properties similar to that extracted from cotton seed (Hussein *et al.*, 1989).

Many investigators pointed out the water regime effects on growth and yield of different medicinal and aromatic plants. With roselle, El-Shafie *et al.* (1994) found that, frequency of irrigation every 7 days produced taller plants with more branches, higher yield and yield components when compared with irrigation every 14 or 28 days. Refaat and Saleh (1998) on sweet basil found that, plant growth was reduced by increasing irrigation intervals from 7 to 28 days. Irrigation schedul also influenced essential oil yield and components. Ashoub *et al.* (2000) reported that decreasing irrigation intervals from 21 days to 7 days, gave significant increases in seed and straw yield/fed. with sunflower plants.

The significant role of chemical fertilization of medicinal and aromatic plants production is almost fully recognized. However, in the recent years, many constrains have been arisen due to their adverse on public health, environment and national incomes. To comfort this problem, it is necessary to develop alternative methods of applying nutrients to the growing plants. The utilization of biofertilizers is considered today by many scientists as a promising alternative, particularly for developing countries. Biofertilization is generally based on altering the rhizosphere flora by seed or soil inoculation with certain organisms, capable of inducing beneficial effects on a compatible host. Biofertilizers mainly comprise nitrogen fixers, phosphate dissolvers or vesicular arbuscular micorrhizas and silicate bacteria. These organisms may affect their host by one or more mechanisms such as nitrogen fixation (Ruiz-Lozano *et al.*, 1995), production of promoting substances or organic acids (Noel *et al.*, 1996), enhancing nutrient uptake or protection against plant pathogens (Frankenberger and Arshad, 1995).

Microbial inoculation (biofertilizers) by far, are most reliable tools to reduce the rate of chemical fertilizers applied for medicinal and aromatic plants production in all types of soil in Egypt beside improving the environment.

The obtained results from researches indicated that, application of biofertilizers (N_2-fixers, P dissolvers) produced better growth and yield, increased active constituents, reduced the N requirement and enhanced water stress tolerance in many medicinal and aromatic plants such as *Ammi visnaja* (El-Sawy *et al.*, 1998); *Cymbopogon martenii* (Maheshwari *et al.*, 1998) and *Pimpinella anisum* (Gomaa and Abo-Aly, 2001) compared to the untreated plants.

This work aim to evaluate the effect of three irrigation intervals and different fertilization sources on roselle plant growth, yield and yield components as well as chemical constituents.

MATERIAL AND METHODS

Two field experiments were conducted at the Experimental Farm of Faculty of Agriculture, Ain Shams University, Egypt during the two successive seasons of 1999 and 2000. Before planting, physical and chemical properties of the farm soil were determined according to Chapman and Pratt (1978) and data were as follows :

Seeds of roselle (*Hibiscus subdariffa*, L.) plant c.v. Sabahia 17 dark color (obtained from the Horticulture Research Institute, ARC, Ministry of Agriculture, Giza, Egypt) were sown on May 1^{st} of both seasons on rows 60 cm apart in hills 35 cm in between. The open field were prepared three weeks before planting and supplemented during preparation with 20 m^3/feddan of 6 months old cattle manure. All agricultural managements practices were carried out as usually recommended for roselle production in Egypt. The experiment included 12 treatments comprised of three irrigation intervals, i.e. irrigation every 1, 2 and 3 weeks in combination with four mixtures of chemical and bio-fertilizers which were as follows:

a. Full dose of NPK-recommended rate: 150 kg/fed. ammonium sulphate (20.5%) + 200 kg/fed. calcium superphosphate (15.5% P_2O_5) + 150 kg/fed. potassium sulphate (48% K_2O).
b. 50% NPK-recommended rate + 4 kg/fed. biogen.
c. 50% NPK-recommended rate + 4 kg/fed. phosphorin.
d. 50% NPK-recommended rate + 4 kg/fed. biogen + 4 kg/fed. phosphorin.

Table (1):Some physical and chemical analysis of farm soil (average of two seasons).

Physical properties									
	Clay		Silt		Sand			Texture	
	65.10		12.90		22.00			Clay	
Chemical properties									
pH	E.C. mmhos/ Cm	Organic matter	Total	available		Available micronutrients (ppm)			
			(mg/100 g)						
		%	N	P	K	Fe	Mn	Zn	Cu
7.9	1.1	1.6	110	3.00	0.5	75.3	20.6	17.1	14.2

Calcium superphosphate was added during soil preparation, while both amounts of ammonium and potassium sulphate were applied in three equal portions starting after one month from planting at 30 days intervals. Biofertilizers, i.e. biogen and phosphorin are commercial biofertilizers locally produced by the General Organization for Agricultural Equilization Found (GOAEF), Ministry of Agriculture, Egypt. Biogen contains live cells of efficient bacteria which is capable of N_2-fixation. While, phosphorin contains those capable of converting unavailable phosphate to a soluble form. Biofertilizers were applied at 4 kg/fed. from each inoculants as soil application, and were incorporated into the soil by hoeing just before planting.

At harvest (150 days from sowing), random samples from each treatment were taken to determine plant height (cm), number of branches and fruits/plant, fresh weights of fruits and sepals g/plant, dry weight of sepals (g/plant or kg/fed.) and seeds yield (g/plant or ton/feddan). Sepals and seed chemical analysis were determined as follows :

1- Sepals chemical analysis

Anthocyanin pigment was determined following the method described by Du and Francis (1973) which is a modified version of Fuleki and Francis (1968) method, pH values and total soluble solids percentage (T.S.S%) were determined according to the method described by Diab (1968), N,P and K contents were determined following the method of Cottenie *et al.* (1982).

2. Seed chemical analysis

Determination of fixed oil in air dried roselle seeds were determined according to A.O.A.C. (1990) procedures. Data were recorded as g oil/100 g dry seeds, then estimated as g/plant and kg/feddan.

Treatments were arranged in complete randomized block design with three replicates. Each replicate was comprised of 12 plots, each having 3 rows of 3 m length with a total area of 5.4 m²/plot. Data were subjected to statistical analysis procedures according to Snedecor and Cochran (1972). Means were compared by Duncan's test at 5% of probability in the two seasons of experimentation.

RESULTS AND DISCUSSION

3.1. Vegetative growth

3.1.1. Effect of irrigation intervals

Data presented in Tables (2 & 3) clearly indicated that, plant height and number of branches/plant of roselle plants received the same fertilization sources, were significantly increased with decreasing irrigation intervals from 3 to 2 or from 2 to 1 week in both seasons. The drought conditions and the lack of water may negatively reflect on plant growth and development through decreasing photosynthesis rate (Abdel-Nasser and El-Gamal, 1996). Water deficiency has a profound effect on plant metabolism including cell wall and cell expansion. Differentiation of vegetative or productive tissue is directly affected by water deficits (Ashoub *et al.*, 2000). Similar results were reported by Naguib and Hussein (1995) on roselle, Refaat and Saleh (1998) on sweet basil, and Kandeel (2001) on *Rosmarinus officinalis*.

3.1.2. Effect of different fertilization sources

Data presented in Tables (2 & 3) clearly demonstrated that, application of both biofertilizers used or either of them plus half dose of NPK-recommended rate, positively affected growth characters of roselle plants when compared with those fertilized with full dose of NPK-recommended rate solitary and received the same frequency of irrigation in both seasons. The highest values in plant height and number of branches, were obtained from adding both biofertilizers, plus half dose of NPK-recommended rate. While, the lowest values were recorded with adding full dose NPK-recommended rate solitary in both seasons. No significant differences were observed in number of branches between adding both biofertilizers or either of them in both seasons. These results are in accordance with those of Gupta *et al.* (1999) on marigold, and Ibrahim (2000) on fennel plants.

The beneficial effects of biofertilizers on vegetative growth, may be attributed to the increment in bacterial population and its activity into the absorption zone of plant roots. These bacteria increase the availability and uptake of N,P and K which positively reflect on plant cell division and elongation as well as stimulate photosynthesis and metabolic processes of organic compounds in plants (Gomez and Munoz, 1998). Moreover, Neol *et al.* (1996) and Wang (1998) indicated that, non-symbiotic N_2-fixing bacteria (present in biogen) can play an important role in improving soil fertility and plant growth development via N_2-fixation and releasing certain nutrient elements, i.e., Fe, Zn and Mn. In addition, these bacteria produced adequate amounts of gibberellins, auxins and cytokinins-like substances, which could increase the surface area per unit root length and enhance root hair branching with an eventual increase in the uptake of nutrients from soil.

Carletti *et al.* (1996), demonstrated that, plants inoculated with N_2-fixing bacteria, displayed an increase in total root length by 15% compared with the un-inoculated (control).

Phosphate solubilizing bacteria present in phosphorin posses the ability to bring out insoluble phosphorus in cultivated soils into soluble forms by secreting organic acids, such as formic, fumaric, acetic and succinic. These acids lower the soil pH and bring out the dissolution of bound forms of phosphate compounds and render them available for growing plants. Beside that, the reduction of soil pH increases the availability of some micronutrients, such as Fe, Zn, Mn and Cu which would reflect on plant growth (Abd El-Fattah, 1998). Conversion the insoluble phosphate compounds into soluble forms can also be achieved through the inorganic acids (nitric and sulphoric) which result from oxidation of ammonia and sulphur by autotrophic bacteria, i.e. *Azotobacter* and *Azospirillum* or mineralyzation the organic phosphate compounds (Alexander, 1982). This may explain the obtained results which indicated that, application of N and P biofertilizers, was generally more useful than either alone (Mandhare *et al.*, 1998).

3.1.3. Effect of irrigation intervals and different fertilization sources

It is evident from data in Tables (2 & 3) that, plants irrigated every 1 week and fertilized with half dose of NPK-recommended rate plus both biofertilizers used, gave the highest values in plant height and number of branches. While the lowest values were obtained from the treatment irrigated every 3 weeks and fed on 100% NPK-recommended rate solitary comparing with any other treatment in both seasons. Data also revealed that, both criteria of plants fertilized with 100% NPK-recommended rate only, were more negatively affected by prolonging irrigation intervals than those fertilized with 50% NPK-recommended rate plus both biofertilizers or either of them in both seasons. Similar results were reported by Barrett and Ash (1992) on eucalyptus, and Wendler and Millard (1996) on *Betula pendula*. The less negative effect of prolonging irrigation intervals on the growth of plants fertilized with mineral fertilizers in the presence of both biofertilizers or either of them, versus those fertilized with mineral fertilizers only, may be due to the biofertilizers capability of enhancing water stress tolerance in many plants, as well as increasing soil water holding capacity and availability (Maheshwari *et al.*, 1998), as well as soil aggregation. This in turn enhances bacterial population and its microbial and biological activities into the absorption zone of plant and increases the availability and uptake of macro and micro nutrients which positively reflected on plant growth (Mandhare *et al.*, 1998)

3.2. Yield and its components

3.2.1. Effect of irrigation intervals

It is evident from data in Tables (2,3,4 & 5) and Figs. (1 & 2) that, decreasing irrigation intervals from 3 weeks to 2 or from 2 to one week, increased all values of yield and its components namely, number of fruits/plant, fresh weights of fruits and sepals/plant, yield of dry sepals (g/plant or kg/fed.) as well as seed yield (g/plant or ton/fed.) of roselle plants received the same fertilization sources. Whereas, the varied differences observed with decreasing irrigation intervals were enough to reach the level of significancy in both seasons, except for yield of dry sepals (g/plant) in both seasons and seed yield (g/plant) in the 1st one. Obtained results agreed with those reported by Naguib and Hussein (1995) on roselle and Ashoub *et al.* (2000) on sunflower.

The observed decreases in yield and its components of roselle plants with prolonging irrigation intervals, may be due to salt accumulation close to the soil surface. This process might inhibit water and nutrient uptake, which affect plant growth and yield (Hason, 1995).

3.2.2. Effect of different fertilization sources

Data presented in Tables (2,3,4 & 5) and Figs. (1 & 2) clearly indicate that, all yield and its components characteristics of roselle plants received the same frequency of irrigation, were positively affected by applying nalf dose of NPK-recommended rate plus both biofertilizers or either of them, when compared with applying full dose of NPK-recommended rate solitary in both seasons. Moreover, mixture of both biofertilizers was more efficient in increasing rossele yield and its components than single application in both seasons. No significant differences were observed in number of fruits/plant in both seasons, yield of dry sepals (g/plant) in the 1st season, as well as seed yield (g/plant) in the 2nd one, when applying biogen or phosphorin were compared. Similar results were reported by Soliman (1997) on *Nigella sativa* and Gomaa and Abo-Aly (2001) on anise plants. Gomez and Munoz (1998), reported that, mixture of N and P biofertilizers was more efficient in increasing onion yield than single application.

The enhancing effect of biofertilizers on roselle yield and its components could be attributed to various mechanisms, such as: increasing availability of macro and micronutrients, augmentation of critical enzyme activities, or production of plant growth promoting substances (Maheshwari *et al.*, 1998). Therefore, biofertilizers can affect bedding plant growth by modifying the physicochemical and microbiological characteristics of plant growth medium beneficially, which reflected on vegetative growth, yield and yield components of roselle plant.

3.2.3. Effect of irrigation intervals and different fertilization sources

Data presented in Tables (2,3,4, & 5) and Figs. (1 & 2) show that, the treatment irrigated every 1 week and fertilized with half dose of NPK-recommended rate plus both biofertilizers (biogen and phosphorin) produced the maximum values in all characters of yield and its components. While, the minimum values were obtained from the treatment irrigated every 3 weeks and fertilized with full dose of NPK-recommended rate solitary when comparing with any other treatment in both seasons. The percentage increases in yield of dry sepals (kg/fed.) and seed yield (ton/fed.) of roselle plants irrigated every 1 week and fertilized with half dose of NPK-recommended rate plus both biofertilizers used over those irrigated every 3 weeks and fertilized with full dose of NPK-recommended rate solitary, amounted to 62.93 & 82.27% in the 1st season and 36.66 & 78.86% in the 2nd one, respectively.

Table (2): Effect of different irrigation intervals and fertilization sources on the growth, yield and yield components of roselle (*Hibiscus sabdariffa*, L.) plant during the first season (1999).

Irrigation intervals	Fertilization sources	Plant height (cm)	No. of branches /plant	No. of fruits /plant	Fruits fresh weight (g/plant)	Sepals fresh weight (g/plant)	Yield of dry sepals (g/plant)	Yield of dry sepals (kg/fed.)
1 week	100% (NPK)	178.30f	12.00b-e	43.00c	231.50h	99.93g	12.57c-e	251.40g
	50% (NPK) + biogen	194.35c	13.75ab	46.67b	261.36e	108.92d	13.63b-d	272.60e
	50% (NPK) + phosphorin	189.88d	13.39a-c	47.27b	269.70c	111.72c	14.28a-c	285.60c
	50% (NPK) + biogen + phosphorin	210.20a	14.30a	51.62a	292.28a	123.91a	15.74a	314.80a
2 weeks	100% (NPK)	168.49h	10.87ef	34.32e	210.38j	88.85l	11.64e	232.80l
	50% (NPK) + biogen	188.71d	12.93a-d	40.04d	241.76g	100.42g	13.08c-e	261.60f
	50% (NPK) + phosphorin	183.80e	12.55a-e	41.12d	250.82f	103.45f	13.67b-d	273.40e
	50% (NPK) + biogen + phosphorin	207.47b	13.69ab	45.84b	276.50b	115.86b	15.27ab	305.40b
3 weeks	100% (NPK)	143.84j	9.37f	26.6f	189.07k	69.88j	9.66f	193.20j
	50% (NPK) + biogen	171.16g	11.51c-e	33.36e	222.90l	88.06i	11.71e	234.20l
	50% (NPK) + phosphorin	165.79l	11.11d-f	34.75e	231.17h	91.14h	12.29de	245.80h
	50% (NPK) + biogen + phosphorin	180.02f	12.53a-e	40.20d	264.89d	105.20e	13.97a-d	279.40d

Values within each column followed by the same letter are not statistically different at 5% level.

Table (3): Effect of different irrigation intervals and fertilization sources on the growth, yield and yield components of roselle (*Hibiscus sabdariffa*, L.) plant during the second season (2000).

Irrigation intervals	Fertilization sources	Plant height (cm)	No. of branches /plant	No. of fruits /plant	Fruits fresh weight (g/plant)	Sepals fresh weight (g/plant)	Yield of dry sepals (g/plant)	Yield of dry sepals (kg/fed.)
1 week	100% (NPK)	180.00g	12.30bc	46.01d	246.66h	103.13d	13.09ef	261.80h
	50% (NPK) + biogen	194.40c	13.71ab	50.15bc	271.33e	113.44c	14.10d	282.00f
	50% (NPK) + phosphorin	190.80d	13.53ab	50.70b	282.43c	115.51c	14.88bc	297.60d
	50% (NPK) + biogen + phosphorin	209.70a	14.39a	55.77a	308.33a	128.91a	15.84a	316.80a
2 weeks	100% (NPK)	168.87l	11.25c	35.75g	227.04j	90.75f	12.33g	246.60j
	50% (NPK) + biogen	186.20e	12.54bc	42.67ef	256.14g	95.50e	13.19ef	263.80h
	50% (NPK) + phosphorin	182.40fg	12.27bc	43.60e	268.00f	106.27d	14.28cd	285.60e
	50% (NPK) + biogen + phosphorin	199.20b	13.29ab	47.97cd	299.08b	120.79b	15.43ab	308.60b
3 weeks	100% (NPK)	144.30k	8.90d	26.96h	185.86k	81.41h	11.59h	231.80k
	50% (NPK) + biogen	176.80h	11.08c	34.56g	228.22j	87.86g	12 94fg	258.80l
	50% (NPK) + phosphorin	163.07j	10.94c	35.75g	240.66l	98.20e	13.68de	273.60g
	50% (NPK) + biogen + phosphorin	183.50ef	12.36bc	40.84f	274.85d	114.75c	15.08b.	301.60c

Values within each column followed by the same letter are not statistically different at 5% level.

Table (4): Effect of different irrigation intervals and fertilization sources on seed and fixed oil yield of roselle (*Hibiscus sabdariffa*, L.) plant during the first season (1999).

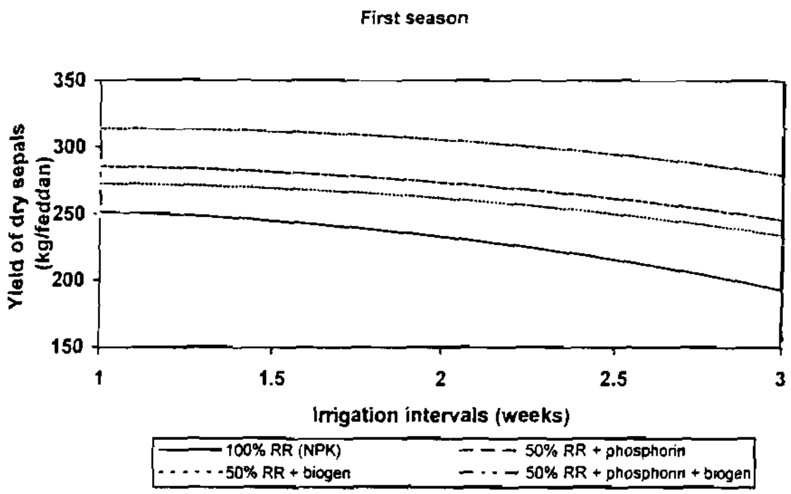
Irrigation intervals	Fertilization sources	Seed yield (g/plant)	Seed yield (ton/fed.)	Fixed oil% in dry seeds	Fixd oil yield (g/plant)	Fixed oil yield (kg/fed.)
1 week	100% (NPK)	45.97e	0.919e	15.30f	7.03h	140.60k
	50% (NPK) + biogen	51.03b-d	1.021c	17.60de	8.98e	179.60g
	50% (NPK) + phosphorin	52.48b	1.050b	18.45c-e	9.69cd	193.80e
	50% (NPK) + biogen + phosphorin	57.59a	1.152a	19.98a-c	11.51a	230.20b
2 weeks	100% (NPK)	44.10f	0.882f	16.77ef	7.39gh	147.80j
	50% (NPK) + biogen	49.98cd	1.00d	18.66cd	9.33de	186.60f
	50% (NPK) + phosphorin	51.53bc	1.031c	19.54a-c	10.07bc	201.40d
	50% (NPK) + biogen + phosphorin	57.05a	1.141a	20.92ab	11.94a	238.80a
3 weeks	100% (NPK)	31.62h	0.632l	17.52de	5.54l	110.80 l
	50% (NPK) + biogen	40.03g	0.801h	19.13b-d	7.66g	153.20l
	50% (NPK) + phosphorin	41.53g	0.831g	20.00a-c	8.31f	166.20h
	50% (NPK) + biogen + phosphorin	49.52d	0.990d	21.17a	10.48b	209.60c

Values within each column followed by the same letter are not statistically different at 5% level.

Table (5): Effect of different irrigation intervals and fertilization sources on seed and fixed oil yield of roselle (*Hibiscus sabdariffa*, L.) plant during the second season (2000).

Irrigation intervals	Fertilization sources	Seed yield (g/plant)	Seed yield (ton/fed.)	Fixed oil % in dry seeds	Fixd oil yield (g/plant)	Fixed oil yield (kg/fed.)
1 week	100% (NPK)	51.34f	1.027g	15.27h	7.84g	156.80g
	50% (NPK) + biogen	55.96d	1.119d	16.00gh	8.95de	179.00e
	50% (NPK) + phosphorin	57.75c	1.155c	17.04fg	9.84c	196.80d
	50% (NPK) + biogen + phosphorin	63.05a	1.261a	18.83de	11.87a	237.40b
2 weeks	100% (NPK)	45.18gh	0.904l	17.94ef	8.10fg	162.00f
	50% (NPK) + biogen	51.15f	1.023g	19.14c-e	9.79c	195.60d
	50% (NPK) + phosphorin	53.07e	1.061f	20.00b-d	10.62b	212.40c
	50% (NPK) + biogen + phosphorin	59.83b	1.197b	20.30bc	12.15a	243.00a
3 weeks	100% (NPK)	35.24i	0.705k	18.27ef	6.43h	128.60h
	50% (NPK) + biogen	44.09h	0.882j	20.00b-d	8.81ef	176.20e
	50% (NPK) + phosphorin	46.06g	0.921h	20.98ab	9.66cd	193.20d
	50% (NPK) + biogen + phosphorin	54.32e	1.086e	21.70a	11.78a	235.60b

Values within each column followed by the same letter are not statistically different at 5% level.



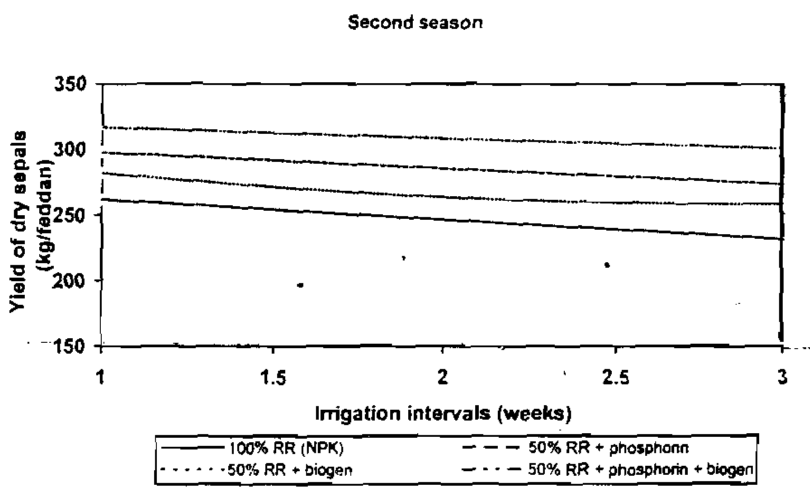
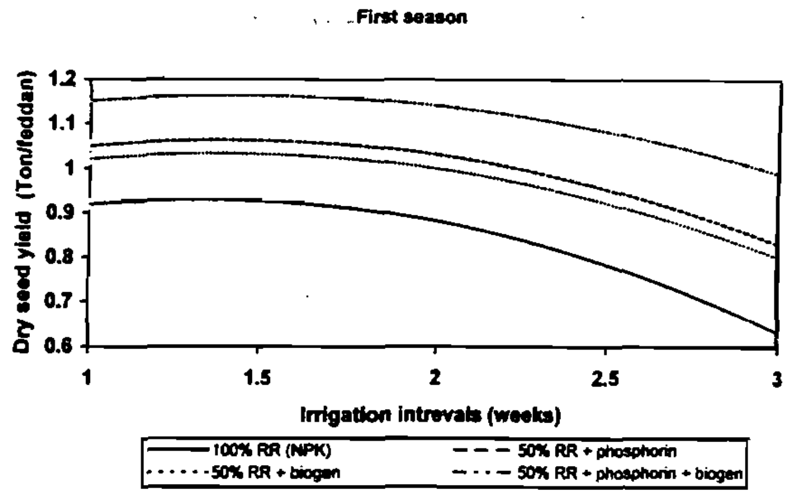


Fig. (1): Effect of different irrigation intervals and fertilization sources on the yield of dry sepals (kg/fed.) of roselle plant during the two seasons of 1999 and 2000.



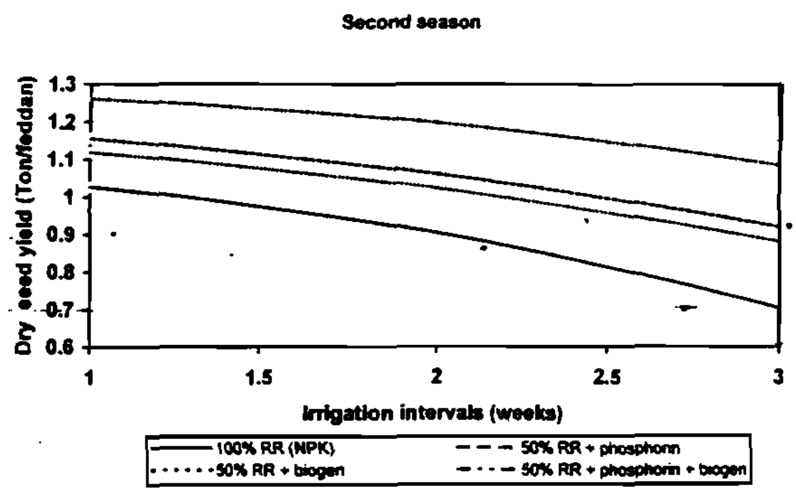


Fig. (2): Effect of different irrigation intervals and fertilization sources on dry seed yield (ton/fed.) of roselle plant during the two seasons of 1999 and 2000.

3.3. Chemical constituents

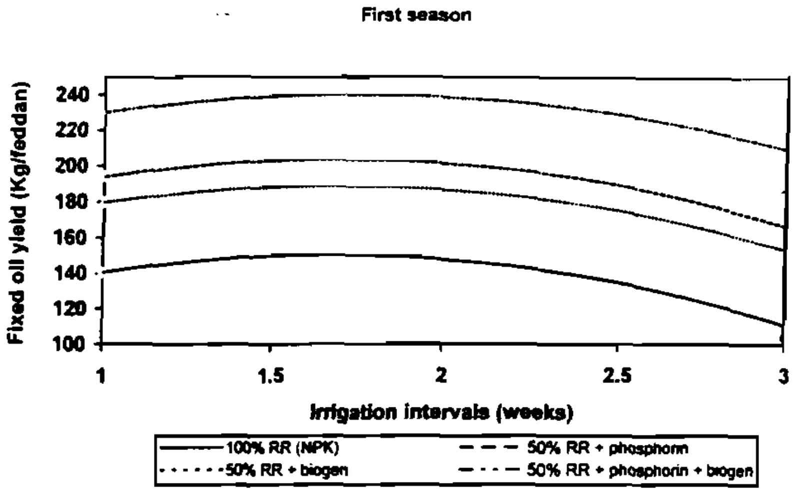
3.3.1. Effect of irrigation intervals

In response to different irrigation intervals, chemical constituents of roselle plants received the same fertilization sources showed three types of response. Data in Tables (6 & 7) clearly demonstrated that, the studied chemical constituents namely total anthocyanin (mg/g dry sepals) pH value, as well as N,P and K contents were considerably varied in response to different irrigation intervals. All previous criteria were gradually increased with decreasing irrigation intervals in both seasons. The varied differences observed with prolonging irrigation intervals, were enough to reach the level of significancy, specially N, P and K contents in both seasons, as well as anthocyanin content in the 2nd one. The decrease in pH values obtained from plants irrigated every 3 weeks may be due to the effect of low soil moisture in increasing organic acids in the cell sap, as they are the products of respiratory catabolic processes (Mahfouz, 1997). On the other hand soil water deficiency negatively affected N, P and K availability and uptake which in turn reduced N, P, K and anthocyanin contents in plants. The second type of response was restricted to total soluble solids (T.S.S) and fixed oil percentages (Tables 4,5,6 & 7) which showed an opposite trend as affected by different irrigation intervals. Both criteria were gradually increased with increasing irrigation intervals in both seasons and reached to the significant levels only in the 2nd season. The increases in T.S.S% associated with prolonging irrigation intervals, may be due to the decrease in plant cell water content which caused a remarkable increase in cell sap concentration. It is well known that, plants grown under environmental stress as water deficiency, tended to produce more secondary products (fixed oil%). The third type of response was restricted to fixed oil yield (g/plant or kg/fed.) which showed different response as affected by different irrigation intervals (Tables 4 & 5) and Fig. (3). The highest values in both criteria were obtained from plants irrigated every 2 weeks and followed by those irrigated every 1 and 3 weeks, respectively in both seasons. The varied differences observed with increasing or decreasing irrigation intervals were enough to reach the level of significancy in fixed oil yield (kg/fed.) in both seasons.

Obtained results are in harmony with those reported by Naguib and Hussein (1995) and Mahfouz (1997) on roselle plant.

3.3.2. Effect of different fertilization sources

Data presented in Tables (4,5,6 & 7) and Fig. (3) clearly demonstrate that, at the same frequency of irrigation, application of 50% NPK-recommended rate plus both biofertilizers, used or either of them, proved to be significantly very effective in enhancing chemical constituents namely, total anthocyanin content, T.S.S%, N, P and K contents, fixed oil percentage, as well as fixed oil yield (g/plant or kg/fed.) when compared with applying 100% NPK-recommended rate only in both seasons. Data also show that, application of both biofertilizers proved to be superior in improving such chemical traits than applying either of them alone in both seasons. On the other hand, phosphorin was more insignificantly effective in increasing all previous criteria than biogen except for anthocyanin and nitrogen contents which the opposite were true in both seasons.



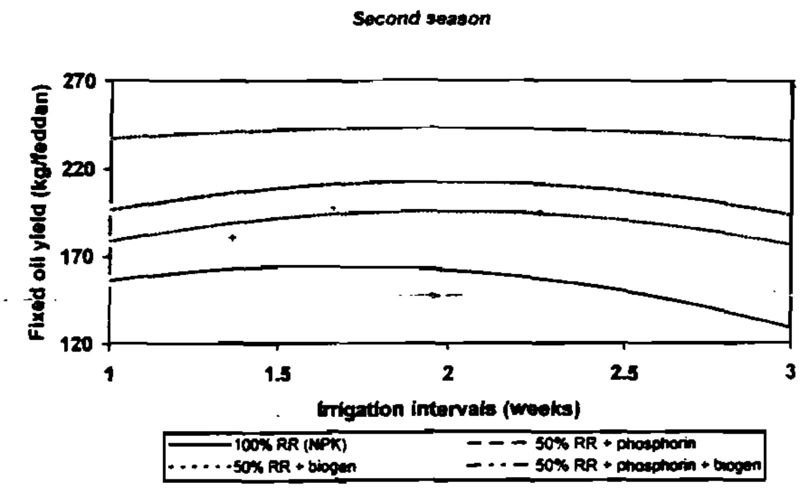


Fig. (3): Effect of different irrigation intervals and fertilization sources fixed oil yield (kg/fed.) of roselle plant during the two seasons of 1999 and 2000.

Regarding the effect of different fertilization sources on pH value, data in Tables (6 & 7) showed that, pH values were significantly higher with adding 100% NPK-recommended rate solitary than in combination with both biofertilizers used or either of them in both seasons. In most cases, no significant differences were observed between adding both biofertilizers or either of them on reducing pH values in both seasons. The more beneficial effects of mineral fertilizers in the presence of biofertilizers than mineral fertilizers alone on the chemical constituents of rosell plants through some mechanisms previously mention, leading to: reducing soil pH value, increasing macro and micronutrient, production of promoting substances and organic acids, could explain the present results.

Previous results were in agreement with those obtained by Ibrahim (2000) on fennel and El-Zeiny *et al.* (2001) on tomato.

3.3.3. Effect of irrigation intervals and different fertilization sources

Data in Tables (6 & 7) demonstrated that, the most significant increases in anthocyanin, N,P and K contents were obtained from the treatment irrigated every 1 week and fertilized with 50% NPK-recommended rate plus both biofertilizers used. While the minimum values were obtained from the treatment irrigated every 3 weeks and fertilized with 100% NPK-recommended rate solitary comparing with any other treatment in both seasons. As for T.S.S and fixed oil percentages, data in Tables (4,5,6 & 7) showed that, the highest values were significantly produced from the treatment irrigated every 3 weeks and fertilized with 50% NPK-recommended rate plus both biofertilizers used. While the minimum values were obtained from the treatment irrigated every 1 week and fertilized with 100% NPK-recommended rate solitary in both seasons. Moreover, the treatment irrigated every 1 week and fertilized with 100% NPK-recommended rate only, produced the highest pH values. While the minimum values were obtained from the treatment irrigated every 3 weeks and fertilized with both biofertilizers used plus 50% NPK-recommended rate when compared with any other treatment in both seasons (Tables 6 &7).

At last, different trend was observed with respect to fixed oil yield (g/plant or kg/fed.). Data in Tables (4 & 5) and Fig. (3), showed that, the maximum values were obtained from the treatment irrigated every 2 weeks and fertilized with half dose of NPK-recommended rate plus both biofertilizers. While the treatment irrigated every 3 weeks and fertilized with full dose of NPK-recommended rate solitary produced the minimum values comparing with any other treatment in both seasons.

The percentage increases in fixed oil yield (kg/fed.) of roselle plants irrigated every 2 weeks and fertilized with 50% NPK-recommended rate plus both biofertilizers (the best treatment) over the plants irrigated every 3 weeks and fertilized with 100% NPK-recommended rate solitary amounted to 115.58 & 88.95% in the 1st and 2nd seasons, respectively. Similar results were reported by Barrett and Ash (1992) on eucalyptus, and Wendler and Millard (1996) on *Batula pendula*.

Table (6): Effect of different irrigation intervals and fertilization sources on sepal and seed chemical constituents of roselle (*Hibiscus sabdariffa*, L.) plant during the first season (1999).

Irrigation intervals	Fertilization sources	Total anthocyanin (mg/g) dry sepals	T.S.S. %	pH value	N %	P %	K %
1 week	100% (NPK)	5.8de	25.13d	3.16a	2.05g	0.55de	2.27g
	50% (NPK) + biogen	6.54bc	29.05c	2.99bc	2.47ab	0.59bc	2.53d
	50% (NPK) + phosphorin	6.09cd	29.55c	3.01b	2.36d	0.62ab	2.61c
	50% (NPK) + biogen + phosphorin	7.19a	30.68c	2.98bc	2.56a	0.65a	2.74a
2 weeks	100% (NPK)	5.37fg	30.48c	3.16a	1.89h	0.45h	2.09l
	50% (NPK) + biogen	6.15cd	33.38ab	2.98bc	2.37cd	0.52ef	2.38f
	50% (NPK) + phosphorin	5.70d-f	33.42ab	3.01b	2.25ef	0.55de	2.47e
	50% (NPK) + biogen + phosphorin	6.91ab	33.53ab	2.97bc	2.46bc	0.59bc	2.65b
3 weeks	100% (NPK)	4.48h	32.37b	3.15a	1.65l	0.40l	1.84j
	50% (NPK) + biogen	5.54e-g	34.50a	2.95cd	2.20f	0.48gh	2.18h
	50% (NPK) + phosphorin	5.10g	34.76a	2.98bc	2.08g	0.51fg	2.28g
	50% (NPK) + biogen + phosphorin	6.42c	34.88a	2.92d	2.33de	0.56cd	2.52d

Values within each column followed by the same letter are not statistically different at 5% level.

Table (7): Effect of different irrigation intervals and fertilization sources on sepal and seed chemical constituents of roselle (*Hibiscus sabdariffa*, L.) plant during the second season (2000).

Irrigation intervals	Fertilization sources	Total anthocyanin (mg/g) dry sepals	T.S.S. %	pH value	N %	P %	K %
1 week	100% (NPK)	6.69cd	26.02e	3.13a	2.31h	0.63c	2.33f
	50% (NPK) + biogen	7.55b	30.57d	3.03b-d	2.72bc	0.68b	2.60d
	50% (NPK) + phosphorin	6.97c	30.96d	3.07a-c	2.61de	0.70ab	2.76c
	50% (NPK) + biogen + phosphorin	8.26a	34.24c	3.01c-e	2.81a	0.73a	2.96a
2 weeks	100% (NPK)	5.85f	31.48d	3.09ab	2.15l	0.52f	2.16h
	50% (NPK) + biogen	6.95c	35.06c	2.98d-f	2.63d	0.61cd	2.46e
	50% (NPK) + phosphorin	6.38de	35.29c	3.01c-e	2.50f	0.63c	2.62d
	50% (NPK) + biogen + phosphorin	7.83b	37.42b	2.94ef	2.75b	0.68b	2.87b
3 weeks	100% (NPK)	4.70h	34.84c	3.04b-d	2.06j	0.45g	1.90 i
	50% (NPK) + biogen	6.05ef	37.33b	2.91f	2.57e	0.55ef	2.26g
	50% (NPK) + phosphorin	5.51g	37.44b	2.93f	2.43g	0.58de	2.42e
	50% (NPK) + biogen + phosphorin	7.11c	38.92a	2.80g	2.70c	0.64c	2.72c

Values within each column followed by the same letter are not statistically different at 5% level.

Previous results indicated that, longer irrigation intervals had less negative effect on chemical constituents on roselle, when plants were fertilized with the combinations of mineral NPK fertilizers and both biofertilizers or either of them than when they were fertilized with mineral NPK only.

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تأثير فترات الرى والتسميد الحيوى والمعدنى على إنتاجية نبات الكركديه

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أجريت هذه الدراسة الحقلية بمزرعة كلية الزراعة – جامعة عين شمس – شبرا الخيمة – القاهرة خلال عامى ١٩٩٩ ، ٢٠٠٠ لدراسة تأثير فترات الرى ومصادر التسميد المختلفة على نمو ومحصول والمركبات الكيميائية لنبات الكركديه . شملت التجربة ١٢ معاملة تكونت من ٣ فترات رى كل أسبوع ، أسبوعين و ٣ أسابيع ، ٤ مخاليط من الأسمدة الكيماوية والحيوية والتى كانت كالآتى :-

١ – الجرعة الموصى بها من التسميد الكيماوى وهى : ١٥٠ كجم/فدان من سلفات الأمونيوم (٢٠,٥%) + ٢٠٠ كجم/فدان من سوبر فوسفات الكالسيوم (١٥,٥%) + ١٥٠ كجم/ فدان من سلفات البوتاسيوم (٤٨%) .

٢ – ٥٠% من جرعة السماد الكيماوى الموصى به + ٤ كجم/فدان بيوجين .

٣ – ٥٠% من جرعة السماد الكيماوى الموصى به + ٤ كجم/فدان فوسفورين .

٤ – ٥٠% من جرعة السماد الكيماوى الموصى به + ٤ كجم/فدان بيوجين + ٤ كجم/ فدان فوسفورين .

– أظهرت النتائج أن المعاملة التى تم ريها كل أسبوع وسمدت بنصف الجرعة الموصى بها من السماد الكيماوى مضافاً إليه كل من البيوجين والفوسفورين أفضل النتائج بالنسبة لطول النبات وعدد الأفرع والثمار/نبات ، الوزن الطازج للثمار والسبلات/نبات ، المحصول الجاف للسبلات والبذور لكل من النبات والفدان بالإضافة إلى محتوى الانثوسيانين وكل من النيتروجين ، الفوسفور والبوتاسيوم فى السبلات وذلك خلال عامى التجربة .

– أقل القراءات الخاصة بالـ pH والتى أعطت أعلى حموضة وكذلك أفضل نتائج فى النسبة المئوية للمواد الصلبة الكلية (T.S.S) والزيت الثابت للبذور أمكن الحصول عليها من المعاملة التى رويت كل ٣ أسابيع وتم تسميدها بنصف الجرعة الموصى بها من السماد الكيماوى مضافاً إليه كل من البيوجين والفوسفورين خلال عامى التجربة . فى حين أن المعاملة التى رويت كل أسبوعين وسمدت بنصف الجرعة الموصى بها من السماد الكيماوى مضافاً اليه البيوجين والفوسفورين سببت أفضل النتائج الخاصة بمحصول الزيت الثابت للبذور لكل من النبات والفدان خلال عامى التجربة .