Effect of Irrigation Regime and Nitrogen Fertilization Levels on Sugarcane Yield and Its Components

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ABSTRACT

Two field experiments were carried out at the Research Experimental Farm of Sabahia Agricultural Research Station in Alexandria during the two successive growing seasons of 2011/ 12 and 2012/ 13. G2006-77 sugarcane variety (*Saccharum officinarum* L) was cultivated to investigate the effect of irrigation regime and nitrogen fertilizer level and their interaction on sugarcane yield and its components. Main plots were represented by three irrigation regime:1- (large interval) 18 irrigations/ year was given to first treatment irrigation at (15 days interval in Summer, 20 days interval in Spring and Autumn and 30 days interval in Winter seasons), 2- (middle interval) 25 irrigations / year was given to second treatment irrigation at (10 days interval in Summer, 15 days interval in Spring and Autumn and 21 days interval in Winter seasons) and 3- (short interval) 32 irrigations / year was given to third treatment irrigation at (7 days interval in Summer, 13 days interval in Spring and Autumn and 15 days interval in Winter seasons,). The sub plots were used for the three nitrogen levels (140, 200 and 260 kg N / Fed). The results indicated that:

The second regime middle irrigation intervals was insignificantly increased stalk length, stalk diameter, stalk yield, sugar yields, T.S.S (%), sucrose (%) and purity (%) compare with the first and third regime through the two successive seasons.

Increasing applied N levels from 140 up to 200 Kg N /fed. significantly increased stalk length, stalk diameter, stalk yield, sugar yields T.S.S (%), sucrose (%) and purity (%).

The interaction between irrigation intervals and nitrogen levels on the studied traits were not significant except sucrose (%) in the two seasons.

Keywords: Sugarcane (*Saccharum officinarum* L), irrigation intervals, nitrogen fertilizer rate , stalk length, stalk diameter, stalk yield, sugar yield, T.S.S%, sucrose% and purity%.

INTRODUCTION

Sugarcane (*Saccharum officinarum* L) requires substantial inputs of both water and nitrogen to achieve maximum yields. Regional water supplies are often limited. Compared to other crops, little is known about how far water can be stretched in sugarcane without affecting sugar yield. In particular, there is little information on the response of important yield forming processes to soil water deficits. Irrigation can increase sugarcane yield and it increases the sustainability of crop production Gary *et al*., (2000)

Water present about 75% of sugarcane stalks and has a vital role in absorption and transporting of mineral nutrients from soil to plant roots and shoots. Yadav *et al*.,(1990). Availability of water is an important factor causing variation in sugarcane yield and juice quality Wiedenfeld and Enciso (2008) found that increasing irrigation levels increased sugar and sugarcane yields and sucrose content. Ali (1996) mentioned that irrigated sugarcane at 15 or 45 available soil moisture and reported that juice quality was unaffected by irrigation treatments. El- Shafai (1996) cleared that applying irrigation at shorter intervals increased stalk diameter and applying 26 irrigations/ season produced the highest sugarcane yield without significant differences with the others 20 and 17 irrigations/ season. Gomaa (2000) irrigated sugarcane every 14, 21, 28, 35 and 42 days. The results showed significant differences among the sugarcane varieties (G.T.54-9, G.85-37, G.84-47 and F.153) for average stalk height and sucrose percentage which was increased as irrigation intervals decreased in both seasons. On the contrary, sugar recovery percentage decreased as irrigation intervals decreased. Increasing irrigation intervals caused a reduction in sugarcane yield/fed., but this reduction was not significant while increasing irrigation intervals significantly decreased sugar yield/fed. According to Azzazy *et al*., (2000) water is the key to sugarcane growth, development and subsequent conversion of recoverable sugar to sucrose. Immbaby (2003) and Maher (2003) said that application of 22 or 19 irrigations / season resulted the highest cane and sugar yield. El-Geddawy *et al.*, (2004) showed that sugar recovery%, number of millable cane and sugar yields were insignificantly affected by the applied irrigation regimes. Bekheet (2006) concluded that stalk length, stalk diameter and cane yield/fed were significantly increased by decreasing irrigation intervals from 20 to 12 days. in both seasons. Applying irrigation water every 12 or 16 days attained significant increase in the number of millable cane/fed. and sugar yield/fed.

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However both of sucrose and sugar recovery percentages were negatively and significantly affected by increasing the periods between irrigation. Inman-Bamber and Smith (2005) Indicated that responses to increased irrigation may not be as large as generally believed. It is remarkable that yield of cane, sucrose and biomass were not affected by irrigation varying from 349 to 672 mm in a dry year Yahaya *et al.*, (2010) irrigation scheduled at 1-, 2-, 3-, and 4- week intervals. The yield and yield components were highest with irrigation at 1-week interval. Barbosa *et al.*, (2014) Water balance with values less than -13 mm cause a significant decrease in the final population of plants, regardless of the variety, and values below -35 mm, leads to the death of all plants.

Nitrogen is the most essential element having direct effect on cane growth, sugarcane yield, and juice quality. Studies have established that N increase the quantity of green tops, yield components and yield of cane and sugar Azzazy and El-Geddawy, (2003), El-Geddawy *et al.,* (2003), Nassar *et al.*, (2005) and El-Geddawy *et al.*, (2005) Similarly, Yousef *et al*., (2000) reported that nitrogen has significant influence on cane growth, yield, quality and recoverable sugar. However, nitrogen application at high rates exceeding sugarcane plant utilization has adverse effect on cane quality. However Qureshi *et al*., (2001) reported that the amount of water utilized by cane plant has a linear relationship to total dry matter produced. A favorable soil water condition during cane growth also has a significant effect on the yield and quality response of sugarcane to nitrogen fertilization Bhatti *et al*., (1986). According to Taha, *et al*., (2003), meeting the nutrient and water requirements of sugarcane effectively makes the crop flourish and yield profitably.

More information is regime on the influence of nitrogen fertilizer levels on sugarcane yield and quality under various irrigation regimes. This knowledge is required to develop better fertilizer and irrigation practice in the crop. The objectives of this research were to determine the effect of nitrogen fertilizer levels and irrigation regime on sugar yield, yield components and sugar quality of sugarcane.

MATERIALIS AND METHODS

Two field experiments were conducted in the Research Experimental Farm of Sabahia Agricultural Research in Alexandria Station during the successive growing seasons of 2011/ 12 and 2012/ 13. G2006-77 sugarcane variety (*Saccharum officinarum* L) was cultivated to study the effect of irrigation regimes and nitrogen fertilizer levels and their interactions on sugar yield and its components of sugarcane.

27 Plots (15 m^2) for each treatments, were used to carry out the experiment with three replicates in a split plot design. Main plots were used for the irrigation regime: 1- (large intervals) 18 irrigations/ year were given to first treatment irrigation at (15 days intervals in Summer, 20 days intervals in Spring and Autumn and 30 days intervals in Winter seasons), 2- (middle intervals) 25 irrigations / year were given to second treatment irrigation at (10 days intervals in Summer, 15 days intervals in Spring and Autumn and 21 days intervals in Winter seasons) and 3- (short intervals) 32 irrigations / year were given to Third treatment irrigation at (7 days intervals in Summer, 13 days intervals in Spring and Autumn and 15 days intervals in Winter seasons).

Irrigation was conducted through a water meter of 0.1 cubic meter accuracy used to be tightly hooked where the wide inlet towards the main permanent canal and the outlet towards the lateral temporary field canal of the irrigated plots. Each plot was irrigated individually by allowing water to flow over the plot through an opening in the temporary field canal. After a complete saturation of the plot, the opening whole is closed and water allowed to flow over another plot. This plots were surrounded with borders of 2 meters width to prevent the seepage of water to other plots.

The sub plots for the nitrogen fertilizer levels (140, 200 and 260 Kg N /fed.) as ammonium nitrate (33.5%N). were added in two equal doses the 1st one after 60 days from planting and the 2nd after 30 days later. Before planting soil samples were randomly taken from the experimental site at a depth of 0 to 30 cm and prepared for chemical analysis (Table 1) according to standard methods edited by to Ankerman and large (1974). G2006-77 sugarcane variety was obtained from Sugar Crops Research Institute, Agricultural Research Center, Giza. Stem cutting were hand planted in October in the two seasons. All the agronomic practices for growing sugarcane were carried out as recommended by the Sugar Crops Research Institute. At harvested five plants from each sub-plot were taken at random to determine the following data:

1- Stalk length (cm) was measured from soil surface to the top point of visible dewlap.

2- Stalk diameter (cm) was measured at the middle part of stalk.

3- Stalk yield (ton/fed) cane stalks of each plot were off cleaned from trash, weighed and cane yield was calculated.

4- Total soluble solids (T.S.S.%) was measured by hand refractometer according to the methods outlined in the A.O.A.C.(1985).

Table 1. Some chemical properties of soil at the experimental site:

Season	EC	pH	Cations (meq/L)				Anions (meq/L)				mg/ kg soil
	dS m^{-1}		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	CO_3^{2-}	Cl^{-}	SO_4^{2-}	N
1st	2.7	8.0	7.5	6.9	10.2	1.2	1.5	0.0	24.6	1.6	11.0
2nd	2.9	8.1	8.0	6.9	12.0	1.1	1.4	0.1	25.5	1.5	11.3

5- Sucrose (%) was determined by Digital Automatic Polarimeter A.O.A.C.(1985).

6- Purity (%) was calculated using the following formula according to Singh and Singh (1998)

7- Juice purity(%) = sucrose(%), / T.S.S.(%) X100.

8- Sugar yield (ton /fed) was determined by multiply yield of stalks X sucrose%.

The obtained data of the two investigated seasons were computed and statistically analyzed for testing the significance of the studied factors and their interactions by L.S.D. test according to Steel and Torrie (1981).

RESULTS AND DISCUSSION

1- Yield and yield components:

The effect of irrigation and nitrogen levels on stalk length, stalk diameter, stalk yield and sugar yield through the two successive seasons 2011/12 and 2012/13 were highly significant as shown in (Table 2).

Increases in irrigation regime consistently resulted in a significant decrease in stalk length. Application of nitrogen at 200 and 260 kg/fed resulted in significantly higher cane length compared to 140 and 200 kg. N/fed that are statistically comparable these results are similar to those Gomaa (2000), and Bekheet (2006).

Data given in (Table 2), showed that the irrigation regime had a significant effect on stalk diameter, in both seasons .Applying irrigation water at intervals of the second regime at (10 days intervals in Summer, 15 days intervals in Spring and Autumn and 21 days intervals in Winter seasons) resulted in the thickest stalks compared with other regimes. These results matched these reported by El- Shafai (1996), Gomaa (2000) and Bekheet (2006).

The results in (Table 2) showed that nitrogen fertilizer levels significantly effect on stalk diameter, in both seasons. Increasing the applied N doses from 140 up to 260 Kg. N /fed. increasing stalk diameter, gradually. These results in agreement with Nassar *et al.*,(2005).

The results in (Table 2) showed that the middle irrigation regime of the second regime significantly increased stalk yield compared with the first and third regimes through the two successive seasons 2011/12 and 2012/13. Increasing N level from 140 up to 200 Kg N/fed. increasing stalk yield (39.34 and 38.87 ton/ fed.) in the first and second seasons, respectively.

Table 2. Means of stalk length (cm), stalk diameter (cm.), stalk yield(ton/ fed), and sugar yields(ton /fed) as affected by irrigation regime and nitrogen levels and their interactions during 2011/12, 2012/13 seasons

Factors	Stalk length (cm)		Stalk diameter (cm)		Stalk yield (ton /fed)		Sugar yield (ton /fed)	
Seasons	1st	2nd	1st	2nd	1st	2nd	1st	2nd
A- Irrigation regime / year								
18 irrig. large	189.30 a	198.20 b	2.43 b	2.64 b	30.69 b	32.74 b	4.70 b	4.50 b
25 irrig. middle	201.70 a	210.70 a	2.51 a	2.86 a	33.96 a	34.92 a	4.98 a	4.92 a
32 irrig. short	172.70 b	186.20 c	2.10 c	2.54 c	28.49 c	30.92 c	4.25 c	4.16 c
LSD.05	12.56	3.46	0.05	0.08	1.05	1.05	0.21	0.14
B- Nitrogen levels Kg /fed.								
140	181.20 b	164.80 c	2.37 b	2.32 c	22.53 c	27.42 c	3.52 c	3.51 c
200	207.50 a	192.40 b	2.51 b	2.71 b	39.34 a	38.87 a	5.89 a	5.63 a
260	225.10 a	238.10 a	2.50 a	3.03 a	31.26 b	32.29 b	4.52 b	4.46 b
LSD.05	20.7	7.3	0.03	0.07	0.94	0.82	0.94	0.29
C-Interactions								
A× B	ns	ns	ns	ns	ns	ns	ns	ns

*LSD = Least significant difference

*, ** and NS, significant at 0.05, 0.01 probability level and non-significant, respectively

These findings may be due to the increase in the vigorous characteristics of plant grown which let to more competition between them consequently increased plant mortality It could be concluded that the 200 Kg/fed. N level was quite satisfactory to produce the maximum stalk yield in both seasons. The results are in agreement with those reported by Azzazy and El-Geddawy, (2003) and El-Geddawy *et al.*, (2005).

The results in (Table 2) obtained that the differences between the studied irrigation regime had significant effect on sugar yields in both seasons. The second irrigation regime produced the highest sugar yields which were (4.98 and 4.92 ton/ fed) in the 1st and 2nd seasons, respectively. Concerning fertilization treatments, the obtained results showed that sugar yields were statistically affected by fertilization treatments. The highest values of sugar yield (5.89 and 5.63 ton/ fed) produced from the application of nitrogen fertilizer level (200kgN/fed) during the two growing seasons, respectively. The results are in the line with that reported by El-Geddawy *et al.*, (2005)

The interactions between irrigation regimes and nitrogen levels effect on the studied treats did not reach the significance level in the two seasons (Table 2).

2- Juice quality

Juice quality measurements of sugarcane in terms of as affected by irrigation regime and nitrogen levels as well as their interactions are shown in (Table 3).

The effect of irrigation regimes and nitrogen levels on the quality of cane juice, as expressed by T.S.S (%), sucrose (%) and purity (%) contents of the cane juice are presented in (Table 3). The influence of irrigation regime on cane quality characters were highly significant in the two seasons. Although increase in irrigation regime appears to reduce T.S.S (%), in the two seasons, the difference in T.S.S(%), due to 1st and 2nd irrigation regime were statistically significant. The second irrigation regime produced higher T.S.S(%), which were (19.94 and 19.53 %) in the 1st and 2nd seasons, respectively. The data also showed that T.S.S(%),sucrose(%) and purity (%) diminish in a linear fashion with increasing irrigation regime interval, the maximum reduction being at the longest interval 32 irrigations/year in both seasons. The result is in accordance with Gomaa (2000)

The results showed that nitrogen levels had significant effect on all the cane quality attributes in 2011/12 and 2012/13 seasons where the T.S.S (%), sucrose (%) and purity (%) recorded at 140 kg N /fed. was statistically at par with that at 260 kg/fed. with regard to T.S.S (%), Generally application of 200 kg N /fed seems to have caused greater significant increacing in quality compared to lower and higher levels. The result is in the line with that reported by Bahrani *et al.*, (2009).

The interaction between irrigation regimes and nitrogen levels effects on all juice quality parameters were not significant in T.S.S (%) and purity (%) among the two seasons. Sucrose (%) was significantly influenced by the interaction between irrigation regime and nitrogen levels in both seasons.

Table (4) revealed that statistically significant of interaction differences between irrigation regimes and nitrogen levels for, sucrose (%) in both seasons 2011/ 12, 2012/ 13.

Table 3. Means of T.S.S(%), sucrose(%) and purity(%) as affected by irrigation regime and nitrogen levels and their interactions during 2011/12 and 2012/13 seasons

Factors	T.S.S.%		Sucrose %		Purity %	
Seasons	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**
A- Irrigation regime / year						
18 irrig. large	19.49 b	19.03 b	13.88 b	14.38 b	72.5 b	73.92 b
25 irrig.middle	19.94 a	19.53 a	14.34a	14.71 a	75.3 a	77.69 a
32 irrig. short	19.09 c	18.72 c	13.61 c	13.98 c	68.5 c	70.40 c
LSD.05	0.12	0.16	0.13	0.14	1.05	1.56
B- Nitrogen levels Kg /fed.						
140	18.85 b	18.05 b	13.97 b	14.56 b	70.52 b	73.92 b
200	20.76 a	20.41 a	14.95 a	15.41 a	81.55 a	82.36 a
260	18.93 b	18.81 b	12.90 c	13.11 c	64.35 c	65.72 c
LSD.05	0.21	0.23	0.20	0.22	0.73	1.46
C-Interactions						
A× B	ns	ns	*	**	ns	ns

*LSD = Least significant difference.

*, ** and NS, significant at 0.05, 0.01 probability level and non-significant, respectively.

Table 4. The interaction between irrigation regime and nitrogen levels on Sucrose% of sugarcane plant during 2011/12, 2012/13 seasons.

Seasons	2011/12			2012/13		
Irrigation regime / year N. (kg/fed)	18 irrig.	25 irrig.	32 irrig.	18 irrig.	25 irrig.	32 irrig.
140	12.58	14.51	13.75	12.57	15.19	14.19
200	12.78	15.38	13.95	13.06	15.56	14.63
260	13.36	14.90	14.22	13.69	15.48	14.87
LSD.05		0.14			0.16	

The highest value of sucrose percentage (16.07and 17.20%) were recorded from application 25 irrigations / year (middle interval) was given to second treatment irrigation at10 days intervals in Summer, at 15 days intervals in Spring and Autumn and at 21 days intervals in Winter seasons and 200 Kg N / fed. conversely the least values of sucrose percentage (12.01 and 12.02%) were obtained from applying 18 irrigations / year (large interval) was given to first treatment irrigation at15 days intervals in Summer, at 20 days intervals in Spring and Autumn and at 30 days intervals in Winter seasons and 140 Kg N / fed. in the 1st and 2nd seasons, respectively.

In conclusion, the study demonstrates a general positive relationship between increasing N fertilizer up to (200 kg/fed), middle irrigation interval on stalk and sugar yields besides juice quality of G2006-77 sugarcane variety under Alexandria conditions. Results further revealed that excess of N (260 kg/fed), short and long interval of irrigation are decreasing the sugar quality

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الملخص العربي

تأثيرنظم الري ومستويات التسميد النتروجيني علي المحصول ومكوناته لقصب السكر

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أقيمت تجربتان حقليتـان خـلال موسـمى الزراعـة ٢٠١٢/١١، ١٣/١٢ ٢٠ بمحطـة البحـوث الزراعيـة بالصبحية، مركز البحوث الزراعية بالاسـكندرية بهـدف دراسة تأثير نظم الرى ومستويات التسميد النتروجيني علي محصول ومكوناته لقصب السكر وجودة العصير.

وقد أستخدم فى التجربة تصميم القطع المنشقه split –plot design في ثلاث مكررات حيث احتوت القطع الرئيسـية علي معاملات الري الثلاث{١٨ رية/سنة (فترة كبيرة) فيها الري كل ١٥ يوم في فصل الصيف، وكـل٢٠ يومـا فـي فصلي الربيع والخريف، وكل٣٠ يوما في فصل الشـتاء}، {٢٥ رية/سنة(فترة متوسطة) فيها الري كل ١٠ ايام فـي فصل الصيف، وكل١٥ يوما في فصلي الربيع والخريـف، وكل٢١ يوما في فصل الشتاء} و{٣٢ رية/السـنة (فتـرة قصيرة) فيها الري كل ٧ ايام في فصل الصيف، وكـل١٣ يوما في فصلي الربيع والخريف، وكل١٥ يوما في فصـل الشتاء} واحتوت القطعة الفرعية علـي معـدلات التسـميد النتروجيني الثلاث(١٤٠ و ٢٠٠ و٢٦٠) كجـم نتـروجين /فدان فى صورة نترات أمونيا (33.5%N) ويمكن تلخـيص أهم نتائج هذه الدراسة فيما يلى:

اوضحت النتائج أن زيادة عدد مرات الري الـي ٢٥ رية/سنة ادي الي زيادة معنوية في طـول سـاق القصـب وقطره ومحصول السكر ونسبة المـواد الصـلبة الكليـة (T.S.S.%) ونسبة النقاوة والنسبة المئوية للسكروز مقارنـه بعدد ١٨ رية /سنة و٣٢ رية/السنة، كما ان زيادة معدلات التسميد بالنتروجين من ١٤٠ حتي ٢٠٠ كجم N/ فدان ادي الي زيادة معنوية في طول ساق القصب وقطره ومحصول السكر ونسبة المواد الصلبة الكلية(T.S.S.%) ونسبة النقـاوة والنسبة المئوية للسكروز.

من جهه آخري لم يكن هناك تأثيرا معنويا للتفاعل بـين فترات الري ومستويات النيتروجين المدروسة فيما يتعلـق بصفات: طول ساق القصب وقطره ومحصول السكرو نسبة المواد الصلبة الكلية(T.S.S.%) ونسبة النقـاوة بينمـا كـان التفاعل معنويا فى موسمى الزراعة فيما يتعلـق بالنسـبة المئوية للسكروز حيث كانت اعلي نسـبة للسـكروز عنـد تطبيق ٢٥ رية/سنة والتسمبد بالنتروجين بمعدل ٢٠٠ كجم ن /فدان (١٥.٣٨ - ١٥.٥٦ % في الموسمين بالترتيب.

واستنادا إلى النتائج التي تم الحصول عليها بإن اعلـي محصول للسيقان والسكر(طن/الفدان) ودرجة النقاوه ونسبة السكروز ونسبة المواد الصلبة الكلية عند زراعـة قصـب السكرصنف G2006-77 تم الحصول عليها عند تطبيق ٢٥ رية/سنة والتسميد النتروجيني بمعـدل ٢٠٠ كجـم /فـدان تحت ظروف الاسكندرية.