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Effect of drip irrigation frequency and n-fertilization on yield and water use efficiency of cucumber (*Cucumis sativus*) in Ado-Ekiti, Nigeria

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ABSTRACT

The proper irrigation scheduling and nitrogen management are crucial for sustainable cucumber production. A field experiment was therefore, set up during the dry seasons of 2018 and 2019 at the Teaching and Research Farm Faculty of Agricultural Sciences, Ekiti State University, Ekiti State Nigeria to evaluate the effect of drip irrigation frequency and N-fertilization on yield and water use efficiency of cucumber. The experiment was laid out in randomized complete block design (factors 3 × 2) in split-plot arrangement with three replications. The main block consisted of three levels of drip irrigation frequencies: twice a week (I_2), three times a week (I_3) and four times a week ($I\text{-}_4$) while the subplots were nitrogen fertilization *viz.*, no fertilization (N_0) and N_{180} (180 kg N/ha through urea). The highest yield (186 t/ha) was obtained from three times a week irrigation with N at 180 kg/ha treatment which was 58.49% higher than the lowest yield (132 t/ha) obtained from two times a week irrigation without N fertilization. Drip irrigation frequency and N-fertilization significantly influence (P<0.05) number of fruits, yield and water use efficiency of cucumber. Irrigation water use efficiency was greatest with two times a week irrigation without N fertilization treatment. Reducing the frequency of water application to treatment I_2 increased cucumber water use efficiency (WUE). Correlation was obtained (r = 0.51*, r = -0.42*) between water use efficiency and fruit yield, respectively for the two years of study. This study observed that WUE could be good criteria for evaluating the effectiveness of irrigation base on the results obtained and it was concluded that treatment of thrice a week water application with 180 kg/ha N as urea was adequate in terms of fruit yield and water use efficiency and hereby recommended for cucumber cultivation. Therefore, the three times a week irrigation with N at 180 kg/ha treatment could successfully be used to reduce water and fertilizer application for improving cucumber yield on the field.

Key Words : Cucumber, drip irrigation, fertilizer management, water use efficiency, yield

INTRODUCTION

Cucumber origin has been traced to both Kalahari and Sahara deserts in Africa (Jarret *et al.*, 1996). According to Huh *et al.* (2008), cucumber is one of the most widely cultivated plants in the world because of its dietary and economic value. Globally, cucumber is attaining importance and has a leading production of about 40 million tonnes per year. Its consumption is high, accounting for 60% of the world area devoted to vegetables production (Gunner and Wehner, 2004 Goreta *et al.*, 2005). In Nigeria, cucumber production has been limited to the drier savannah region of Nigeria where it thrives better (Anonymous, 2006; Awe *et al.*, 2016). Cucumber has a lot of health and nutritional values (Minh, 2019) and that is why the demand for its production is now high in Nigeria. But its production remains low, thereby making the fruit to be expensive and not affordable for the poor vulnerable members of the society. Therefore, there is need to produce more cucumber in commercial quantity in Nigeria using modern technology like drip irrigation.

There is need for efficient use of water to maintain balance in blue economy. In an attempt to achieve this, drip irrigation system has been advocated for ensuring the best use of water for agriculture and improving irrigation efficiency (Awe *et al.*, 2016). Scheduling water application is very critical to make the most efficient use of drip irrigation system as excessive irrigation decreases yield, while insufficient irrigation causes water stress and reduces production (Awe *et al.*, 2016). On the other hand, the intensity of this operation requires that the soil water supply be kept at the optimal level to maximize returns to the farmer (Sezen *et al.*, 2007). Several researchers have reported some responses of cucumber to drip irrigation frequency (Simseka *et al.*, 2005; Beyaert *et al.*, 2006; Mamun Hossain *et al* 2018; Dattatray *et al.*, 2018). Simseka *et al.* (2005), working on cucumber found that fruit yield ranged from 40 to 70 t/ha and was significantly reduced as drip irrigation rate decreases from 900 to 600 mm. Mamun Hossain *et al.* (2018) also discovered that application of drip water at 85% of field capacity and fertilizer (N at 420 and K at 305 kg/h.m^2) combination was successfully used to improve cucumber marketable yield.

For good sustenance of cucumber production there is need for proper soil fertility management. Adeniyan and Ojeniyi (2006) stated that the main purpose of fertilization in agriculture is to obtain a high yield and to enhance soil fertility. It has however been pointed out by Amer *et al.* (2009) that soil nutrient status can be improved by fertilization but maximum plant growth could only be achieved when the nutrient availability coincide with water availability. Therefore, the development of water and fertilizer management technology that will enhance efficient water use has become an important strategy to guarantee sustainable cucumber production (Awe *et al.*, 2016). Several researchers have carried out studies on the effect of water and fertilizer management on cucumber growth, yield and water use efficiency (Beyaert *et al.*, 2006; Semiha *et al.*, 2006; Amer *et al.*, 2009; Kamal *et al.*, 2009; Li *et al.*, 2010; Awe *et al.*, 2016; Dattatray *et al.*, 2018; Mamun Hossain *et al.*, 2018).

The application of nitrogen fertilizer with the use of drip irrigation system provides an opportunity to improve nutrient use efficiency and crop production through better timing and placement of water and nutrients and reduced nutrient losses by deep percolation and erosion (Bar-Yosef, 1999; Mohammad, 2004a, Mohammad, 2004b). Mao *et al.* (2003) evaluated the effect of drip irrigation on cucumber (*Cucumis sativus*) and found that fresh fruit yield of cucumber was highly affected by total volume of irrigation water, with the least productive irrigation regimes were those that had water deficiencies during fruiting stages. Amer *et al.* (2009) reported that cucumber yield was not increased alone by surplus irrigation but maximum yield was obtained with adequate water applied within fertilizer treatment and with increasing amounts of N applied. Therefore, that management of cucumber for maximum yield requires optimizing irrigation water supply in combination with N management.

The use of drip irrigation system and good fertilizer management for cucumber production may result in economic and environmental benefits for farmers. Therefore, this arises a need to quantify cucumber yield, nitrogen and water use efficiencies under the drip irrigation system. The objective of this study was to evaluate the effect of drip irrigation frequency and nitrogen fertilization on yield and water use efficiency of cucumber in Ado-Ekiti, Nigeria.

MATERIALS AND METHODS

Description of Experimental Site

The field experiment was conducted between January to March during 2018 and 2019 at the Irrigation and Research Farm, Ekiti State University, Ado-Ekiti, South-Western Nigeria. The site was located on longitude 4^{O} 45' to 5^{O} 45' E and latitude 7^{O} 15' to 8^{O} 51' N and 434 m above sea-level. It has a humid-tropical climate characteristic with distinct dry and wet seasons receiving moderate mean annual rainfall of about 1367.7 mm while temperature almost uniform throughout the year with little deviation from mean was 27 ^{O}C. The soil of the study site belongs to the broad group of Alfisol (Soil Survey Staff, 2014), with top sandy clay loam (Kadiri, 2017). The results of the physical and chemical properties of 0-15 cm of soil surface layer of the experimental area before the commencement of the study are shown in

Table 1 below. According to the cropping history of the land, it has been used previously for the cultivation of *Citrullus lanatus* (water melon), *Abelmoschus esculentus* (okro), *Zea mays* (maize) and *Cucumis sativus* (cucumber) for 5 years prior to this study.

Experimental Design and Treatment

The experiment was a two-factorial laid out in a randomized complete block design (RCBD) in a split-plot arrangement comprising of three replications. Irrigation constituted the main factor at 3 irrigation regimes namely: I_2 = Irrigation applied two times a week, I_3 = Irrigation applied three times a week and I_4 = Irrigation applied four times a week. The subplots were N-fertilization constituted by N_0 = Control (no fertilizer application) and N_{180} = Nitrogen fertilizer at 180 kg N/ha through urea.

Land Preparation, Field Layout and Installation of Drip Irrigation System

The experiment site was prepared by ploughing followed by harrowing and unburied grasses were properly removed to ensure a clean field. In the field layout, there were 3 plots of 2 m × 5 m in each of the 6 blocks, giving a total field area of 180 m^2. The drip irrigation system adopted from Awe *et al.* (2017), consisted of 3000 L tank, 25 mm diameter main pipe and submains end plugs, T-Joint plugs, rubber hose, gum, gate valve, laterals cum drippers, pipe nipples etc. The mainline delivered water from the tank to the sub mains and submains into the drip lines, while the emitters delivered water to the field at a rate of 4 L/hr. The field and part of the drip irrigation set up are shown in Fig. 1.

Sowing and Field Management

Sowing of cucumber was done on the 18th and 22nd of January 2018 and 2019, respectively on the prepared plots. Two to three seeds of cucumber (Ashley variety) were sown at a spacing of 60 x 60 cm using a sowing depth of about 5 cm. A week after sowing (WAS), excess seedlings were thinned to two plants per stand, giving a plant population of 55,555 plants/ha. The field was adequately irrigated for crop emergence and establishment. After

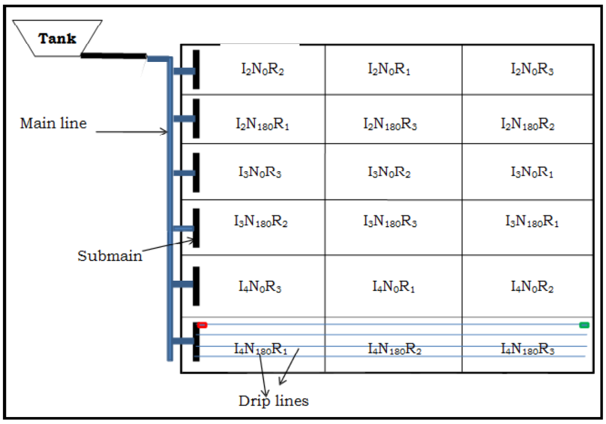

Fig. 1. Installation of drip irrigation set up and field layout (Green part : End plug; Red part : Nipple; I_2, I_3 and I_4 : Two, three and four times weekly irrigation, respectively; N_0 and N_{180} : No fertilizer and 180 kg N/ha as urea fertilizer, respectively; R_1, R_2 and R_3: Replications).

crop establishment, both irrigation and nitrogen fertilizer treatments were imposed. The fertilizer treatment of 180 kg N/ha through urea was applied by hand method at two WAS. Weed control was done manually three times and other cultural practices including crop protection were conducted.

Soil Sampling and Analysis

Prior to sowing, soil samples were randomly collected from 0-15 cm depth from three representative locations and were mixed to obtain a composite sample, which were air-dried, grounded with mortar and passed through a 2 mm sieve for the determination of soil physical and chemical properties. The soil pH was determined using the digital electrode pH meter, Bray-P-1 extractant was used to extract available P (Olsen and Sommers, 1982) while organic carbon and total N were determined by Walkley-Black (1934) oxidation and Kjeldahl digestion techniques, respectively (Bremmer and Mulvancy, 1982), exchangeable K, Ca, Mg and Na were extracted using normal ammonium acetate, using flame photometry (JENWAY PFP7 Clinical Flame Photometer) to determin K, Ca and Na while Mg was determined by the atomic absorption spectrophotometry (AAS, Perkins Elmer 2280 model). Effective cation exchange capacity (ECEC) was obtained by the sum of exchangeable K, Ca, Mg, Na and exchangeable acidity. Particle size distribution was determined by hydrometer method of soil mechanical analysis as outlined by Bouyoucos (1951).

Two representative profiles were also dug within the experimental field and undisturbed soil samples were collected at 0-10, 10-20 and 20-30 cm soil layers using core samplers made from metallic cylinders, 43.4 mm diameters and 40 mm high for the determining of bulk density. After obtaining the saturation weight, the undisturbed samples were oven-dried at 105 ^{O}C for 48 hours and the weight of dry soil was determined (Blake and Hartge, 1986).

$$BD = Ms/V$$

Where, BD = Bulk density (g/cm^3), Ms = weight of dry soil (g), V = Volume of soil (cm^3).

Fruit Yield and Water Use Efficiency

Matured cucumber fruits were harvested from an area of 1 x 1 m from each plot periodically and the weight was measured with a sensitive scale. The yield components evaluated included number of fruits, fruit length and fruit diameter. The total fruits yield was obtained from the sum of the various harvests and total yield was therefore converted to kg/ha. Irrigation water use efficiency (IWUE) received during the growing period were calculated according to the FAO (1982) equation below:

$$IWUE = Yield\ (kg/ha)/Irrigation\ (mm)$$

Where, IWUE is the irrigation water use efficiency (kg/ha mm).

Data Analysis

Data collected were subjected to statistical analysis of variance (ANOVA) and means were separated by Fisher's least significant difference (LSD) test at 5% level of probability. Pearson correlation was carried out between yield and WUE. All the analysis were performed using SPSS software (IBM version 20).

RESULTS AND DISCUSSION

Irrigation Water Used

The amount of irrigation applied to the different irrigation treatments showed that the twice weekly water application (I_2) received 261.5 and 384.3 mm in the first and second season respectively, and the thrice weekly water application received 380.2 and 541.1 mm in the first and second season, while the four times a week water application received 455.2 and 623.5 mm in the first and second season (Table 2). The crop received more water in the second season because of some additions that came from unexpected rainfall in the dry season.

Effect of Drip Irrigation and N-Fertilization on Cucumber Growth and Yield Parameters

The results of the effect of drip irrigation frequency and N-fertilization on fresh yield and growth parameters are given in Tables 3, 4 and 5 and Figs. 1, 2, 3, 4 and 5. Both drip irrigation frequency and N- fertilization had significant ($P < 0.05$) effect on fruit length (cm) and fruit diameter (mm) for the second season

Table 1. Properties of the soil's surface layer (0-15 cm) before the experiment

Bulk density (g/cm^3)	Physical properties				
	Sand	Silt (g/kg)	Clay (%)	Gravel	Textural class
1.36	592.0	156.0	252.0	11.85	Sand clay loam

pH (H_2O)	OM	TN	AP	K	Na	Ca	Mg	EA	CEC	ECEC	BS	ESP
	(%)		(mg/kg)				(cmol/kg)				(%)	
5.8	2.12	0.18	22.50	0.66	0.61	2.41	0.95	2.13	4.38	6.51	68.59	13.72

Chemical properties

OM = Organic matter; TN = Total nitrogen; AP = Available phosphorus; CEC = cation exchange capacity; ECEC = Effective cation exchange capacity; BS = Base saturation, ESP = Exchange sodium percentage.

Table 2. Irrigation water applied during the drip irrigation period

Treatment	Irrigation applied (mm)	
	1st growing season (2018)	2nd growing season (2019)
I_2N_0	261.5	384.3
I_2N_{180}	261.5	384.3
I_3N_0	380.2	541.1
I_3N_{180}	380.2	541.1
I_4N_0	455.2	623.5
I_4N_{180}	455.2	623.5

I_2, I_3 and I_4: Two, three and four time weekly irrigation, respectively; N_0 and N_{180}: No fertilizer and 180 kg N/ ha as urea fertilizer, respectively.

only while the interaction effect was significant for fruit length (cm) in the second season (Table 3). However, both drip irrigation frequency and N-fertilization had significant ($P< 0.05$) effect on total number of fruits and total fruits yield (t/ha) (Table 4). The highest marketable cucumber yield was obtained by three times a week irrigation with N at 180 kg/ha as urea (186.24 t/ha) while the lowest yield was obtained with two times a week irrigation without N fertilization treatment (132.12 t/ha). The highest cucumber yield was 58.49% greater than the lowest yield. It was observed that cucumber yield increases with water application up to a certain limit before declining (Table 4 and Figs. 4 and 5). Consistent trend was obtained for the results for number of fruits and total yield (t/ha) for the two years of study. This may be attributed to the number of irrigation water applied to cucumber for both years (Table 2). More water was applied in 2019 season than the 2018 season (Table 2). The results obtained in this study agreed with the findings of Yuan *et al.* (2006) who found that irrigation water significantly affected plant growth and yield of cucumber with increase in irrigation water up to certain limit. Gallardo *et al.* (1996) also reported that decreased water supply had a greater effect on the fresh weight than on the dry weight.

In our study, drip irrigation and fertilizer interaction was more effective on cucumber yield (Table 4). Al-Omran and Louki (2011) concluded in their study that, deficit irrigation (80% of crop evapotranspiration, ETc) was more effective to good marketable yield and water saving compared with 100% of ETc. In this study, it was observed that certain level of deficit water application combined with proper fertilization can improve marketable yield (Table 4). The highest yield of cucumber in this study was obtained by three times a week irrigation with N at 180 kg/ha as urea. Statistical analysis had proved that water and N-fertilizer application significantly influence ($P<0.05$) average cucumber yield in this study (Table 4). Specifically, the average cucumber yields for three times a week irrigation with N at 180 kg/ha and four times a week irrigation

Table 3. Effect of drip irrigation frequency, N-fertilization and their interaction on cucumber fruit length and fruit diameter at Ado-Ekiti Experimental Station, Nigeria

Irrigation	Fruit length (cm)	Fruit diameter (mm)	Fruit length (cm)	Fruit diameter (cm)
	1st Season (2018)		2nd season (2019)	
I_2	27.12a	60.64a	28.04b	53.04a
I_3	26.22a	60.68a	29.10ab	53.47a
I_4	26.24a	60.49a	29.46a	54.50a
LSD (p<0.05)	NS	NS	1.27	NS
N-Fertilizer				
N_0	26.63a	61.11a	28.72a	53.30a
N_{180}	26.42a	60.09b	29.01a	53.37a
LSD (p<0.05)	NS	0.90	NS	NS
Interaction				
I_2N_0	27.09a	61.15a	27.60b	52.91a
I_2N_{180}	27.15a	60.13a	28.39ab	53.17a
I_3N_0	26.64a	61.51a	29.27ab	53.61a
I_3N_{180}	25.80a	59.85a	28.93ab	53.33a
I_4N_0	26.15a	60.67a	29.22ab	53.38a
I_4N_{180}	26.32a	60.31a	29.70a	53.61a
LSD (p<0.05)	NS	NS	1.96	NS

I_2, I_3 and I_4: Two, three and four time weekly irrigation respectively; N_0 and N_{180}: No fertilizer and 180 kg N/ha as urea fertilizer, respectively. Means in a column followed by different letters differed significantly at P=0.05 level of probability by least significant difference (LSD) test; NS: Not Significant.

Table 4. Effect of drip irrigation frequency, N-fertilization and their interaction on cucumber (*Cucumis sativus*) yield and yield components at Ado Ekiti Experimental Station, Nigeria

Irrigation	Total number of fruit	Total fruit yield (t/ha)	Total number of fruit	Total fruit yield (t/ha)
	1st Season (2018)		2nd season (2019)	
I_2	76.00ab	132.13a	80.00b	139.71b
I_3	67.67b	114.94b	95.67a	174.78a
I_4	78.33a	134.85a	93.33a	169.67a
LSD ($p<0.05$)	9.72	16.43	12.44	29.91
N-Fertilizer				
N_0	80.89a	142.65a	87.22b	161.25b
N_{180}	67.11b	111.96b	92.11a	174.12a
LSD ($p<0.05$)	13.51	28.00	4.20	7.46
Interaction				
I_2N_0	89.67a	159.29a	75.33c	132.12b
I_2N_{180}	62.33b	104.96b	84.67b	147.30ab
I_3N_0	70.67ab	123.59ab	91.67ab	163.21ab
I_3N_{180}	64.67ab	106.28b	99.67a	186.24a
I_4N_0	82.33a	145.06ab	94.67ab	168.88a
I_4N_{180}	74.33ab	124.64ab	92.00ab	170.46a
LSD ($p<0.05$)	26.10	51.09	38.7	33.11

I_2, I_3 and I_4: Two, three and four time weekly irrigation, respectively; N_0 and N_{180}: No fertilizer and 180 kg N/ha as urea fertilizer, respectively. Means in a column followed by different letters differed significantly at P=0.05 level of probability by least significant difference (LSD) test.

Table 5. Effect of drip irrigation frequency and N-fertilization on cucumber yield and water use efficiency

Treatment	Yield (t/ha)		IWUE (t/ha mm)	
	1st Season	2nd Season	1st Season	2nd Season
I_2N_0	159.29a	132.12b	0.61	0.34
I_2N_{180}	104.96b	147.30ab	0.41	0.38
I_3N_0	123.59ab	163.21ab	0.33	0.30
I_3N_{180}	106.28b	186.24a	0.28	0.34
I_4N_0	145.06ab	168.88a	0.32	0.27
I_4N_{180}	124.64ab	170.46a	0.27	0.27
LSD $p<0.05$	51.09	33.11		

1st Season : 2018; 2nd Season : 2019.

with N at 180 kg/ha treatments were significantly ($P<0.05$) different from all other treatments as given in Table 4. Similar cucumber yield was reported by Ayas and Demirtas (2009) that the highest yield was recorded at 148 t/hm^2 and 108 t/hm^2 using 100% water application and 75% of Class A evaporation pan in greenhouse condition respectively. The yield advantage obtained with drip irrigation in this study may be related to the fact that application of water and nutrients was more frequent and in close proximity to the shallow root system of the cucumber plants.

Irrigation Water Use Efficiency (IWUE) and Yield

The irrigation water use efficiency

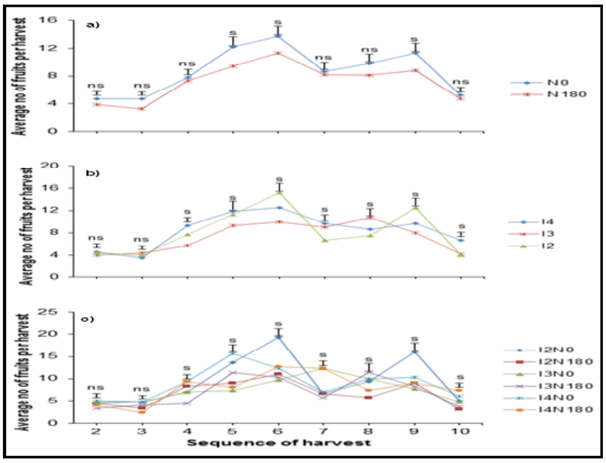

Fig. 2. Variability of number of fruits of cucumber (*Cucumis sativus*) due to a) N-fertilization, b) irrigation regimes, and c) interaction between irrigation and fertilization during the first growing season (I_2, I_3 and I_4: Two, three and four times weekly irrigation, respectively; N_0 and N_{180} : No fertilizer and 180 kg N/ha as urea fertilizer, respectively. The vertical bars are the standard error of mean; s : Significant; ns: Not significant at 5% level of probability by LSD test).

(IWUE) was determined to evaluate the productivity of irrigation in the treatments. The results are presented in Table 5. IWUE were highest (0.61 t/ha mm) from two times a week irrigation with no fertilizer while four times a week irrigation with N at 180 kg/ha treatment had the minimum value (0.27 t/ha

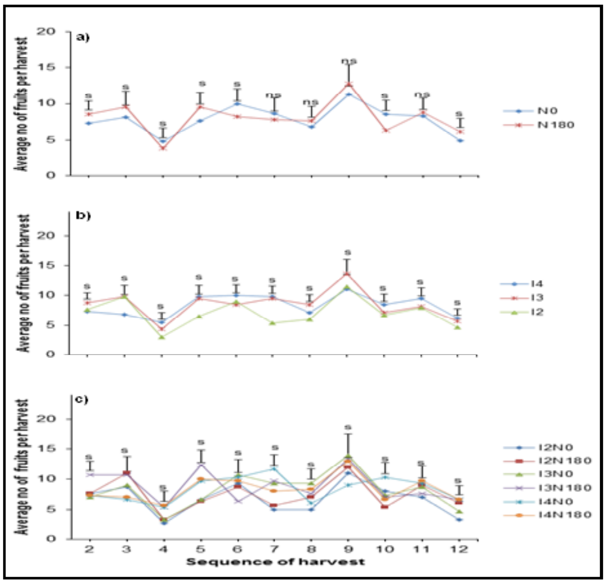

Fig. 3. Variability of number of fruits of cucumber (*Cucumis sativus*) due to a) N-fertilization, b) irrigation regimes, and c) interaction between irrigation and fertilization during the second growing season (I_2, I_3 and I_4: Two, three and four times weekly irrigation, respectively; N_0 and N_{180} : No fertilizer and 180 kg N/ha as urea fertilizer, respectively. The vertical bars are the standard error of mean; s : Significant; ns: Not significant at 5% level of probability by LSD test).

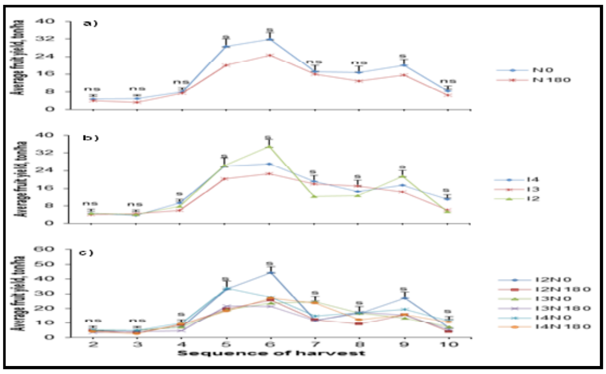

Fig. 4. Variability of fruit yield of cucumber (*Cucumis sativus*) due to a) N-fertilization, b) irrigation regimes, and c) interaction between irrigation and fertilization during the first growing season (I_2, I_3 and I_4: Two, three and four times weekly irrigation, respectively; N_0 and N_{180} : No fertilizer and 180 kg N/ha urea as fertilizer, respectively. The vertical bars are the standard error of mean; s : Significant; ns: Not significant at 5% level of probability by LSD test).

mm). Some researchers have reported highest IWUE values for cucumber under deficit irrigation conditions (Kirnak and Demirtas

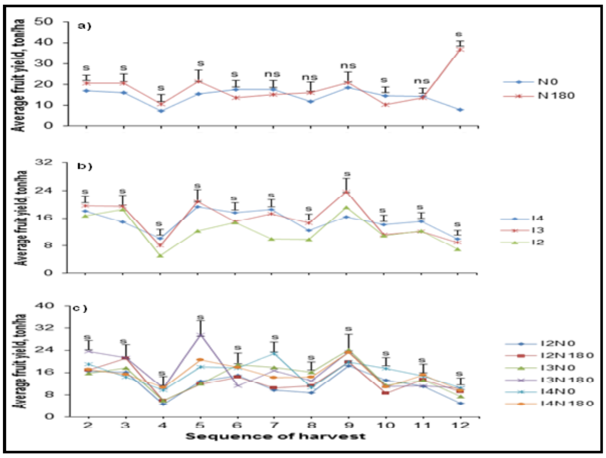

Fig. 5. Variability of fruit yield of cucumber (*Cucumis sativus*) due to a) N-fertilization, b) irrigation regimes, and c) interaction between irrigation and fertilization during the second growing season (I_2, I_3 and I_4: Two, three and four times weekly irrigation, respectively; N_0 and N_{180} : No fertilizer and 180 kg N/ha as urea fertilizer, respectively. The vertical bars are the standard error of mean; s : Significant; ns: Not significant at 5% level of probability by LSD test).

2006; Hashem *et al.*, 2011; Abdul Hakkim and Jisha Chandy, 2014). The results also confirm that water productivity under water saving strategy was higher from two times a week irrigation without N fertilization treatment than the full or excess water application.

The relationship between water application (mm) and WUE (kg/ha mm) was a productive one (r = 0.51, -0.42). The result that IWUE increased by decreased application of water, which also corresponds to increasing marketable yield. From the result it can be concluded that the water and fertilizer treatment combination has efficiently improve the WUE, which is consistent with the previous study reported by Wang and Xing (2016). The data analysis shows that irrigation and fertilization for all the treatment combinations could significantly (P<0.05) affect WUE. The WUE with two times a week irrigation without N fertilization and two times a week irrigation with N at 180 kg/ha treatments were found significantly different compared to other treatments.

In this study we have observed that water use efficiency increased with decreasing amount of irrigation water. Sezen *et al.* (2007) also reported significant second degree poly nominal relationship between irrigation water applied and water use of bell paper. The use of proper water quantity application allows plants to use water and nutrients from deep soil, thus increases water and nutrient use efficiency and reduces nitrogen leaching. These results suggest that IWUE could be a good criterion for evaluating the effectiveness of irrigation. Positive significant correlation (r = 0.51*) was observed between water use efficiency and yield of cucumber in the first Season while a negative correlation (r = -0.42) was observed in the second season maybe as a result of increase in quantity of irrigation water applied which was high when compared to the water applied in the first season (Table 2).

CONCLUSIONS

Based on the two years data obtained from this study it can be concluded that drip irrigation scheduling of three times a week combined with N-fertilization of 180 kg/ha as urea can successfully improve cucumber marketable yield along with better profitability with increased water use efficiency.

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