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Effect of irrigation intervals on the yield of three released sugarcane varieties in Nigeria

Ethan, S.*, A.K. Gana, A.C. Wada and J. Baba

National Cereals Research Institute Badeggi P.M.B. 8, Bida, Niger State, Nigeria

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A field experiment was conducted in 2008-2010 to evaluate irrigation intervals that would improve the production of sugarcane. Effective rainfall was also considered in meeting the sugarcane water requirements since sugarcane is a long duration crop. The irrigation intervals used were 7, 14 and 21 days and the equivalent soil moisture potentials were 33, 45 and 60 kPa respectively. The results showed that NCS 002, NCS 003 and Co 957 sugarcane varieties performed very well at 7 days irrigation interval. The highest stalk yield was obtained from NCS 002 with a value of 65 t ha^{-1}. Irrigation at 14 and 21 days intervals led to decline in yield when compared with 7 days irrigation interval. Roots were observed to be deeper at 21 days irrigation interval, signifying deep exploitation of soil moisture because of water stress experienced by the crop. Crop water use was affected by varying irrigation intervals and the highest water use was obtained from the 7 days irrigation interval.

Keywords: Irrigation Interval, water requirements, sugarcane varieties, sugarcane yield.

Introduction

In many parts of the world, crop production is often constrained by water together with soil characteristics and evaporative demand. These also determine the pattern of water availability for plants overtime and the ensuing crop biomass and economic yield (Qureshi *et al*. 2002). To optimize crop yields in an irrigated environment, irrigation should be timed in a way that non-productive soil evaporation and drainage losses are minimized. Water deficits should coincide with the least sensitive growth stages of the crop (Arora and Garji, 1998).

Irrigation practice in use for a long time is the application of irrigation water to agricultural fields based on fixed-rotation, where water is normally applied to agricultural fields on a weekly or 14-days basis. Together with the simple flood or furrow irrigation techniques used and low level of training of

* Corresponding author: Ethan S; e-mail: sauletham@yahoo.com

the farmers, current water distribution policy makes it difficult to vary irrigation depth or frequency based on crop needs. Consequently, any model-based irrigation schedules developed should at least on a seasonal basis, adhere to constant irrigation intervals and irrigation application depths. However, given the limited water resources it is imperative to establish irrigation depths and intervals, be they weekly to bi-monthly, which minimizes water losses.

Nutrient uptake from soil solution is closely linked to plant root and water status. A decline in soil moisture is associated with a decrease in the diffusion rate of nutrients from the soil matrix to the absorbing root surface (Mujtaba and Alam, 2002). The reduction in uptake and transpiration are usually associated with a reduction in the water content of the shoots and stomata aperture, because water stress has developed in the leaves. Maximum water uptake occurs in young roots, but continued aging of the roots after cessation of growth would result in reduction in the root permeability to water and nutrients (Mujtaba and Alam, 2002). Water and nutrient uptake due to reduced root permeability causes disturbance in root metabolism. Changes in soil moisture regime can alter root morphology and anatomy, pore size distribution, and angle of root penetration, which affect root proliferation. Mineral uptake decreased when water stress is increased.

The objective of this study therefore, was to determine irrigation interval suitable for sugarcane production, given limited water supply during the offseason.

Materials and methods

Experimental site

The experiment was conducted at the upland sugarcane research field, located at latitude $9^{0}06^{'}$N and longitude $5^{0}59$'E Badeggi on sandy loam soil. Average rainfall for the area was 1200 mm with distinct wet and dry season. The soil of the study area was sandy loam in texture, sand 72.2 %, silt 18.3 % and clay 9.5 % with a bulk density of 1.3 g cm^{3}. It was derived from Nupe sandstone (Table 1).

Table 1. Physico-chemical properties of the soil at the experimental site.

Sand (%)	72.2
Silt (%)	18.3
Clay (%)	9.5
pH (H_2o)	6.0
O C (%)	0.83
O M (%)	1.48
Total N (%)	0.07
Av. P (cmol kg^{-1})	0.03

Exch.K (cmol kg^{-1})	0.26

Experimental design

The experiment was laid out in a split plot design with water management as the main plot and varieties as the subplot replicated 3 times. The irrigation intervals were 7, 14 and 21 days while the varieties of sugarcane evaluated were NCS 002, NCS 003 and Co 957. Plot size was 4.0 x 5.0 m and the fertilizer application rate was 120 kg N ha^{-1}, 60 kg $P_20_5ha^{-1}$, 90 kg K_2 ha^{-1} and row spacing was 1 meter.

Crop factor (Kc)

The crop factors shown in Table 2 were derived from those defined by Doorenbos and Kassam (1979) and was used to estimate crop evapotranspiration (ETc).

Table 2. Crop factors (Kc) at different sugarcane growth stages.

Crop age months	Growth stage	Kc
0-1	Harvest to 0.25 full canopy	0.40
1-2	0.25 – 0.5 full canopy	0.70
2 – 2.5	0.5 - 0.75 full canopy	0.95
2.5 – 4	0.75 to full canopy	1.10
4 – 10	full canopy	1.15
10 – 11	early senescence	0.85
11 – 12	ripening	0.65

Crop evapotranspiration (ETc)

The crop evapotranspiration (ETc) was obtained by multiplying the ETo by the appropriate crop factor (Kc) according to the equation given by Doorenbos and Kassam (1979). Reference evapotranspiration (ETo) was calculated from the following equation:

$$ETo = Epan \times 0.7 \quad (1)$$
$$ETc = ETo \times Kc \quad (2)$$

Where ETc is crop evapotranspiration, ETo is reference crop evapotranspiration and Kc crop factor and Epan is class A pan evaporation.

Effective Rainfall (Re)

Rainfall data for 2 years was converted to effective rainfall according to the following equation (Hershfield, 1964):

$$Re = 0.9\ (R-2)\ SMD \qquad (3)$$

Where R is rainfall and SMD is soil moisture deficit.

Soil moisture deficit was determined gravimetrically and soil moisture potential was determined for every treatment with a tensiometer before irrigation water was applied. This was on average -33 Kpa for 7 – day irrigation interval, 45 Kpa for 14-day interval and 60 Kpa for 21-day interval.

Results and discussions

Effect of irrigation interval on yield and growth components of sugarcane

Table 2 shows the effect of irrigation intervals on growth components of sugarcane crop. There was significant difference in the stalk lengths of the sugarcane varieties irrigated at 7, 14 and 21 days intervals with values ranging between 86.30 cm and 98.02 cm. Irrigation at 7 days interval had the longest stalk lengths with a value of 98.02cm, this was so because of the adequate soil moisture of the treatment. While the shortest stalk lengths were obtained from irrigation interval of 21 days. This implies that irrigation at 7 days interval was suitable for stalk length elongation of sugarcane in this area because the canes were not subjected to water stress. This is in agreement with the study conducted by Qureshi *et al*. (2002) who observed 7 days irrigation interval as suitable for sugarcane production.

Similarly, significant differences were observed in the stalk girth of sugarcane due to the irrigation intervals imposed with values ranging from 1.90 and 2.30 cm. However, there was no significant difference in stalk girth of the canes at irrigation intervals of 14 and 21 days with values of 1.90 and 2.12 cm respectively in the 2 seasons of the study. Thus, suggesting that the canes have some degree of tolerance to water stress.

Internode lengths varied between 14 and 16 cm and were significantly different due to water management. Irrigation interval of 7 days had the longest internodes while the shortest was recorded from irrigation interval of 21 days. This was expected because irrigation interval of 7 days had adequate soil moisture for growth and development. Canes subjected to water stress often have shorter internode lengths (Qureshi *et al*. 2002).

There was also significant difference recorded in stalk yield due to irrigation scheduling with yields ranging between 47.87 and 61.64 t ha^{-1}. Seven-day irrigation interval had the highest stalk yield with a value of 61.64 t ha^{-1}. However, irrigation at 14-day and 21-day intervals had no significant differences with values of 47.87 and 50.89 t ha^{-1} respectively. This shows tolerance of the canes to drought conditions imposed. The yield formation or grand growth period is the most critical period for moisture supply in sugarcane. This is because the actual cane build-up or stalk growth takes place in this period. The production and elongation of internodes and its expansion, girth improvement, ultimately the stalk weight takes place in this period. It is also the period for production of sugar storage tissue. Water deficit at this stage will be inimical to the growth and yield of sugarcane.

Table 3. Main and subplot effects on yield and yield components of sugarcane

Irrigation Interval (IRR)	**Yield (t/ha)**	**Stalk length (cm)**	**Stalk Girth (cm)**	**Internode Length (cm)**
7 days	61.64 a	98.02 a	2.30 a	16 a
14 days	50.89 b	86.30 b	2.12 b	15 b
21 days	47.87 c	86.19 b	2.19 b	14 c
SEM	6.15	5.58	0.05	0.92
Varieties (Va)				
NCS 003	42.75 c	81.97 c	2.02 b	14 c
Co 957	58.32 b	91.61 b	2.07 b	16 a
NCS 002	65.25 a	99.90 a	2.27 a	15 b
SEM	1.78	3.17	0.04	8.84
Interactions				
IRR x Va	NS	NS	*	*

*Sinificant at $p < 0.05$, Means followed by same letters are not significantly different. Ns = not significant

The effect of subplot treatments on the growth and yield of the varieties

The effect of irrigation scheduling on the stalk length of the varieties was significant with values ranging from 81.97 and 99.90 cm (Table 3). Variety Co 957 had the longest stalks and the shortest stalk lengths were obtained from NCS 003. The analysis indicates that NCS 002 gave the highest stalk yield in the 2 seasons. Similarly, there was significant difference in the stalk girth of the varieties with values ranging from 2.02 and 2.27 cm. Variety NCS 002 had recorded the highest stalk girth with a value of 2.27 cm. However, NCS 003 and Co 957 were not significantly different in stalk girth. The interaction between irrigation interval and varieties was significant with respect to stalk girth, signifying the influence of the 2 factors on stalk girth. There was significant difference in the internode lengths of the three varieties. Variety Co 957 had the longest lengths of internodes while NCS 003 had the shortest with values ranging from 14 and 16 cm. There was significant interaction of irrigation intervals and varieties on the internode lengths. Significant differences were also recorded on stalk yield of the 3 varieties with values ranging between 42.75 and 65.25 t ha^{-1}. Variety NCS 002 had the highest yield; the lowest was however obtained from the variety NCS 003. Interaction between irrigation interval and variety was not significant. Evaluation of the varieties had shown that NCS 002 performed better than the other varieties developed by National Cereals Research Institute under the prevailing soil and climatic conditions.

Effect of irrigation scheduling on root growth of sugarcane

Sugarcane is a long duration crop producing huge amounts of biomass. The crop is classed among those plants having high water requirement and yet it is drought tolerant.

Root distribution of sugarcane raised on sandy loam soil irrigated at 21 days interval is shown in figure 1. Root biomass of sugarcane at 20 cm soil depth was 30% and was the highest concentration while at 120 cm soil depth the concentration was only 5%. Roots of 12 months old crop were more distributed under less frequent irrigation, presumably in response to drying of the surface. Deeper rooting as obtained from the 21 days irrigation interval reduced the vulnerability of crops to soil water deficits by providing increased capacity for uptake of deep reserves of soil water. It also helped in reducing lodging of sugarcane.

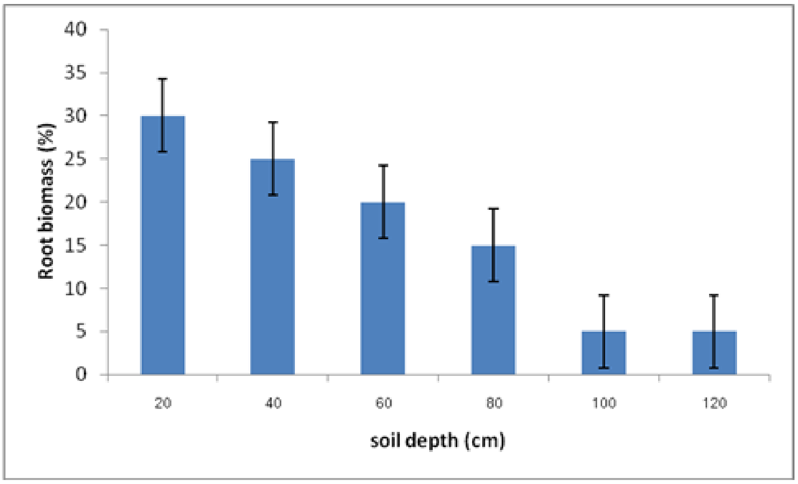

Fig. 1. Root biomass at various soil depths. Vertical bars indicate standard error.

Water management of sugarcane

During the offseason there is always competition in using the scarce water resources from the perennial stream by domestic, industrial and agricultural water users. Application of irrigation water at 7 days interval had the highest values of water applied and water use for the sugarcane production (Table 4). The lowest values for water applied and water use were however obtained from irrigation at 21 days interval. Irrigation at 14 and 21 days intervals had less water use than the 7 days interval and this had detrimental effects on the cane yield. Contribution of effective rainfall reduced the amount of irrigation water that could have been applied (irrigation events). Overall, results show that the most likely irrigation strategy that would optimize the use of limited water supply appeared to be 7 days irrigation interval. Which depending on the dose at the different moisture tensions provided crop water satisfaction. Strategies based on the management of the soil moisture deficit systematically required less irrigation than the scenarios based on irrigation frequencies and irrigation doses.

Table 6. Water requirement of sugarcane

Irrigation Interval (days)	Water applied (mm)	Water use (mm)	Effective Rainfall (mm)	Soil moisture Deficit (%)
7	1520	875	314	12
14	1270	702	370	23
21	1020	532	385	34

Conclusion

The sugarcane varieties developed by national Cereals Research Institute Badeggi NCS 002, NCS 003 and Co 957 were tested for irrigation intervals and drought tolerance. The results showed that irrigation interval of 7 days at soil moisture tension of 33 KPa had the highest stalk yield. However, irrigation at 14 days interval witnessed a decline in stalk yield at soil moisture tension of 45 KPa. The lowest yield was obtained at irrigation interval of 21 days at soil moisture tension of 60 KPa. The results indicated that NCS 002 and Co 957 are more tolerant to drought than NCS 003 in that environment and also irrigation interval of 7 days is suitable for the sugarcane varieties. However, irrigation at 14 days interval could be used in situations of scarce water supply with little decline in yield.

Roots of a 12 month old crop were more uniformly distributed under less frequent irrigation at 21 days interval. Presumably in response of the drying conditions of the surface soil. Deeper rooting reduced the vulnerability to soil water deficits by providing increased capacity for uptake of deep reserves of soil water. It also helped in reducing lodging of sugarcane.

References

Arora, V.K., Garji, P.R. (1998). Evaluation of crop growth-water balance model for Analyzing wheat response to climate and water limited environments. Field crop Res. 59:213- 224.

Doorenbos, J., and Kassam, R.H. (1979). Yield response to water. *F.A.O* Irrigation and Drainage paper No 33, F.A.O. Rome .

Hershfield, D.M. (1964). Effective rainfall and irrigation water requirement. Proceedings of the American Society of Civil Engineers, Journal of Irrigation and Drainage Division. 90:33-37.

Mujtaba, S.M., and Alam, S.M. (2002). Drought phenomenon and crop growth. Pers. Communication.

Qureshi, S.A., Madramootoo, C.A. and Dodds, G.T. (2002). Evaluation of irrigation Schemes for sugarcane in Sindh, Pakistan, using SWAP 93. Agricultural water Management 54:37- 48.

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