Effects of ratooning on yield and yield components of non-irrigated sugarcane germplasm accessions in the southern Guinea savanna zone of Nigeria

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ABSTRACT

The effects of ratooning on cane yield and its components were investigated in 48 sugarcane accessions grown under non-irrigated conditions in a typical savanna ecology of Nigeria. Cane yield suffered the highest percentage loss, ranging from 58 in the first ratoon crop (FRC) to 74 in the third ratoon crop (TRC), while sucrose in the juice, stalks/stool and leaf area were relatively unaffected by ratoon cropping. Yield loss (%) was highest in the flowering (F) than in the non-flowering (NF) genotypes, early and mid-flowering (EF, MF) genotypes than in the late-flowering (LF) genotypes. Results further showed that one of the check varieties (var. CO957) had greater adaptation to low available soil moisture than the others, while var. CO1001 had very poor tolerance level to soil moisture stress. For the economics of sugarcane production, the maintenance of ratoon crops, more than the second ratoon crop (SRC) in the F varieties and the TRC in the NF varieties may be unprofitable for growers who depend on natural rainfall in this zone.

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RÉSUMÉ

OLAOYE, G. : *Effets d'émission des rejets sur le rendement et les composants de rendement des accessions de germeplasme de canne à sucre non-irriguées au sud de la zone de savane-guinéenne du Nigéria.* Les effets d'émission des rejets sur le rendement de canne a sucre et ses composants étaient enquêtés en 48 accessions de canne à sucre cultivées sous les conditions non-irriguées dans une écologie typique de la savane du Nigéria. Le rendement de canne soufrait le pourcentage de perte le plus élevé variant de 58 dans la 1^{e} culture de repousse (PCR) à 74 dans la 3^{e} culture de repousse (TCR) alors que la saccharose dans le jus, les tiges/pieds et la surface foliaire étaient relativement non affecté par la culture de repousse. Le pourcentage de perte de rendement était le plus élevé dans la floraison (F) que dans les génotypes de non-floraison (NF) et le plus élevé dans la floraison-tôt (FT) et la mi-floraison (MF) que dans les génotypes de la floraison tardive (FL). Les résultats montraient en plus que l'une des variétés de contrôle (var. CO957) possédait d'adaptation plus grande à la basse humidité de sol disponible que les autres, alors que var CO1001 avait une trés faible niveau de tolérance à la tension d'humidité de sol. En ce qui concerne le côté économique de la production de canne à sucre, le maintien de la 2^{e} culture de repousse (DCR) dans les variétés de F et de TRC dans les variétés de NF ne pourraient pas être rentables pour les cultivateurs qui dépendent de la pluie naturelle dans cette zone.

Introduction

Ratooning is one of the unique features of commercial sugarcane (*Saccharum officinarum* L.) cultivation. The practice is borne out of the necessity to spread the costs of planting operations over subsequent ratoon crops. Since the period for which a sugarcane field can be ratooned profitably depends on the cultivar, management practices, and prevailing environmental conditions in a locality (Barnes, 1974; Chapman, Feraris & Ludow, 1992), sugarcane breeders are likely to make faster progress in developing suitable varieties for their locations by obtaining detailed information on the productive potential of their germplasm materials. Such information, which will also assist commercial cane growers in determining the number of profitable ratoon crops, is readily available in countries with well-developed sugar industries. In Louisiana (USA) for example, the SRC is the last profitable crop even though the FRC yields are almost equal to the plant cane (PC) yields (Miligan *et al.*, 1990; Quebedeaux *et al.*, 1994).

In Nigeria, industrial sugarcane is mostly cultivated in the southern Guinea savanna ecology (lat. 8°29 'N and long. 4°24 'E) where two of the three major sugar companies are located. The zone is characterized by a short growing season (May to September/early October) with erratic rainfall distribution pattern (Fig. 1). Thus, supplemental irrigation is ideal for commercial cane cultivation in the zone, especially during the long, dry season. Although such facilities are available on the sugar plantations, the out-growers within the locality depend solely on natural rainfall to grow their canes.

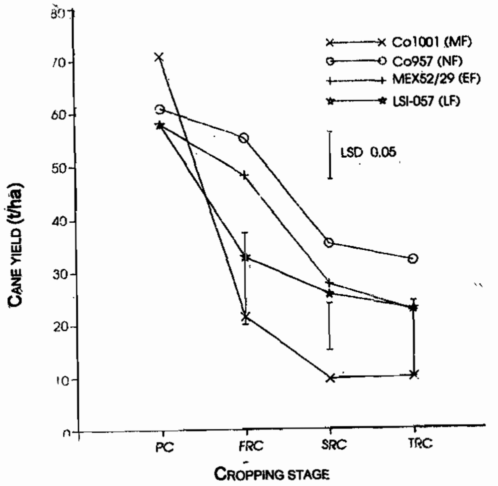

Fig. 1. Productivity of the highest yielding clone in each of the sub-groups in plant cane and the ratoon crops PC= plant crop; FRC = first ratoon crop; SRC = second ratoon crop; TRC = third ratoon crop.

Results from two separate studies conducted at the Nigerian Sugar Company (NISUCO), Bacita in the southern Guinea savanna (Ogunwolu, 1986) and Ibadan in the rain forest zone (Oworu, 1988) showed significant location effects on the productivity of two commercial varieties (CO957 and CO1001) in the ratoon crops. While yield loss was higher for var. CO1001 in the SRC at Bacita, var. CO957 had higher yield loss in all ratoon crops at Ibadan. However, neither of the two cropping practices fits into the cropping situation of the out-growers in the southern Guinea savanna zone who cannot afford the cost implications of providing supplemental irrigation to their cane fields during the usual long, dry spell from October to April in the following year.

This study was, therefore, initiated to assess the productivity of the sugarcane germplasm accessions at the Unilorin Sugar Research Institute (USRI) under rainfed conditions without supplemental irrigation during the dry spell.

Materials and methods

Forty-eight foreign and adapted sugarcane clones, including two commercial varieties (vars CO957 and CO1001) as checks, were grown in a two-replicate randomized complete block in May 1991. Table 1 shows the list of the clones and their origin or point of collection. Each clone was planted into 5-m long two-row plots, using immature three-budded cane setts arranged in an overlapping manner to ensure maximum crop establishment. The inter-row spacing was 1.65 m, giving a total plot size of 0.25 ha. Fertilizer application each year was a mixture of urea, single super phosphate (SSP) and muriate of potash (MOP) at the recommended rate of 100 kg N/ha, 60 kg P, and 60 kg k/ha, respectively. Weed was controlled with a tank mixture of 100 ml gramoxone + 5 kg Velpar K4 (granular) in 10 l of water. This was supplemented by hand weeding during the first cropping season. Subsequent weed control in the ratoon cropping was by hand. The plant cane was harvested in December 1991, but

TABLE 1

List of the Sugarcane Germplasm Accessions and their Point of Collection

S/N	*Accession*	*Point of collection*	*S/N*	*Accession*	*Point of collection*
1	B4681	Barbados	25	D47/115	Guyana
2	B5715	Barbados	26	DB20/58*	Demarara (West Indies)
3	B5992*	Barbados	27	DB51/55*	Demarara (West Indies)
4	B6604*	Barbados	28	DB95/57*	Demarara (West Indies)
5	B61208*	Barbados	29	IAC48/65*	?
6	B69620*	Barbados	30	LSI-019*+	?
7	BR6223*	Barbados	31	LSI-026*	Papa 2 & 3
8	BJ6547*	Java	32	LSI-027*	Siun
9	BJ6552	Java	33	LSI-028*	Olojo
10	CO396*	Combatoire (India)	34	LSI-029*	Ogere-Remo
11	CO404*	Combatoire (India)	35	LSI-031*	Bashi
12	CO440	Combatoire (India)	36	LSI-033*	Ijebu-Ode
13	CO443*	Combatoire (India)	37	LSI-047*	?
14	CO449*	Combatoire (India)	38	LSI-050*	Shaki
15	CO453*	Combatoire (India)	39	LSI-054*	Igunsin
16	CO691	Combatoire (India)	40	LSI-057*	Agbede
17	CO957	Combatoire (India)	41	LSI-058*	Ado-Ekiti
18	CO976	Combatoire (India)	42	LSI-083*	Pambegwa
19	CO997	Combatoire (India)	43	LSI-084	Okirighe
20	CO1001*	Combatoire (India)	44	LSI-085	Owo
21	CO68066*	Combatoire (India)	45	LSI-086	Sapele
22	CP29/116*	Canal point (F1,USA)	46	LSI-087	Yenagoa
23	CP36/111*	Canal point (F1,USA)	47	LSI-098*	Igweuvobia
24	Dacca	?	48	MEX52/29*	Mexico

+ LSI = Adapted sugarcane clones collected from different parts of Nigeria
? = Source of collection unidentified
* = Flowering varieties

subsequently ratooned in November of each year throughout the duration of the study. Brix reading was taken each year at harvest.

The quantitative data collected included days to 50 per cent arrowing (flowering), number of stalks/stool, millable cane population, stalk length, stalk diameter, number of internodes/ stalk, and brix (an estimate of sucrose in the juice). The clones were grouped by the arrowing data as either flowering (F) or non-flowering (NF). The clones, which flowered in early September, were classified as early flowering (EF), while clones which flowered between mid-September and mid-October were classified as mid-flowering (MF). All the clones which flowered after mid-October were also classified as late-flowering (LF). Apart from the arrowing data and cane yield, which were on whole plot basis, other data were collected from 10 random stalks/plot while stalks/stool was based on five competitive stools in a plot. Cane yield was first determined in kg/plot, but later converted to t/ha. Leaf area was estimated as 3/4 BW × L, where BW = greatest width of leaf and L = length of leaf.

The data collected were subjected to analyses of variance (ANOVA), first on individual crop basis before a combined ANOVA over harvest stages. Pertinent means were separated with the Least Significant Difference (LSD) or the Duncan's New Multiple Range Test (DNMRT) (Steel & Torrie, 1980).

Results

Percentage loss was highest in cane yield, ranging from 54.7 in the FRC to 74 in the TRC. Percentage loss in two major yield components (millable canes and stalk length) followed a similar trend, especially beginning from the SRC; thus, affecting the overall productivity of the germplasm accessions. However, sucrose in the juice (as measured by refractometer brix), stalks/stool, and leaf area remained relatively unaffected by ratoon cropping (Table 2). As expected, sucrose content was higher in the FRC than in the PC, but did not differ significantly until the TRC. The effects of ratooning on three of the yield components (stalk length, number of internodes/stalk, and millable cane population) were inconsistent. While the first two characters showed significant decrease in the ratoon crops, millable cane population was significantly higher in the FRC than in the PC, but decreased in the subsequent ratoons.

Yield loss (%) among the F genotypes was higher than in the NF genotypes (Table 3). The

TABLE 2

Means for Cane Yield and Related Traits of 48 Sugarcane Accessions in Each of the Harvested Stages (Ilorin, Nigeria)

Harvest stage	*Cane yield (t/ha)*	*Brix*	*Stalks/ stool*	*Stalk length (m)*	*Stalk diameter (cm)*	*Millable canes*	*Internode no.*	*Internode length (cm)*	*Leaf area (cm²)*
Plant cane	43.67^{a}	16.70^{ab}	10.77^{a}	1.92^{a}	3.09^{a}	112.72^{b}	19.38^{a}	11.64^{a}	409.43^{a}
First ratoon	19.87^{b}	20.25^{a}	14.21^{a}	1.26^{b}	2.20^{a}	171.85^{a}	13.69^{ab}	10.70^{a}	378.77^{a}
Second ratoon	19.8^{b}	18.05^{ab}	10.60^{a}	1.27^{b}	2.22^{a}	70.64^{c}	12.13^{b}	12.10^{a}	379.66^{a}
Third ratoon	11.37^{b}	15.49^{b}	10.24^{a}	0.97^{c}	2.10^{a}	40.66^{c}	13.65^{ab}	11.70^{a}	376.43^{a}

Means in a column followed by the same alphabet(s) are not significantly different.

TABLE 3

Percent Reduction in Cane Yield and Related Traits Due to Ratooning in Flowering (F) and Non-flowering (NF) Sugarcane Accessions (Ilorin, Nigeria)

Trait	*First ratoon crop*		*Second ratoon crop*		*Third ratoon crop*	
	F	*NF*	*F*	*NF*	*F*	*NF*
Cane yield	56.31	49.34	54.82	53.37	76.07	67.01
Brix	++	++	++	++	7.83	5.26
Stalks/stool	++	++	3.11	2.38	7.35	2.65
Millable canes	++	++	38.55	33.31	63.66	64.82
Stalk length	35.05	33.15	34.54	31.55	52.06	42.25
Stalk diameter	30.19	23.62	27.27	30.10	31.81	32.04
No. of internodes	30.00	27.34	37.67	36.65	30.89	25.25
Length of internode	8.86	5.13	3.34	5.45	11.17	3.28
Leaf area	22.11	22.08	6.71	9.12	7.73	9.14

++ Character unaffected by ratoon cropping.

difference ranged from 6.97 in the FRC to 9.6 per cent in the TRC. A similar trend was observed for other yield-related traits, except for millable cane population and stalk diameter where reductions were comparable between both groups in the TRC.

Table 4 shows estimates of reduction in yield and yield components due to ratooning among the three flowering sub-groups (i.e. EF, MF and LF). Yield loss (%) did not follow a definite trend, especially among the MF genotypes that recorded 80.6, 53.5 and 75.7 per cent loss in the ratoon crops. However, a progressive decline in productivity was evident among the EF and LF genotypes in the subsequent ratoon crops.

Mean cane yield of the genotypes in each of the cropping stages when averaged over all crops (Table 5) showed that the F genotypes as a group were prominent among the top 20 per cent. For stability of performance in each of the cropping stages, three of the NF genotypes (CO957, LSI-058 and D47/15) were superior to most of the F genotypes. There was an inverse relationship between cane yield and sucrose content, especially in the PC where varieties LSI-083 and CO1001 with mean cane yield of 81.82 and 70.91, respectively, had very low brix readings (13.5 and 12.5).

Comparison of ratoon potential of the three highest yielders within each major sub-group (i.e. F and NF genotypes) showed that the rate of yield loss in subsequent ratoon crops was higher among the F genotypes than among the NF counterparts (Table 6). For example, the range in yield loss was from 9.29 per cent in CO957 (FRC) to 60.64 per cent in LSI-058 (TRC) in the NF as compared to a range of 74.29 to 86.90 per cent in LSI-083 in the F genotypes. Except for variety LSI-083, the highest reduction for F and NF genotypes was in the SRC.

Discussion

Cane yield is a complex character and also a final product of several intermediate characters all of which are quantitatively inherited. Thus, changes in evironmental factors (for example, low soil moisture regime as in this study) are expected to affect the performance of the genotypes, especially since most of them were bred for ideal growing conditions. The significant reduction observed in cane yield (54.7, 54.6 and 74.0 per cent in the FRC, SRC, and TRC, respectively) and some yield-related characters (Table 2) may be due to the response of the genotypes to differences in

TABLE 4

Percent Reduction in Cane Yield and Related Traits Due to Ratooning in Early, Mid, and Late-flowering Sugarcane Clones (Ilorin, Nigeria)

Trait	*First ratoon crop*			*Second ratoon crop*			*Third ratoon crop*		
	EF	*MF*	*LF*	*EF*	*MF*	*LF*	*EF*	*MF*	*LF*
Cane yield	54.88	80.57	56.70	53.01	53.54	59.40	74.64	75.69	85.19
Brix	++	++	++	++	++	++	4.22	7.34	2.92
Stalks/stool	++	++	++	0.93	7.55	0.00	24.07	22.64	20.20
Millable canes	++	++	++	37.14	44.23	35.52	52.77	69.96	86.24
Stalk length	36.92	35.05	28.06	35.89	32.99	33.16	47.18	56.70	52.04
Stalk diameter	33.75	27.72	27.97	26.75	24.09	32.48	33.12	30.69	38.91
No. of internodes	30.77	32.14	19.65	39.49	34.69	21.97	29.23	33.67	24.25
Length of internode	9.68	7.08	9.82	5.65	4.42	0.85	7.26	10.62	++
Leaf area	25.01	18.52	24.69	13.01	++	++	11.29	4.61	5.06

++ Values unaffected by ratoon cropping. EF = Early flowering; MF = Mid flowering; LF = Late flowering

TABLE 5

Mean Cane Yield (with Corresponding Brix Value) of the Top 20 Per Cent in Each of the Harvest Stages and Combined Over Harvest Stages (Ilorin, Nigeria).

	Plant crop		*First ratoon crop*			*Second ratoon crop*			*Third ratoon crop*			*All crops combined*		
Clone	*Cane yield (t/ha)*	*Brix*	*Clone*	*Cane yield (t/ha)*	*Brix*	*Clone*	*Cane yield (t/ha)*	*Brix*	*Clone*	*Cane yield (t/ha)*	*Brix*	*Clone*	*Cane yield (t/ha)*	*Brix*
LSI-033*	81.82	13.5	CO957	55.28	20.0	D47/15	36.04	21.0	CO957	32.01	16.0	CO957	49.90	19.0
CO1001*	70.91	12.5	MEX52/29*	48.23	18.5	CO957	35.37	22.0	B69620*	26.80	17.5	MEX52/29*	39.14	17.4
B69620*	63.53	16.6	LSI-027*	38.66	18.0	MEX52/29*	27.73	16.5	CP36/111	25.18	16.0	LSI-058*	32.29	18.6
CO957	60.94	18.0	LSI-019*	36.85	17.0	LSI-058*	25.74	22.5	LSI-058	22.78	17.5	D47/15	32.24	18.3
CO440*	59.09	14.0	CO691*	36.18	16.5	LSI-027*	24.03	21.5	CO997	22.60	14.0	LSI-033*	31.33	18.5
BJ6547*	58.79	17.0	LSI-087	35.18	17.5	CO976*	23.37	18.0	DB20/58*	21.78	13.5	LSI-057*	30.23	17.5
LSI-058	57.88	17.0	LSI-058*	32.83	18.5	CO691*	23.22	20.5	D47/15	19.43	13.5	B4681*	29.10	17.6
MEX52/29*	57.88	18.5	CO404*	31.49	18.5	LSI-050*	23.04	18.0	LSI-097	17.09	16.5	CO691*	28.32	15.9
LSI-098*	57.58	18.5	CO396*	30.82	19.0	CO6806*	23.03	22.5	CO449*	14.74	13.0	LSI-019*	28.69	18.3
B4681*	56.06	13.0	D47/15	30.15	20.0	BJ6547*	21.04	18.0	LSI-057*	14.41	13.0	B69620*	28.14	17.4
LSD 0.05	17.99	4.4		17.65	2.2		9.0	3.1		14.54	4.5		7.59	1.2

TABLE 6

Yield Loss (%) of the Highest Yielding Clones Among Flowering (F) and Non-flowering (NF) Sugarcane Accessions (Ilorin, Nigeria)

Variety	*First ratoon crop*	*Second ratoon crop*	*Third ratoon crop*
		F	
LSI-033	74.29	86.90	85.66
LSI-057	16.67	52.78	60.64
MEX52/29	23.30	63.36	71.32
		NF	
CO957	9.29	41.96	47.47
D47/15	30.42	39.90	55.16
LSI-058	43.28	55.53	60.64

soil moisture regime which varied each year, depending on the amount and period of rainfall. The significant G × HS interaction recorded for all characters in this study further attest to this view.

There was no appreciable decrease in sucrose content until the TRC reduced to 23.5 per cent (Table 2). Several studies (Smith & James, 1969; Singh *et al.*, 1983) have shown that sucrose in the juice tends to increase in the ratoon crops and so is unaffected by crop age. However, the belief that flowering diverts photosynthates from sucrose accumulation to flowering (Arceneaux, 1965) is further reinforced by a higher reduction in the brix reading of the F genotypes relative to the NF genotypes (Table 3), and in the EF and MF genotypes relative to the LF genotypes (Table 4).

The number of stalks/stool and millable cane population were unaffected in the FRC (Tables 3 and 4), probably due to the supply of irrigation immediately after harvesting the PC to ensure proper re-establishment. However, this increase did not translate to yield gain, since the stalks were shorter and thinner than those of the PC (Table 2). Results have been similar even under ideal experimental conditions at Bacita (Ogunwolu, 1986) where increase in sugarcane shoots and millable cane population in ratoon crop did not result in concomitant yield advantage over the PC.

The delay in harvesting of the F varieties may significantly reduce yield, while their NF counterparts still have ample opportunity to continue accumulating biomass yield. Thus, yield loss in ratoon crops in the NF genotypes should be less than in their F counterparts. In this study, the F genotypes were prominent among the top 20 per cent in each of the cropping stages and when yields were averaged over all cropping stages (Table 5). This tends to suggest that the F clones were superior in yielding ability under low moisture compared to the NF clones. However, the ratoon performance of the three top yielders in each group (Table 6) and those of the highest yielding clone in each of the sub-groups (Fig. 2) showed that the NF clones as a group were actually better ratooners than the F clones, as they showed lower percent yield reduction in the ratoon crops. For example, yield reduction in var. CO1001 (F) ranged from 71 to 85 per cent compared to a range of 9 to 47 per cent in var. CO975 (NF) in FRC, SRC and TRC, respectively. Flowering will definitely increase the rate of yield loss in ratoon crops.

Apart from loss of vigour with age, the decline in productivity of sugarcane genotypes in ratoon crops can also be attributed to incidence of insect pests and diseases, weed infestation, and other prevailing environmental conditions specific to a locality. For example, the focus of this study was to simulate the growing conditions of a cane field in a typical drier ecology without supplemental irrigation. Due to the short growing season and the erratic rainfall distribution, genotypic expression is bound to be different from that observed under a favourable environment.

A comparison of the ratoon performance of the two check varieties (vars CO975 and CO1001) under three different cropping situations (Table 7) showed that var. CO975 had a better adaptation to the different ecologies and cropping situations in the sugarcane-growing areas of the country. At Bacita with availability of supplemental irrigation, and Ibadan with longer growing season and better rainfall distribution, yield loss was comparable between the two varieties in the ratoon crops. Conversely, yield was drastically reduced in var. CO1001 in the ratoon crops under a moderately stressed condition at Ilorin. This poor ratoon performance of var. CO1001 is probably related to its poor regrowth after ratooning, its flowering habit, and lower number of tillers/millable cane population as noted in this study. The superiority of var. CO975, on the other hand, may be closely related to early tillering as well as broad adaptation to different ecologies in the country.

The results for this study indicate that it may be unprofitable to maintain a ratoon field beyond the SRC in F varieties and the TRC in NF varieties under rainfed cultivation in the Guinea savanna

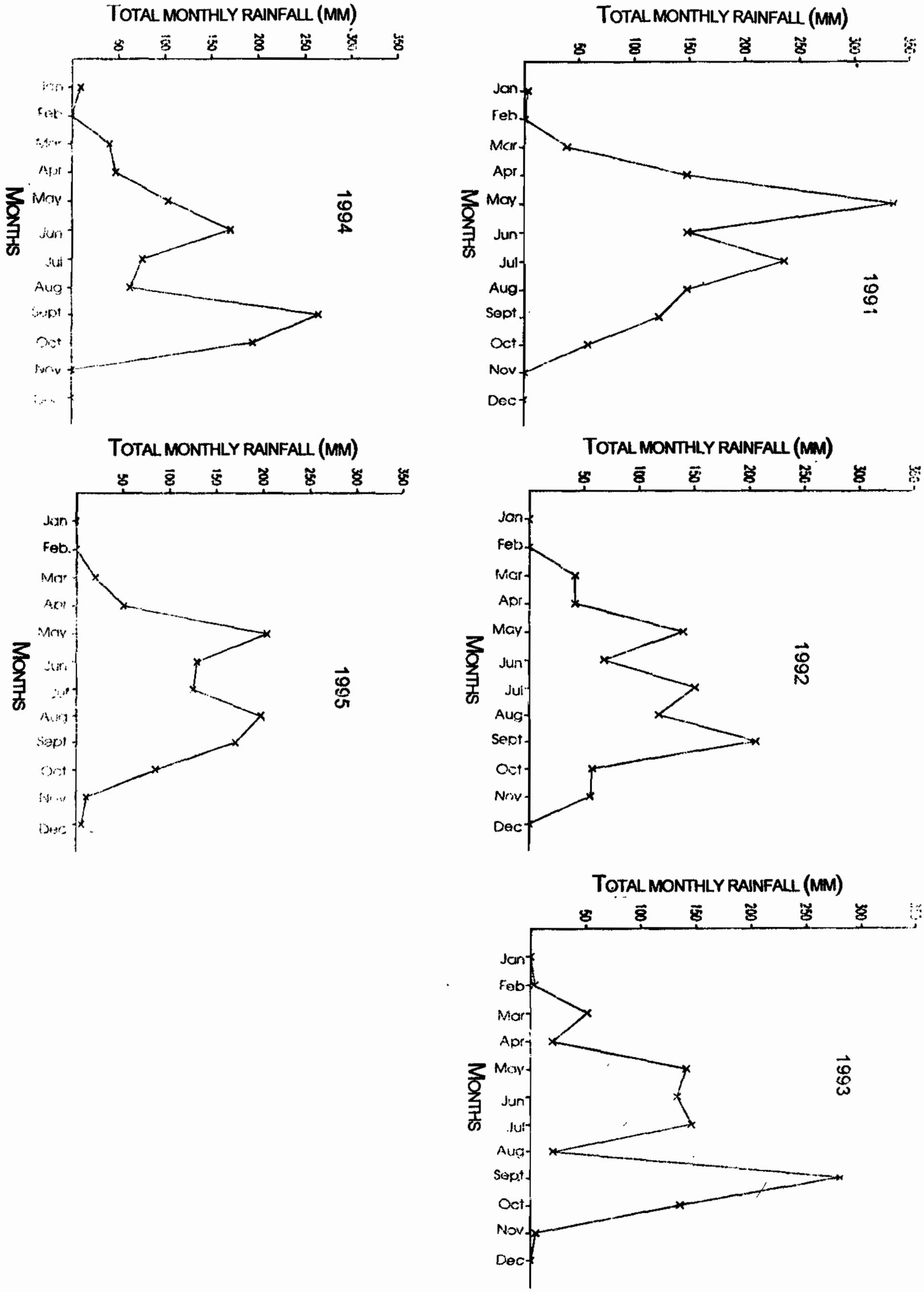

Fig. 2. Cumulative rainfall (mm) over a five year period (1991-1995) at Ilorin (Nigeria)

TABLE 7

Yield Loss (%) in Two Commercial Sugarcane Varieties Under Three Different Cropping Situations in Nigeria

Variety	*First ratoon crop*	*Second ratoon crop*	*Third ratoon crop*	*Fourth ratoon crop*	*Fifth ratoon crop*
		**Favourable environment (Bacita)*			
CO957	2.02	6.66	-	-	-
CO1001	++	16.56	-	-	-
		***Favourable environment (Ibadan)*			
CO957	19.10	30.10	38.10	57.60	78.90
CO1001	3.50	18.80	30.50	58.50	75.30
		Unfavourable environment (Ilorin)			
CO957	9.29	41.96	47.47	-	-
CO1001	70.57	86.77	85.19	-	-

* Availability of irrigation facilities (Adapted from Ogunwolu, 1986)
** Longer growing season and better rainfall distribution (Source: Oworu, 1988)
++ Value unaffected by ratoon cropping

zone of Nigeria.

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