GROWTH AND YIELD RESPONSE OF SUGARCANE (S OFFICINARUM) UNDER DIFFERENT IRRIGATION REGIMES AND NITROGEN RATES

M.S. Yahaya; A.M. Falaki;E.B. Amans and D. B. Ishaya

Abstract

The growth and yield response of sugarcane under varying levels of irrigation and nitrogen was investigated during 2001-02 and 2002-03 season using a complete randomized block design at the National Cereals Research Institute Badeggi. Three levels of nitrogen fertilizer 0, 120, and 240 kg ha^{-1} were applied with four irrigation regimes: 1-, 2-, 3- and 4- week interval. The results showed that the number of tillers $plant^{-1}$ and leaf N content were significantly affected by N rate in the two seasons. The effect of N on stem height was only significant in 2001-02 but its effect on number of stalks $stool^{-1}$ was not significant in the season. Cane yield showed significant increase with increased N rate and decreasing irrigation interval in the two seasons. The interaction of N and irrigation interval on cane yield was significant in 2002-03 season only. The interaction results suggest that increasing nitrogen levels can be detrimental to cane yield when water stress set in at longer irrigation interval.

Introduction

Sugarcane, the principal sugar crop in Nigeria is well established as a commercial crop. Being a long duration crop, with a high water requirement, its growth is mainly by means of irrigation in areas with adequate temperature and suitable rainfall regime (Yahaya *et al*., 2007). The cultivation of sugarcane is presently threatened by rapid depletion of available irrigation water supplies. Furthermore, water is becoming a global concern as domestic and industrial needs along with environmental concerns limit the amount available for agriculture (Qureshi *et al*., 2001).

Sugarcane is a biomass-producing crop that requires substantial input of both water and nitrogen to achieve maximum yield (Wiedenfeld, 1996). The yield of the crop has been found to increase directly with the amount of available water for unirrigated (Jones, 1980) and irrigated (Azzazy & Elgadaway, 2003) crops up to a water application rate 1.46 times the rate of pan evapotranspiration (Santos, 1987). The nitrogen requirement of sugarcane has been shown to vary with age of the crop, soil type, soil $N0_3$ N levels and cultivar (Ismaila, *et al*., 2000). Responses to N fertilizer may also be affected by water availability to the crop.

Studies on the relationship between moisture and N availability on sugarcane showed that irrigation at higher soil moisture potential and lower N application improved sugarcane growth parameters with no significant interaction between the factors (Azzazy *et al*., 2000). Similarly, El-Geddaway *et al.* (1997) reported high cane yield where the crop received the highest N application rate and the most frequent irrigation. According to Glaz, *et al*., (2000) the response potential of fertilizer N is greatly masked or rendered ineffective due to moisture stress. Significant interactions between nitrogen and moisture with positive effects on cane yield at high rates of both N and soil moisture was reported by Azzazy *et al*., (2003). This study was conducted to determine the effects of different levels of irrigation on sugarcane growth and yield in response to N application.

Materials and Methods

The experiment was carried out in 2001-02 and 2002-03 seasons at the field of the National Cereals Research Institute (NCRI) Badeggi located at 9^0 45' N, 6^0 07; E and at 70.5 meter above sea level in the Guinea Savannah ecological zone. The soil of the experimental area (Appendix 1) is well drained, often-leached Ultisol and sandy loam in texture (Ayotade & Fagade, 1995).

The experiment was laid out in a randomized complete block design with three replications. The levels of nitrogen used were 0, 120 and 240 kg ha^{-1}, which were applied as urea (45% N). The N application was split: half was drilled into the soil prior to planting and half was top dressed onto the soil surface 90 days after planting (DAP). All plots were uniformly irrigated after planting to establish a stand. Water was subsequently applied to each plot at 1-, 2-, 3- and 4- week interval using gated pipe with approximately 100 mm of water applied at each irrigation. The experimental plot was 5 x 10 m, consisting of six rows of cane that were spaced 1.0 m apart. The sugarcane variety NCS – 005 was planted on 15 November of each season by placing stalk pieces end to end in furrows and covering lightly. The recommended agronomic and plant-protection practices in line with NCRI sugarcane production guidelines (Busari & Agboire, 1998) were employed during each growing season.

Growth parameters such as number of tillers per plant and stem height were taken on a random sample of five stools at 3 and 6 month after planting (MAP) respectively. At final harvest, the numbers of stalk stool-1 and cane yield were determined. Cane yield was assessed by weighing of all harvested cane of millable size. The leaf N content was analyzed using Kjeldahl procedures consisting of sulfuric acid digestion and steam distillation (IITA, 1995). All data were analyzed statistically using the GLM procedure of the SAS software (SAS, Institute Inc., 1985). Irrigation and nitrogen effects were evaluated by mean comparison using DMRT at 5% significant level.

Results

Growth

Number of tillers $plant^{-1}$ at 3MAP was significantly (P = 0.01) affected by N in the two seasons (Table 1). Each increase in N up to 240 kg ha^{-1} significantly increased the number of tillers $plant^{-1}$ except in 2002-03 season where the effect of N at 120 and 0 kg ha^{-1} are statistically at per. The effect of irrigation interval on number of tillers $plant^{-1}$ was significant (P= 0.01) in 2001-02 season only. Delayed irrigation from 1- to 2-week interval had no significant affect on the number of tillers $plant^{-1}$, a further delay from 2- up to 4-week interval significantly reduced the parameter. The interaction between N level and irrigation interval on number of tillers $plant^{-1}$ was not significant.

The variation in stem height due to N application was significant (P = 0.05) only in 2001-02 (Table 1), where N at 0 kg ha^{-1} was statistically at per with 120 kg ha^{-1}, but significantly higher than the 240 kg ha^{-1}. However, the effect of irrigation interval on stem height was highly significant in the two seasons. Each increase in irrigation interval accompanies a significant reduction in stem height in each season, except in 2002-03 season where differences in height between 3- and 4-week interval was insignificant. The interaction between N and irrigation on stem height was not significant in this study.

Table 1 showed significant (P = 0.01) effect of N application and irrigation interval on leaf N content in all the seasons. There was a linear increase in leaf N content with each increase in N rate. Similarly each increase in irrigation interval significantly increase leaf N content up to 3-week beyond which it stabilizes. No significant interaction between N and irrigation interval on leaf N content was recorded in both seasons.

The results in Table 1 indicate that N rate had significant (P = 0.01) effect on number of stalks stool^{-1} in 2002-03 season only. Increasing the N rate from 0 to 120 kg ha^{-1} significantly increase the number of internodes stalk^{-1}, further increases in N to 240 kg ha^{-1} had no significant effect on the parameter. Irrigation interval caused significant variation in number of stalks stool^{-1} in both seasons, where each increase in irrigation interval significantly reduced the number of stalks stool^{-1} except the increase in interval from 1- to 2-week and from 3- to 4-week in 2001-02 and 2002-03 seasons respectively. The interaction between N level and irrigation interval on number of stalks per stool was not significant in this study.

Cane yield

Mean yield data of sugarcane due to N level, irrigation interval and their interaction are presented in Table 1. The results showed that N application and irrigation interval had significant (P = 0.01) influence on cane yield in the two seasons. In 2001-02 season, N at 0 kg ha^{-1} had significantly lower cane yield compared with N at 120 and 240 kg ha^{-1} that were statistically at par. In 2002-03 season, each increase in the level of N resulted in a significant increase in cane yield. With regard to the effect of irrigation, significant increase in cane yield with each successive increase in irrigation interval was observed in all the season

The interaction between N level and irrigation interval on cane yield was significant (P= 0.01) in 2002 -03 season only (Table, 2). With irrigation at 1- and 4-week intervals, each increase in the level of N had significant affect on cane yield. Nevertheless, at 2- and 3-week interval, N at 0 kg ha^{-1} had significantly lower cane yield compared to 120 and 240 kg ha^{-1} that were statistically at par. With different irrigation intervals, the interaction further showed that at 0 kg ha^{-1} an increase in interval from 1- up to 3-week had significant effect on cane yield. When N was applied at 120 and 240 kg ha^{-1}, a significant reduction in cane yield was observed with each increase in irrigation interval.

Discussion

Statistically significant difference in cane growth characters were observed as N rates increased from the non-fertilized control (0kg ha^{-1}) treatment to the highest rate (240 kg ha -1). The increase in growth with increase N application may be due to greater growth of plant organs at high than at low N rate, as crop growth included increase in dry matter and increase in size and weight of plant organs (El-Sayed, 1996). Similarly, Cock (2003) observed that sugarcane growth and development involved the growth of vegetative organs, stems and roots. Furthermore, statistically valid increase in cane yield was recorded with rates of N application over the no-N treated control. The increasing trend in cane yield with increase N rate may be related to greater effect on biomass with higher N during the preceding period of growth (Yahaya, *et al*., 2007) and probably also to greater allocation of dry matter to the stem at maturity. Allison and Pammenter (2002) reported 20 percent greater stem dry mass with higher than low N rates at 178 DAP and ascribe the increase production of biomass on the crop to increase size and efficiency of the photosynthetic system,

Generally, cane growth characters responded significantly to irrigation interval. The response of cane growth to irrigation has been reported (Kadrivelu & Ragan 1991; Muchow & Keating, 1998). There was a significant decline in cane yield with increase in irrigation interval from 1- up to 4-week in this study. The observed reduction in cane yield with increased interval of irrigation may be due to the effect of soil moisture stress on cane growth and subsequently yield. This is consistent with the opinion of Azzazy and El-geddawy (2003) who suggested that adverse moisture condition at early stage of crop growth was detrimental to the development of physical component of cane yield like shoot population and thickness, length and weight of cane stalks. Similarly, Singh *et al*., (2000) reported the sensitivity of sugarcane growth and yield to soil water stress.

The result of interaction showed that when no fertilizer was supplied, cane yield rose with increased irrigation interval from 1- to 2-week beyond which yield decline as the interval was raised. When N was supplied to the crop, a general decline in yield was observed as the interval of irrigation was increased from 1- to 4-week under this condition; the prediction is that increased irrigation intervals lead to a gradual depletion of soil water content creating a moisture deficit and stress on the crop as previously reported by Yahaya, *et al*., (2008). Similarly, Wolf *et al*., (1988) have indicated that the interaction between water stress and N deficiency can have a significant impact on crop yield.

Table 1 Effects of Nitrogen Rate, Irrigation Interval and Their Interaction on Growth Parameters and Cane Yield In 2001-02 And 2002-03 Seasons

	Tillers plant^{-1} 3MAP		Stem height (cm) 6MAP		Leaf N content (%)		Number of stalks stool^{-1}		Cane yield (t/ha)	
Treatments	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03
Nitrogen level (kg/ha)										
0	12.92c	6.08b	142.42a	209.03	1.27c	1.19c	12.75	8.25b	63.14b	46.56c
120	16.00b	6.58b	137.42ab	212.58	1.62b	1.52b	12.42	9.17a	72.51a	55.19b
240	17.67a	8.92a	134.92b	220.77	1.77a	1.71a	13.17	9.00a	71.98a	62.26a
SE ±	0.36	0.22	1.94	4.42	0.04	0.04	0.23	0.24	1.00	0.67
Significance	**	**	*	NS	**	**	NS	*	**	**
Irrigation interval (week)										
1	17.67a	6.78	156.22a	240.98a	1.93a	1.83a	14.89a	11.22a	83.56a	74.93a
2	16.89a	7.44	143.89b	223.33b	1.70b	1.60b	14.22a	10.11b	78.94b	62.06b
3	15.22b	7.22	130.22c	199.20c	1.34c	1.25c	12.11b	07.33c	62.77c	45.04c
4	12.33c	7.33	122.67d	192.47c	1.26c	1.20c	09.89c	06.56c	51.56d	36.65d
SE ±	0.41	0.26	2.24	5.11	0.05	0.05	0.26	0.28	1.15	0.77
Significance	**	NS	**	**	**	**	**	**	**	**
Interaction										
N x I	NS	NS	NS	NS	NS	NS	NS	NS	**	NS

Means followed by the same letter(s) within a column of a treatment group are not statistically different using DMRT. *, ** = significant at 5 % and 1 % levels, respectively. NS = not significant.

Table 3. Irrigation Intervals And Nitrogen Levels Interaction on Cane Yield (Tonne) Per Hectare in the 2002-03 Season.

Nitrogen level (kg/ha)	Irrigation interval (week)			
	1	2	3	4
	2002-03			
0	59.70_d	54.74_e	35.20_h	36.61_h
120	74.57_b	65.89_c	50.43_f	29.86_i
240	90.51_a	65.56_c	49.49_f	43.49_g
SE±	1.33			

Means followed by the same letter in the same column and rows are not statistically different using DMRT.

References

Allison, J.C.S. & Pammenter, N.W. (2002). Effect of nitrogen supply on the production and distribution of dry matter in sugarcane. *South African Journal of plant and Soil*. 19(1): 12-16.

Ayotade, K.A., & Fagade, S.O., (1995). Proc. Intern. Con. Wetland utilization Rice production Sub-Saharan Africa. 4 - 8 Nov. Ibadan, Nigeria. p.251-260. In:

Azzazy, N.B. & El-Geddawy, I.H. (2003). Effect of nitrogen fertilization on yieod and quality of some sugar cane varieries under developed surface irrigation system. *Egypt journal of agricultural Research.* 81(3): 1137-1147.

Azzazy, N.B., El-Shafai, A.M.A. & El-Geddawy, I.H. (2000). Yield and quality of stubble cane as affected by irrigation, nitrogen fertilization, and varieties. *Egyptian Journal of Agricultural Research.* 78(4): 1615-1624.

Busari, L.D., & Agboire, A., (1998). Training manual on sugarcane production. *National Cereals Research Institute* Badeggi. p. 1-65.

Cock, J.H. (2003). Sugarcane Growth and Development. *International Sugar Journal.* 105 (1259): 540-552.

El-Geddawy, I.H., El-debaby, A.S., Saad, A.M.M. & Azzazy, N.B. (1997): Irrigation systems and nitrogen fertilizer in relation to yield and quality of sugarcane varieties. *Egyptian Journal of Agricultural Research,* 75(4): 1037-1052.

El-sayed, G.S., (1996). Plant population and nitrogen fertilizer and their effect on yield and quality of some sugarcane varieties. M.Sc. Thesis. *In*: Yousef, *et al*., 2000. Influence of some cultural practices on yield and yield components of some sugar cane varieties. Egypt. J. Agric. Res. 78(5):1995-2008.

Glaz, B., Powell, G., Perdomo, R. & Ulloa, M.F. (2000). Sugarcane genotype response to phosporus fertilizer in the everglades. *Agronomy journal*. 92:887-894.

Ismail, A.M.A., El-Amary, T.S. & Azzazy,N.B. (2000). Response of yield and quality of sugarcane to nitrogen and zinc fertilization. *Egyptian Journal of Agricultural Research*. 78 (3): 1161-1168.

IITA, (1975). Selected methods for soil and plant analysis. International Institute for Tropical Agriculture. Ibadan Nigeria. p. 44.

Muchow, R.C., & Keating, B.A., (1998). Assessing irrigation requirements in the Ord Sugar Industry using a simulation modeling approach. *Australian J. Expl. Agric.* 38: p. 345-354.

Jones, C.A. (1980). A review of evapotranspiration studies in irrigated sugarcane in Hawaii. Plant Rec., 59:195-214.

Kadrivelu, A.K. & Rajan, S.D. (1991). Irrigation cum trash mulching in sugarcane culture on sandy soils of Pandiyarajapuram Factory Zone (Madurai District). *The Madras Agricultural Journal*. 5: 189-194.

Qureshi, M.E., Wegener M.K., Harison, S.R. & K.L. Bristow (2001). Economic evaluation of irrigation system for sugarcane in the Burdekin delta in north Queensland, Australia, Water Resource Management, edited by brebbia C,A., Anagnostopoulos, K., Katsifarakis, K. and A.H.D. Cheng., WIT Press, Boston, pp.47-57.

Santo, L.T. (1987). Effects of irrigation and nitrogen on yields of drip irrigated sugarcane, Rep. Hawaii Sugar Technol., pp. A21-A23

SAS Institute, Inc. (1985). SAS/STAT™ guide for personal computer. 6th ed. *SAS Inst.* Cary NC.

Wiedenfeld, R.P. (1996). Effects of irrigation and nitrogen fertilizer application on sugarcane yield and quality. *Field Crops Research* 43: 101-108.

Worlf, D.W., Henderson, D.H., Hsiao, T.C. & Alvino, A. (1988) Interactive water and nitrogen effects of senescence of maize. I. Leaf area duration nitrogen distribution, and yield. *Agronomy Journal* 80: 859-864

Yahaya, M.S., Falaki, A.M., Ahmed, M.K., Amans, E.B. & Busari, L.D. (2007). Response of sugarcane (*Sacchrum officinarum* L) to nitrogen levels and irrigation frequency. *Unpublished PhD Dissertation,* Department of Agronomy, ABU Zaria, Nigeria.

Yahaya, M.S., Falaki, A.M., Ahmed, M.K., Amans, E.B. & Busari, L.D. (2008). Effect of Nitrogen Fertilizer and Irrigation Interval on Sugarcane (*saccharum officinarum L*) **I**: Yield Attribute and Cane Yield. *Biological and environmental science journal for the tropics. vol. 5. No. 4.*

Appendix 1. Some Characteristic of the Soil at the Experimental Site 2002-03 And 2003-04 Seasons

COMPOSITION	**2001-02**	**2002-03**
Physical Properties (%)		
Sand	90.940	90.900
Silt	7.980	7.990
Clay	1.070	1.000
Textural class	Sandy	Sandy
Chemical Properties		
pH in H_20 (1:2.5)	5.100	5.200
Organic carbon (g/kg)	0.610	0.480
Organic matter	2.410	1.140
Total nitrogen	0.030	0.070
Available phosphorus (mg/kg)	7.790	7.870
Exchangeable Cations (cmol/kg)		
Potassium	0.130	0.250
Magnesium	0.330	0.230
Calcium	1.200	1.200
Sodium	0.120	0.150
C.E.C	5.740	5.800