EFFECT OF MOISTURE STRESS ON BIOMASS YIELD OF SUGARCANE AND ITS ROOT CHARACTERISTICS

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ABSTRACT
30 sugarcane accessions were screened for drought tolerance using polythene bags arranged in completely randomized design in three replicates. The experiment was conducted for two years. From the results, accessions were different in tolerance to moisture stress. Accessions with high desiccation score (susceptible) could not recover even after two weeks of moisture relief. Accessions that showed less symptom of desiccation were also observed to have fewer roots and lower root weights. Low root : shoot ratio was generally observed thus indicating that shoot growth was greater than root growth. Screen house screening is however not enough to justify selection of drought tolerant sugarcane varieties as it must be complemented with field screening.

Key words: Moisture stress, biomass yield, roots, sugarcane, drought

INTRODUCTION
Sugarcane (*Saccharum officinarum* L.) is an important cash crop grown mostly in the tropics and sub-tropical regions of the world. It is normally propagated vegetatively using cane setts. Commercial cultivation of sugarcane did not start in Nigeria until 1950 while industrial production of refined sugar began early 1960s with the establishment of the Nigeria Sugar Company (NISUCO) at Bacita (Busari and Misari, 1996). Although sugarcane is widely grown in many ecologies, in Nigeria it is grown predominantly under rain fed conditions and suffers from moisture stress at one stage of its growth or the other since it takes between 10-12 months to mature.

Sugarcane is a remarkably drought tolerant plant as it is observed to grow under conditions of severe drought (Moore, 1987). This is usually through structural modification such as deep wide spreading root systems, an efficient conducting system and a small reduction in leaf area, and other various mechanisms (Levitt, 1972). These factors slow down the development of internal water deficits and thereby delay the occurrence of drought injury.

Despite great potentials of new sugarcane varieties, the frequent occurrence of drought occasioned by erratic rainfall distribution and early cessation of rains is the greatest hindrance to increased sugarcane production (Olaoye, 1999). Drought resulting from moisture stress is therefore one of the several factors that reduce cane and sugar yields, especially under non-irrigated condition. Little success in screening plants for drought tolerance has been obtained through selection for morphological features such as extensive root systems (William *et al*, 1967). Screening for root characteristics is also difficult because of the underground distribution of roots and associated soil variations (Krishnamurthy *et al*, 1996). Consequently, identification of traits that adapt plants to drought would be a strategy for yield improvement under moisture stress condition. It is therefore intended to study the influence of root characteristics and associated biomass yield in adaptation of sugarcane to moisture stress.

MATERIALS AND METHODS
In November 1999, stalks of the 30 accessions of sugarcane clones were cut into one-eye-bud setts and pre-sprouted. The sprouted buds were planted in polythene bags filled with topsoil, 20cm deep and 5cm wide. The experimental materials were arranged on screen house benches in a completely randomized design and replicated three times. Two moisture regimes were used for this study, viz: normal watering (control) and water

withdrawal. All plants were initially watered for four weeks after planting (WAP), and then stressed for two weeks. Plant desiccation score was taken at 7, 11 and 14 days of moisture stress based on a scale rating in Table 1 (IRRI, 1984). Watering of the stressed experimental materials was resumed for one week to allow for recovery of desiccated plants.

The polythene bags were carefully cut open and the soil mass washed off to extract the roots. All the roots arising from the crown were counted, weighed and dried to constant weight. The fresh weight of the shoot was also taken. After oven drying, both the roots and the shoot dry weights were taken. Percent moisture losses from both root and shoots were then determined using the gravimetric method

$$MC = \frac{Fresh\ weight - Dry\ weight}{Dry\ weight} \times 100$$

MC = Moisture Content

The root: shoot dry matter ratio was also computed as

$$\frac{Root\ dry\ weight}{Shoot\ dry\ weight}$$

The experiment was repeated in 2001 and the same data were collected to ascertain the precision of the procedures and methodologies used in the screen house exercise. The results of the two years were pooled and analyzed using Analysis of Variance.

RESULTS AND DISCUSSION

Mean performance of the accession for desiccation and recovery ratings across years are presented in Table 1. Results showed significant differences among the accessions but with N7 and F141 exhibiting tolerance, while other accessions were either moderately resistant or susceptible. Few accessions viz: N7, F141, USRI24, Bida Local, Co740, KN-10, OG-06 also recovered quickly following re-watering, which is an indication of some level of tolerance to moisture stress in these accessions. Except few accessions (F141, USRI24, N7, Cos510, KN-10, Co1148, Co312 and BJ6252) which had low score, most of the accessions did not recover from moisture stress even after two weeks of moisture relief (recovery). Drought, being a complex trait is known to manifest in different ways. Some of the accessions (Co396, Co421, B63340, Co285, USRI24, and B70607) that were observed to be susceptible under the screen house condition exhibited tolerance under a similar condition in the field (Ishaq *et al* 2002). This could be due to the fact that the roots of such accessions that were tolerant in the field but susceptible under the screen house condition required a wider spacing for root expansion; which was not available in the polythene bags used in the screen house.

Means across years for biomass yield and root characteristics in the screen house are presented in Table 2. Significance differences were observed for all characters in both moisture stress and unstressed condition. Biomass yield in unstressed condition was generally more than four times the yield in stressed condition. Co453 was superior for biomass yield in both moisture stressed and non-moisture stressed conditions. In non- moisture stressed condition Co404 had the highest root dry weight which was significantly different from those of many genotypes while KD-10 had the lowest weight. Number of roots was highest in Bida local under moisture stress condition and significantly higher than other accessions. In the unstressed condition however, OG-08 had the highest number of roots which was significantly higher than most other accessions. This shows that number or weight of root does not depend on tolerance ability of sugarcane accessions. It probably depends on number of viable eye buds on cane setts. Previous studies by Blum, (1988) have shown that plants with well developed extensive and deep roots tolerate drought better than those with shallow and fewer roots. Narayan and Misra (1989) also observed that some crop varieties have roots, which penetrate deeply in moisture stressed condition in order to find water that is not available at the soil surface. However in this study, the accessions that showed less symptoms of desiccation were those with fewer numbers of roots and also with lower root weight. This may be due to the fact that root development in sugarcane is different from those of other crops. For example, unlike sorghum, rice and most other grain crops, extensive roots could develop in sugarcane without a corresponding shoot growth. Furthermore, Sugarcane usually develops two types of roots viz: the sett roots, which grow first, and then the shoot roots (Venkataramana and Naidu, 1989). The latter is the supportive root upon which sugarcane depends to source nutrients up till maturity. The roots formed during the screen house study were essentially the sett roots rather than the shoot roots, which often replace sett roots during active vegetative phase (Barnes, 1974).

Table 1: Mean desiccation and recovery scores for 30 sugarcane accessions subjected to two moisture regimes in the screen house (2000 and 2001 combined).

S/N	Accessions	*Plant desiccation			*Plant recovery		
		7 days	11 days	14 days	5 days	10 days	14 days
1	Co997	2.17	7.67	8.00	8.33	8.00	7.67
2	OY-21	1.00	3.33	7.33	7.00	6.00	5.33
3	BJ6252	2.17	2.83	6.33	6.33	4.67	4.00
4	OY-12	4.67	6.00	7.33	7.33	7.00	6.33
5	Co312	1.33	2.00	4.00	5.67	4.67	4.33
6	NCS-005	4.67	7.33	8.67	9.00	9.00	9.00
7	Co396	1.83	4.50	6.00	6.00	5.67	5.33
8	OG-08	3.17	7.00	8.00	6.67	6.00	5.67
9	KD-10	0.50	4.50	6.33	6.33	6.00	5.67
10	Co1148	1.50	4.00	6.00	5.33	4.33	4.00
11	Co421	4.50	5.33	7.00	7.00	6.33	5.67
12	B63340	0.50	2.83	6.33	5.67	5.33	5.33
13	Co404	3.00	5.33	8.67	7.33	6.33	6.33
14	C0453	2.67	5.00	8.00	7.67	7.33	7.33
15	KD-11	0.67	2.33	6.00	5.33	4.33	4.00
16	KN-10	1.83	4.67	6.67	4.33	3.00	2.67
17	KD-01	0.67	4.83	3.70	7.33	7.00	6.33
18	Co285	1.00	3.00	6.67	6.00	5.67	5.33
19	N7	1.00	1.17	1.83	2.00	1.67	1.33
20	OG-06	1.67	2.67	5.00	5.33	5.00	3.67
21	USRI24	0.53	2.00	4.33	4.33	3.33	2.33
22	B70607	0.17	2.00	5.33	5.00	4.83	4.67
23	F141	0.00	0.67	2.00	1.33	0.83	0.33
24	Co331	0.33	3.00	6.67	7.67	7.00	7.00
25	LS-8	1.33	4.33	8.00	7.67	7.00	6.67
26	BD-06	1.83	2.33	5.33	5.67	4.67	4.67
27	Bida Local	1.83	3.00	5.00	4.00	3.33	2.67
28	Sok-02	2.50	6.33	7.67	7.00	6.33	6.00
29	Co740	2.50	4.67	7.33	7.33	7.00	2.67
30	Cos510	3.33	3.67	4.33	4.33	3.33	6.67
	LSD	2.42	2.82	3.67	2.39	2.25	2.36
	CV(%)	39.46	34.22	36.36	24.61	25.96	29.18

*** 1 3=tolerant, 4 9=susceptible**

Table 2: Biomass yield and root characteristics of 30 sugarcane accessions subjected to two moisture regimes in the screen house (2000 and 2001 combined).

		Biomass yield (g)		Root dry wt (g)		No. of roots		Root/shoot dry wt ratio	
S/N	Accessions	Stressed	Unstressed	Stressed	Unstressed	Stressed	Unstressed	Stressed	Unstressed
1	Co997	1.16	10.67	0.97	1.67	35.83	39.00	2.52	0.36
2	0Y-21	1.46	7.68	0.45	2.05	26.33	34.83	0.50	0.27
3	BJ6252	1.44	6.22	0.28	2.08	26.67	30.50	0.22	0.33
4	0Y-12	1.76	5.99	0.52	1.54	26.50	24.83	0.33	0.28
5	Co312	1.90	4.65	0.46	2.30	27.83	27.17	0.28	0.52
6	NCS-005	1.20	8.03	0.29	2.51	30.83	39.50	0.22	0.30
7	Co396	1.99	10.46	0.85	1.36	31.17	39.50	0.46	0.13
8	OG-08	1.99	7.74	0.87	1.42	30.17	49.17	0.89	0.21
9	KD-10	1.42	9.19	0.55	0.57	35.00	39.17	0.37	0.25
10	Co1148	1.55	5.65	0.48	0.97	23.67	28.50	0.31	0.18
11	Co421	2.01	7.60	0.84	1.97	23.67	40.00	0.45	0.28
12	B63340	1.48	7.87	0.34	1.41	22.17	29.33	0.13	0.20
13	Co404	1.35	9.03	0.47	2.89	21.67	35.00	1.32	0.33
14	C0453	4.25	11.39	1.08	1.39	35.00	42.83	0.27	0.17
15	KD-11	2.95	7.17	0.48	1.22	25.17	36.67	0.22	0.21
16	KN-10	3.01	4.64	1.10	1.15	20.67	20.50	0.42	0.25
17	KD-01	2.00	7.85	0.53	1.17	31.67	40.83	0.26	0.20
18	Co285	1.39	8.28	0.35	0.83	27.17	31.83	0.26	0.11
19	N7	1.68	4.69	0.80	1.54	25.33	26.50	0.56	0.32
20	OG-06	2.13	5.63	0.42	0.96	21.50	43.67	0.20	0.28
21	USRI24	2.12	3.79	0.57	1.08	31.83	27.17	0.26	0.30
22	B70607	1.10	7.85	0.16	1.01	26.17	32.00	0.16	0.16
23	F141	2.19	9.53	0.17	1.55	23.17	31.17	0.12	0.33
24	Co331	1.49	8.22	0.58	1.47	25.67	35.17	0.72	0.18
25	LS-8	2.39	6.68	0.51	1.16	21.00	30.67	0.30	0.21
26	BD-06	2.07	4.76	0.91	1.35	30.00	40.67	0.44	0.30
27	Bida Local	2.78	6.44	0.62	1.59	45.50	41.50	0.24	0.25
28	Sok-02	1.38	5.77	0.42	1.87	33.50	33.67	0.40	0.34
29	Co740	1.59	7.08	0.27	1.10	26.67	23.50	0.16	0.16
30	Cos510	2.48	8.07	0.45	2.67	35.00	43.33	0.19	0.31
	LSD	0.94	2.38	0.43	0.60	7.92	10.48	0.80	0.17
	CV(%)	30.66	20.37	46.10	24.03	17.32	18.56	33.46	41.26

Table 3: Means ranges and coefficient of variation (%) for Biomass yield root characteristics and of 30 Sugarcane accessions Subjected to two moisture regimes in the screen house (2000 and 2001 combined).

Trait	Mean		Range		Coeff. Variation (%)	
	Stressed	Unstressed	Stressed	Unstressed	Stressed	Unstressed
Biomass yield	1.907 ± 0.24	7.27 ± 0.61	1.10 – 4.25	3.79 – 11.39	30.66	20.37
Root dry weight	0.561 ± 0.11	1.56 ± 0.15	0.17 – 1.10	0.83 – 2.67	26.10	24.03
No. of roots	28.22 ± 1.99	34.61 ± 2.62	20.50 – 49.17	20.67 – 45.50	17.32	18.56
Root/Shoot ratio.	0.44 ± 0.13	0.26 ± 0.04	0.12 – 2.52	0.11 – 0.52	33.46	41.26

In terms of root: shoot dry weight ratio, the highest ratio was observed in Co997 in the stressed condition and this was significantly higher than for all other accessions. In the unstressed condition however Co312 had the highest root: shoot dry weight ratio which was significant but did not differ much from other accessions. Increase in root: shoot ratio is usually observed under moisture stress condition (Quizenbery, 1988). In this study, low root: shoot ratio was generally observed; which indicates that shoot growth was greater than root growth. Maji *et al* (1988) had earlier reported that root: shoot dry matter ratio in rice is not a reliable index of moisture stress as the distribution and volume of roots in the soil is important. Roots require wider space for expansion and for nutrient sourcing. Increase in root volume is usually a result of a reduced top growth relative to root growth. Krishnamurthy *et al* (1996) have also observed that several factors (in shoot and root) operate jointly or independently to enable plant to cope with drought stress.

Means, ranges and coefficient of variation across years for biomass yield and root characteristics are presented in Table 3. Means observed in the unstressed condition were higher than those of moisture stressed condition, which shows the adverse effect of drought stress on these characters. Large ranges in the means were also observed under unstressed condition except that number of roots had larger range in moisture stressed condition. Coefficient of variation was observed to vary much under both stressed and unstressed conditions.

CONCLUSION

Although drought is a complex trait, screening for its resistance must consider the environment and the traits. Screen house screening is however not enough to justify selection of drought tolerant sugarcane varieties for a breeding programme. It must be complemented with field result. Screen house result is however an indication of trait to be looked for when mass selection for such a complex trait is to be practiced especially in a large germplasm or when assessing drought tolerance at seedling level.

REFERENCES

Barnes, A.C. (1974). The sugarcane, 2nd edition Leonard Hill books London 572 pp.

Blum, A. (1988). Plant Breeding for stress environments CRC Press Inc. Florida USA Pp43-77

IRRI (1984). Standard Evaluation system for Rice Int. rice research Inst. Los. Banos Philippines

Krishnamurthy, L. C., C. Johansen, and O. Ito (1996). Genotypic variation in root system development and its implication for drought resistance in chickpea. In Root and Nitrogen in cropping systems of the semiarid tropics, edited by O. Ito *et al*. Pages 235 - 250

Levitt, J. (1972). Response of plants to Environmental Stresses. Academic Press New York. In: Plant Breeding for Drought Resistance by E.A. Hurd, Pp 3:2-53.

Maji A. T., B.N. Singh and M.E. Akenova (1996). Root development of rice, (*O. Sativa L. and O. glaberrima steud*) under drought condition. *Paper presented at the 35th Ann. Conf. Of ASN at National Cereals Research Institute Badeggi.* Pp 135-139

Moore, P. H. (1987). Physiological basis for varietal Improvement in sugarcane. *In: Proc. of Int. sym. On sugarcane varietal Improvement held at sugarcane Breeding Institute. Coimbatore, 3- 7 September, 1987.* Pp 19 -56.

Narayan D. and R. D. Misra (1989) Drought resistance in varieties of wheat (*Triticum aestivum*) in relation to root growth and drought indices. Ind. J. Agric Sci. 59 (9): 595- 598.

Olaoye, G. (1999). Developing drought tolerant varieties for the Savannah agro-ecologies of Nigeria. *In: Genetics and Food security in Nigeria in the 21st century. A commemorative publ. of GSN pp 173- 187.*

Quizenberry, J.E. (1988). Breeding for drought resistance and plant water use efficiency.

Venkataramana S., P. N. G. Rao and K. M. Naidu (1983) Evaluation of Cellular membrane thermostability for screening drought resistance in sugarcane varieties. *Sugarcane (No 4): 13- 15.*

Williams, T.V. R.S. Suell and J.F. Ellis (1967). Methods of measuring drought tolerance in corn. *Crop sci. 7: 179- 182.*