INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
12–1060/2013/15–4–737–742
http://www.fspublishers.org

Full Length Article

Optimizing the Nitrogen, Phosphorus and Potash Fertigation Rates and Frequency for Eggplant in Arid Regions

Mostafa Nabawy Feleafel[1,2]* and Zohair Mahmoud Mirdad[1]
[1]*Department of Arid Land Agriculture, Faculty of Meteorology, Environment and Arid Land Agriculture, King Abdulaziz University, Jeddah, Saudi Arabia*
[2]*Department of Vegetable Crops, Faculty of Agriculture, Alexandria University, Alexandria, Egypt*
*For correspondence: most363@gmail.com

Abstract

This study was conducted at the Agricultural Experiment Station, Hada-Alsham, King Abdulaziz University, during the winter season of 2011/2012, to evaluate the impact of the NPK fertigation rates at various frequencies on the growth, yield, quality and nutrient uptake of eggplant crop, under arid land conditions. The experiment included 12 treatments, which were the combinations of three NPK fertigation rates (60%, 80% and 100% of recommended; 250, 90, 250 kg N, P_2O_5, K_2O ha^{-1}, respectively) and four fertigation frequencies; one dose biweekly (six doses $season^{-1}$), one dose weekly (12 doses $season^{-1}$), two doses weekly (24 doses $season^{-1}$) and three doses weekly (36 doses $season^{-1}$). Vegetative growth, mineral contents of leaves and fruits, fruits yield ha^{-1} and some fruit quality characters of eggplant; length, dimeter and firmness of fruits, were significantly increased with an increase NPK fertigation rate up to 100% of NPK recommended. Whereas, the results demonstrated that split application of NPK fertigation up to three doses weekly, significantly, increased all the aforementioned traits of eggplant plants. The increases of the fruit yield ha^{-1}, and fruits number characters were 278.4% and 146.7% of three doses weekly (36 doses $season^{-1}$), orderly as compared with one dose biweekly (six doses $season^{-1}$). The combination treatment of fertigation NPK at 100% of recommended at three doses weekly is the most efficient combination treatment, which gave the best results for growth and yield characters of eggplant, when were applied from 2nd week to 14th week after transplanting.

Keywords: Eggplant; NPK; Fertigation; Growth; Yield

Introduction

Eggplant (*Solanum melongena* var. esculenta L.) is one of the most important crops grown in the Saudi Arabia. Eggplant fruits contain a considerable amount of carbohydrates, proteins and some minerals (El-Nemr *et al.*, 2012).

Use of drip irrigation in the vegetable production causes a restriction of the root system spread of plants and that concentrated only in the wetness root zone, which requires to frequent supply of irrigation water and fertilizers (fertigation) for the root zone soil (rhizosphere), during critical periods of nutrient demand (Mikkelsen, 1989; Kohzushka and Romanets, 1994; Qasim *et al.*, 2008).

Fertigation has been found as one of the most successful ways of water and nutrient; particularly, N, K and micronutrient, applied through the drip irrigation system. The right combination of water and nutrients in fertigation is the key for high yield and quality of vegetable crops. Through a fertigation can be injected one or more fertilizers in a small amount with irrigation water and applied at various frequencies (daily, every other day, several times each week, or weekly to bi-monthly), depending mainly on crop type, fertigation system design, soil type and on grower preference.

Many investigators studied the effects of the drip fertigation rates and frequency on the growth, yield and quality of the vegetable crops such as (Miller *et al.*, 1976; Abdel-Aziz, 1998). Similarly, Tropea *et al.* (1982) found that a chilli yield was higher with fertigation of 313:214:538 kg N: P: K ha^{-1} in a monthly interval as compared to side dressing in two splits. Pareya (1992) reported that chilli (Anaheim cv.) fruit production was maximized at 240 kg N ha^{-1} applied weekly through drip irrigation. Furthermore, Olsen *et al.* (1993) found that highest fruit yield of pepper was with nitrogen fertigation up to 280 kg ha^{-1} in ten equal doses. Moreover, Singandhupe *et al.* (2003) reported that application of nitrogen at 120 kg N ha^{-1} through the drip irrigation in ten similar splits at 8-days intervals achieved a supreme tomato fruit yield as compared to the furrow irrigation when nitrogen was applied in two equal splits. Shashidhara (2006) stated that chilli responded well to fertigation with 11 to 22 applications in terms of increased growth and yield properties. Vijayakumar *et al.* (2010)

To cite this paper: Feleafel, M.N. and Z.M. Mirdad, 2013. Optimizing the nitrogen, phosphorus and potash fertigation rates and frequency for eggplant in arid regions. *Int. J. Agric. Biol.*, 15: 737–742

found that maximum shoot length and number of branches plant^{-1} as well as higher yields in eggplant (42.33 t ha^{-1} in I crop and 37.90 t ha^{-1} in II crop) were recorded in treatment drip irrigation at 75% of pan evaporation with fertigation of 75% of recommended N and K, when were applied through fertigation with 12 equal splits from 3rd week to 14th week after planting.

In Saudi Arabia, most of the vegetable farmers do not use any soil or water analysis to design their program of fertigation planning. They usually depend on their own experience. Furthermore, fertilization recommendations, based on research conducted regionally or locally, showed their differences between the regions of the country. So it is important to recognize these regional differences when formulating the program of fertigation. Additionally, few studies reported the effect of drip fertigation on growth, crop yields and nutrient uptake patterns.

The present study conducted to explore the impact of the NPK fertigation rates at various frequencies on the growth, yield, quality and nutrient uptake of eggplant, under arid region conditions.

Materials and Methods

This study was conducted at the Agricultural Experiment Station, Hada-Alsham, King Abdulaziz University, Saudi Arabia, during the agriculture season of 2011/2012. Before the initiation of the trial, some important physical and chemical properties of the experimental site soil (0–30 cm) were estimated according to the published procedures by (AOAC, 1995). The soil texture is sandy (91.1% sand, 6.2% silt and 2.7% clay) with pH= 8.2, EC=3.21 dS m^{-1} and O.M = 0.03%. Available soil N, P and K were 17, 7 and 12 mg/kg, respectively.

The irrigation water was obtained from a local well, with an EC of 2.73 dS m^{-1} and contained: Na=0.37, Mg=0.26, Ca=5.86, HCO_3=0.58, Cl=1.85 and SO_4=5.87 meq L^{-1}. The actual evapotranspiration of eggplant crop (ETc), under Hada-Alsham region conditions, was calculated and adjusted at the beginning of each growth stage (Table 1) by multiplying reference evapotranspiration (ET_0) for different months of the growing season (November, 2011 – May, 2012) by a crop coefficient (K_C), $ET_c = ET_0 \times K_C$, as indicated in Allen *et al.* (1998) and Basahi (2007). The drip irrigation system consisted of laterals GR of 16 mm in diameter with drippers at 0.5 m distance. The drippers had a discharge rate 4 L h^{-1}. Irrigation water was applied through the drip irrigation system, every alternate day, to maintain soil moisture above 50% soil moisture depletion, according to Qassim and Ashcroft (2002), which is the optimum level of eggplant plants.

Seedlings of eggplant (Long purple cv.) were transplanted into the field, in rows 8m length and 100 cm apart with a spacing of 50 cm between plants, on November 25, 2011. The experiment included 12 treatments, which were the combinations of three NPK fertigation rates (60%, 80% and 100% of recommended; 250, 90, 250 kg N, P_2O_5, K_2O ha^{-1}, respectively) and four fertigation frequencies; one dose biweekly (six doses season^{-1}), one dose weekly (12 doses season^{-1}), two doses weekly (24 doses season^{-1}) and three doses weekly (36 doses season^{-1}). The schedule of the percentage of NPK fertigation and fertigation frequency during the varied growth stages of eggplant plants are shown in (Table 2). The experimental design used was the split-plot system in a randomized complete blocks design with three replications. The NPK fertigation rates were, randomly, arranged in the main plots, while its fertigation frequencies were, randomly, distributed in the sub-plots. Each sub-plot contained two rows having an area of 16 m^2.

Table 1: Length of the growth stages of eggplant plants, crop coefficients (Kc), reference evapotranspiration (ET_0) and water requirements of eggplant crop (ETc), under Hada-Alsham region conditions, Saudi Arabia

Growth stages	Initiation	Development	Mid season	Late season
Days No. stage-1	30	40	40	20
Crop Coefficients (K_c)	0.41	0.92	1.21	0.95
Reference evapotranspiration (ET0) mm day-1(Basahi, 2007).	5.5	6.96	7.9	7.9
Water requirements of eggplant crop (ET_c) mm day-1	2.3	6.7	9.6	7.5

The fertilizers used in the experiment were NPK (20-20-20), urea, phosphoric acid (85%), potassium sulphate, which formed the source of water soluble fertilizers in fertigation treatments, were injected directly into the irrigation water using a venture - type injector. All agricultural practices were done as commonly followed in the commercial production of eggplant in the drip irrigation system.

In each experimental unit, the first row was allocated to measuring the vegetative growth characters; plant height, number of branches and leaves, leaf area and dry weight per plant, and mineral content of leaves and fruits. The second row was saved to determine the yield and its components, and fruit quality characters.

All obtained data of the present study were, statistically, analyzed according to the design used by the MSTATC computer software program (Bricker, 1991). The comparisons among means of the different treatments were carried out by using the revised L.S.D. test.

Results

Vegetative Growth

Application of NPK, in successive amounts, to the growing eggplant plants, resulted in corresponding and significant increases in all tested vegetative growth characters i.e., plant height, number of branches and leaves, leaf area and dry weight per plant (Table 3).

As regards the effect of fertigation frequencies on

Table2: Schedule of the percentage of NPK fertigation and fertigation frequency during the varied growth stages of eggplant plants

Treatments		Total Doses No.	% and time of NPK addition				Total
			Vegetative growth stage		Flowering and fruiting stages		
% NPK of recommended*	Fertigation frequency		2 WAT**	4WAT	6WAT	12WAT	
60	1 dose biweekly	6	9	13	21.7×3	13	100
	1 dose weekly	12	4.5×2	6.5×2	10.8×6	6.5×2	100
	2 doses weekly	24	2.25×4	3.25×4	5.4×12	3.25×4	100
	3 doses weekly	36	1.5×6	2.2×6	3.6×18	2.2×6	100
80	1 dose biweekly	6	9	13	21.7×3	13	100
	1 dose weekly	12	4.5×2	6.5×2	10.8×6	6.5×2	100
	2 doses weekly	24	2.25×4	3.25×4	5.4×12	3.25×4	100
	3 doses weekly	36	1.5×6	2.2×6	3.6×18	2.2×6	100
100	1 dose biweekly	6	9	13	21.7×3	13	100
	1 dose weekly	12	4.5×2	6.5×2	10.8×6	6.5×2	100
	2 doses weekly	24	2.25×4	3.25×4	5.4×12	3.25×4	100
	3 doses weekly	36	1.5×6	2.2×6	3.6×18	2.2×6	100

*NPK of recommended =250-90-250 Kg ha^{-1}; **WAT= Weeks after transplanting

Table 3: Effect of NPK fertilizers rates and fertigation frequency on the vegetative growth characters of eggplant plants

% NPK of recommended*	Fertigation frequency	Plant Height (cm)	No. Branches per plant	No. Leaves per plant	Leaf Area per plant (m^2)	Dry Weight per plant (g)
60		59.0C**	5.7C	96.3C	0.53C	50.6C
80		68.7B	7.0B	111.4B	0.64B	63.6B
100		77.2A	8.0A	118.4A	0.83A	67.6A
	1 dose biweekly	58.6D	5.9D	97.9D	0.54D	54.0D
	1 dose weekly	65.6C	6.5C	107.8C	0.63C	57.3B
	2 doses weekly	74.8A	7.4A	112.6B	0.70B	55.4C
	3 doses weekly	74.2A	7.8A	116.3A	0.80A	68.1A
60	1 dose biweekly	52.2h	4.9f	84.0h	0.41i	44.7j
	1 dose weekly	56.6g	5.3ef	94.7g	0.48h	46.7i
	2 doses weekly	62.2e	6.2d	98.8f	0.54g	50.7h
	3 doses weekly	64.9d	6.2d	107.6d	0.69de	60.1f
80	1 dose biweekly	59.6f	5.6e	101.3f	0.54g	53.3g
	1 dose weekly	65.6d	6.6d	110.5d	0.61f	65.6de
	2 doses weekly	74.9c	7.5c	116.5b	0.65e	67.5cd
	3 doses weekly	74.9c	8.3b	117.2b	0.74d	68.0c
100	1 dose biweekly	63.9e	7.1c	108.3d	0.68e	64.0e
	1 dose weekly	74.6c	7.5c	118.3b	0.81b	59.6f
	2 doses weekly	87.2a	8.5ab	122.6a	0.91a	70.5b
	3 doses weekly	82.9b	8.9a	124.2a	0.96a	76.0a

*NPK of recommended =250-90-250 Kg ha^{-1}; **Values having the same alphabetical letter in common, within a particular group of means in each character, do not significantly differ, using the revised L.S.D test at 0.05 level

vegetative growth characters, the results shown in Table (3) indicated that increasing the number of fertigation doses of NPK up to three doses weekly correspondingly and significantly increased the plant height, number of branches and leaves, leaf area and dry weight per plant.With the exception in the case of plant height and number of branches, the differences between the two and three doses weekly frequencies were not significant.

The interaction effects of NPK fertigation rates and their frequencies on the vegetative growth characters of eggplant were significant (Table 3). Increasing the number of fertigation doses up to three doses weekly within any NPK fertigation rate, generally, increased number of branches and leaves, leaf area and dry weight per plant. The fertigation of 100% of NPK fertilizers at three doses weekly can be considered the best combined treatment as the values of all vegetative growth characters.

Leaf and Fruit Mineral Contents

Concerning the elemental contents in the leaves and fruits of eggplant, data in Table 4 showed that NPK fertigation had a significant effect on N, P and K contents. Increasing the NPK fertigation rate up to 100% of recommended significantly increased the contents of N, P and K in leaves and fruits of eggplant. Data in Table (4) showed that increasing the fertigation frequencies of NPK fertilizers throughout the growing period up to three doses weekly significantly increased the contents of N, P and K in leaves and fruits of eggplant.

The comparisons among the means of the various combined treatments, presented in Table (4), clearly, illustrated some significant interaction effects between fertigation NPK levels and fertigation frequencies. The

Table 4: Effect of NPK rates and fertigation frequency on the percentages of N, P and K contents in the leaves and fruits of eggplant

Treatments		Leaves			Fruit		
% NPK of recommended*	Fertigation frequency	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
60		1.97C**	0.47C	1.36C	2.67C	0.55C	1.56C
80		2.42B	0.68B	1.46B	2.92B	0.78B	1.69B
100		2.53A	0.86A	1.53A	3.07A	0.89A	1.75A
	1 dose biweekly	2.09A	0.65B	1.42B	2.77B	0.75B	1.65B
	1 dose weekly	2.44B	0.67B	1.43B	2.92A	0.74B	1.60C
	2 doses weekly	2.30BC	0.65B	1.48A	2.96A	0.70C	1.71A
	3 doses weekly	2.39A	0.70A	1.47A	2.90A	0.78A	1.71A
60	1 dose biweekly	1.47d	0.39e	1.31e	2.37c	0.54d	1.50d
	1 dose weekly	2.30b	0.50cd	1.31e	2.66bc	0.57d	1.50d
	2 doses weekly	1.80c	0.46de	1.44cd	2.82ab	0.49d	1.59cd
	3 doses weekly	2.30b	0.54c	1.40d	2.86ab	0.64cd	1.63c
80	1 dose biweekly	2.30a	0.68b	1.45bcd	2.86ab	0.79abc	1.68bc
	1 dose weekly	2.43ab	0.68b	1.46bcd	3.02ab	0.74bc	1.62c
	2 doses weekly	2.50a	0.62b	1.46bcd	2.96ab	0.79abc	1.74ab
	3 doses weekly	2.43ab	0.69b	1.46bcd	2.86ab	0.79abc	1.74ab
100	1 dose biweekly	2.50a	0.88a	1.51abc	3.09a	0.91a	1.77ab
	1 dose weekly	2.60a	0.83a	1.52ab	3.09a	0.90ab	1.67bc
	2 doses weekly	2.60a	0.85a	1.55a	3.09a	0.83ab	1.79a
	3 doses weekly	2.43ab	0.87a	1.54a	2.99ab	0.91a	1.77ab

Table 5: Effect of NPK fertilizers rates and fertigation frequency on the yield characters of eggplant plants

% NPK Of recommended*	Fertigation frequency	Yield ha^{-1} (t)	Relative Yield (%)	Fruits No. per plant	Relative Fruits No. (%)	Fruit weight (g)
60		24.5C**	100.0	37.9C	100.0	34.2B
80		29.9B	122.0	44.4B	117.2	35.4B
100		39.3A	161.2	52.0A	137.2	41.5A
	1 dose biweekly	16.7D	100.0	36.8D	100.0	24.9B
	1 dose weekly	20.5C	122.8	41.2C	112.0	27.2B
	2 doses weekly	41.1B	246.1	46.8B	127.2	48.3A
	3 doses weekly	46.5A	278.4	54.0A	146.7	47.4A
60	1 dose biweekly	13.8f	100.0	30.8g	100.0	24.6g
	1 dose weekly	16.2e	117.4	34.0f	110.4	26.2f
	2 doses weekly	30.5b	221.0	39.6e	128.6	42.4d
	3 doses weekly	37.3b	270.3	47.2d	153.2	43.4d
80	1 dose biweekly	14.9e	107.9	36.0f	116.9	22.8i
	1 dose weekly	19.6d	142.0	40.4e	131.2	26.7f
	2 doses weekly	38.0b	275.4	46.0d	130.0	45.4c
	3 doses weekly	46.9b	339.9	55.2b	179.2	46.7c
100	1 dose biweekly	21.5d	155.8	43.2e	140.3	27.3e
	1 dose weekly	25.8c	186.9	49.6c	161.0	28.6e
	2 doses weekly	54.4a	394.2	54.8b	177.9	54.6a
	3 doses weekly	55.3a	400.7	59.6a	193.5	51.0b

*NPK of recommended =250-90-250 kg ha^{-1}; **Values having the same alphabetical letter in common, within a particular group of means in each character, do not significantly differ, using the revised L.S.D test at 0.05 level

fertigation frequencies up to two or three doses weekly with the highest fertigation NPK rate (100% of recommended) seemed to be the best treatment combination as gave the peak values for the contents of N, P and K in the eggplant leaves and fruits.

Fruits Yield and its Components

Data presented in Table 5 showed clearly that, increasing NPK fertigated level, to the growing eggplant plants, up to 100% of recommended led to progressive significant rises in the fruits yield ha^{-1}, fruits number per plantand average fruit weight. Table 5 further shows that increasing the fertigation frequencies of NPK fertilizers up to three doses weekly, significantly, increased the fruits yield ha^{-1}, fruits number per plant and average fruit weight. The exception was in the case of the average fruit weight was similar whether the number of fertigation frequencies was two or three doses weekly. Concerning the interaction effect of NPK fertigation rates and their frequencies on yield characters, were significant (Table 5). At any NPK fertigation rate, increasing doses of fertigation frequencies, generally, increased fruit yield ha^{-1}, fruits number per plant and average fruit weight. Eggplant plants, which received fertigation 100% of recommended NPK added at two or three doses weekly frequencies, gave the highest mean values of all previous characters.

Table 6: Effect of NPK rates and fertigation frequency on the fruit quality of eggplant plants

% NPK of recommended*	Fertigation frequency	Fruit length (cm)	Fruit Diameter (mm)	T.S.S. (%)	Firmness lb. In^{-2}
60		9.4C**	22.8B	3.25A	50.0C
80		10.7B	24.3A	2.53B	53.4B
100		12.1A	24.5A	1.96C	55.8A
	1 dose biweekly	11.0A	20.9C	2.60A	52.6A
	1 dose weekly	10.7A	23.6B	2.51B	53.9A
	2 doses weekly	10.7A	24.8A	2.57A	53.5A
	3 doses weekly	10.5A	25.5A	2.63A	52.2A
60	1 dose biweekly	9.5d	19.9ef	3.40a	47.7i
	1 dose weekly	9.4d	22.6d	3.40a	50.5g
	2 doses weekly	9.3d	23.9c	3.20ab	52.5f
	3 doses weekly	9.2d	24.8b	3.40a	49.3h
80	1 dose biweekly	10.9c	21.1e	2.70bc	53.4e
	1 dose weekly	10.6c	23.7c	2.60cd	55.5c
	2 doses weekly	10.7c	24.9ab	2.40cde	53.6e
	3 doses weekly	10.4c	25.5a	2.40cde	50.9g
100	1 dose biweekly	12.6a	21.7e	1.70f	56.6a
	1 dose weekly	12.2a	24.5b	1.93ef	55.8bc
	2 doses weekly	12.1a	25.5a	2.10def	54.5d
	3 doses weekly	11.7a	26.1a	2.10def	56.3ab

*NPK of recommended =250-90-250 Kg ha^{-1}; **Values having the same alphabetical letter in common, within a particular group of means in each character, do not significantly differ, using the revised L.S.D test at 0.05 level

Fruit Quality

Regarding the effect of the NPK fertigation rates on the fruit's quality of eggplant plants, the results revealed that increasing the fertigation level up to 100% of NPK recommended led to significant increases in the fruit length, diameter and firmness of eggplant fruits, as well as a reduction in the total soluble solids. Data in Table (6) exhibited that split application of NPK fertilizers throughout the drip irrigation did not reflect any significant effect on the length and firmness of eggplant fruits. However, splitting the amount of NPK applied up to two or three doses weekly caused significant increase in diameter and T.S.S. of eggplant fruits.

Results showed that interactions of NPK fertigation rates and fertigation frequencies had significant influences on the diameter and firmness of eggplant fruits, whereas length and T.S.S. characters were not significantly affected (Table 6). The results also showed that application of 100% of NPK at three doses weekly and biweekly during the growing season were the favorite combination treatments for increase diameter and firmness of eggplant fruits, respectively.

Discussion

The results, generally, indicated that NPK fertilizers rates and fertigation frequencies as well as their interactions, appeared to have clear effects on the vegetative growth, leaves and fruit's mineral contents and fruit yield and its quality of eggplant (long purple cv.). The general performances of most of the studied characters reflected almost similar general responses to the effects of each of the studied main factors and their interactions.

In general, the previous results of the vegetative growth, leaves and fruit's mineral contents, fruit yield and some fruit quality characters of eggplant clarified that increased significantly and successively as the NPK fertilizer level was increased. The results, also, showed that fertigation of 100% of NPK recommended had recorded significantly higher eggplant yield ha^{-1} and fruit's number per plant; 161.2 and 137.2%, respectively as compared with 60% of NPK recommended (relative values, Table 6). Higher yield was due primarily to greater mean fruit mass rather than fruit number. Improved fruit weight was associated with the larger vegetative frameworks established and leaf's and fruit's mineral contents of eggplant (Table 3 and 4); this apparently reflected an improved assimilate capacity in plants, which in turn on increasing fruit yield and improving fruit quality. The above results clearly indicated the importance of nutrients like NPK in the determination of the yield potential in eggplant. The current results are in agreement to a great extent with those reported by (Meniutiu, 2006; Balliu *et al.*, 2007; Akanbi *et al.*, 2010). Moreover, Sawan and Razik (1998) found that applying NPK as compound fertilizer to eggplant at an intermediate (90:30:67) or higher rate (120:60:90) improved growth characteristics, yield and quality as compared with applying the low rate (60:0:45).

Regarding the effects of fertigation frequencies of NPK fertilizers on the vegetative growth, and fruit yield characters of eggplant obtained results illustrated that split application of NPK fertilizers up to three doses weekly throughout drip irrigation, significantly, increased all the aforementioned traits of eggplant plants. The increases of the fruit yield ha^{-1}, and fruits number per plant were 278.4% and 146.7% of three doses weekly, orderly, as compared with one dose biweekly (relative values, Table 6). This can be explained on the basis that fertigation saves fertilizer nutrients as it permits applying fertilizer in small quantity at a time matching with the plants nutrient need. This contributes to an improved availability of moisture, nutrients and uniform distribution of fertigated nutrients in the crop root zone throughout the

growth stages leading to better uptake of nutrients and production of eggplant fruits. These results are in line with those reported on the other crops by Cook and Sanders (1991) who found that marketable yield and fruit size of subsurface drip-irrigated tomato were significantly higher with daily compared with biweekly or monthly fertigation on a loamy sand soil. Sousa *et al.* (1999) found an advantage of fertigation at 0.5 and one day intervals compared with five days intervals for surface drip-irrigated melon grown on a sandy soil. Moreover, Shashidhara (2006) stated that chilli responded well to fertigation with 11 to 22 applications in terms of increased growth and yield properties. Badr and Abou El-Yazied (2007) found that the highest total fruit yields averaged (67.75, 65.13 and 63.29 - t/ha) of tomato with the frequencies of 1, 3 and 7 days, respectively.

The interaction between levels of NPK fertilizers and fertigation frequencies showed that, at any NPK fertilizers rate, the successive increases in fertigation frequencies were associated with significant increased vegetative growth, and fruit yield characters of eggplant. The application of NPK at 100% of recommended at three doses weekly during drip fertigation system was the favorite combination treatment, which resulted in the highest significant mean values for most traits of eggplant plants, especially, the fruits yield ha^{-1} and the number of fruits per plant characters, where the percentages of increase (relative values) were 400.4% and 193.5%, respectively compared to the fertigation of 60% NPK of recommended at once biweekly (Table 6). This two-factor interactive indicated that fertigated nutrients remained concentrated near the point of application and thus helped in improved nutrient availability in the root zone and increased vegetative growth and fruit yield characteristics. Similar results were documented by Vijayakumar *et al.* (2010) who found that higher shoot length, number of branches $plant^{-1}$ and yield in eggplant was recorded in treatment drip irrigation at 75% of pan evaporation with fertigation of 75% of recommended N and K, when were applied through fertigation with 12 equal splits.

In conclusion, the combined treatment of fertigation NPK at 100% of recommended at three doses weekly is the most efficient combination treatment, which gave the best results for growth and yield characters of eggplant, when were applied from 2nd week to 14th week after transplanting.

Acknowledgements

This work was funded by the Deanship of Scientific Research (DSR), King Abdulaziz University, Jeddah, under grant No.(81/155/1432). The authors, therefore, acknowledge with thanks (DSR) technical and financial support.

References

AOAC, 1995. *Official Methods of Analysis*, 12th edition, p: 1359. Association of official analytical chemists. Washington, DC, USA

Abdel-Aziz, A.A., 1998. Evaluation of some modern chemigation techniques. *Ph.D. Thesis*, Faculty of Agriculture, Ain Shams University, Egypt

Akanbi, W.B., O.A. Olaniran, F.M. Tairu, J.A. Akinfasoye, M.A. Ojo, A.S. Adeyeye and E.A.O. Ilupeju, 2012. Response of Solanum melongena to NPK fertilizer and age of transplant in the guinea savana zone of ecological area of southwestern Nigeria. *Libyan Agric. Res. Center J. Int.*, 1: 202–210

Allen, R.G., L.S. Pereira, D. Raes and M. Smith, 1998. *Crop Evapotranspiration-Guidelines for Computing Crop Water Requirements-FAO Irrigation and Drainage Paper No. 56*, pp: 104–114. FAO Rome, Italy

Badr, M.A. and A.A.A. Bou El-Yazied, 2007. Effect of fertigation frequency from subsurface drip irrigation on tomato yield grown on sandy soil. *Aust. J. Basic Appl. Sci.*, 1: 279–285

Balliu, A., G. Sallaku, S. Kuci, E. Cota and S. Kaciu, 2007. The effects of major nutrients (NPK) on the growth rate of pepper and eggplant seedlings. *Acta Hortic.*, 729: 341–346

Basahi, J.M., 2007. Estimation of evapotranspiration and crop coefficient of eggplant with lysimeter in Makkah region. *Misr. J. Agri. Eng.*, 24: 378–390

Bricker B., 1991. *MSTATC: A Micro Computer Program from the Design Management and Analysis of Agronomic Research Experiments.* Michigan State University, USA

Cook, W.P. and D.C. Sanders, 1991. Nitrogen application frequency for drip irrigated tomatoes. *HortScience*, 26: 250–252

El-Nemr, M.A., M. EL-Desuki, Z.F. Fawzy and A.M. El-Bassiony, 2012. Yield and fruit quality of eggplant as affected by NPK-sources and micronutrient application. *J. Appl. Sci. Res.*, 8: 1351–1357

Kohzushka, L.F. and V. Romanets, 1994. Ecological and economical efficiency of mineral fertilizer application as a component of irrigation water. *17th ICID European Regional Conference on Irrigation and Drainage*, May 16-22, pp: 209–213

Meniutiu, D., 2006. Research concerning plant directing method and fertilization method on eggplant cultivated in plastic tunnels. *Notulae Botanicae Horticulture Agrobotanici Cluj Napoca*, 34: 69–74

Miller, R.J., D.E. Rolstan, R.S. Rauschkolb and D.W. Walfe, 1976. Drip irrigation of nitrogen is efficient. *Calif. Agric.*, 30: 16–18

Mikkelsen, R.L., 1989. Phosphorus fertilization through drip irrigation. *J. Prod. Agric.*, 2: 279–286

Olsen, J.K., P.J. Lyons and M.M. Kelly, 1993. Nitrogen uptake and utilization by bell pepper in sub-tropical Australia. *J. Plant Nutr.*, 16: 177–193

Pareya, F.J., 1992. Fertigation in Washington state horticultural association. *Proceedings of the 88th annual meeting, Yakima, Washington, WSA*, December 7-9, pp: 289–291

Qasim, M., I. Ahmad and T. Ahmad, 2008. Optimizing fertigation frequency for *Rosa hybrida* L. *Pak. J. Bot.*, 40: 533–545

Qassim, A. and B. Ashcroft, 2002. *Estimating Vegetable Crop Water use with Moisture-Accounting Method # AG1192, DPI Victoria* Available at: http://www.dpi.vic.gov.au/agriculture/horticulture/vegetables/vegetable-growing-and-management/estimating-vegetable-crop-water-use. (Accessed October 2002)

Sawan, O.M. and F.A. Rizk, 1998. The productivity of eggplant (*Solanum melongena* L.) as affected by sulphur element and NPK mixture. *Egypt. J. Hort.*, 25: 1–16

Shashidhara, K.G., 2006. Response of chilli to drip irrigation and fertigation on a vertisol of malaprabha command area. *M.Sc., Thesis*, Collage of Agriculture, University of Agricultural Sciences, Dharwad

Singandhupe, R.B., G.G.S.N. Rao, N.G. Patil and P.S. Brahmanand, 2003. Fertigation studies and irrigation scheduling in drip irrigation system in tomato crop (*Lycopersicon esculentum* L.). *Eur. J. Agron.*, 19: 327–340

Sousa, V.F., E.F. Coelho and V.B. Souza, 1999. Irrigation frequency in melons cultivated in sandy soil. *Pesq. Agropec. Bras.*, 34: 659–664

Tropea, M., G. Fisichella and A. Longo, 1982. The effect of fertigation on the mineral nutrition and yield of sweet pepper. *Technica-Agricola*, 34: 219–233

Vijayakumar, G., D. Tamilmani and P. K. Selvaraj, 2010. Irrigation and fertigation scheduling under drip irrigation in brinjal (*Solanum melongena* L.) crop. *IJBSM*, 1: 72–76

(Received 15 October 2012; Accepted 07 February 2013)