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Sugarcane Row Spacing Influences Cane Yield in Rainfed Conditions in Côte d'Ivoire

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Abstract: ***Sugarcane smallholders yields in Ivorian sugar complexes have been about 39,7 tc/ha over the seven last years. Three spacing between sugarcane rows (1.5 m, 0.5-1.3 m, 1.2 m) were assessed during three years under rainfed conditions at Ferké in Côte d'Ivoire. The study aims to identify the inter-row that might impact sugarcane yield. The experimental design was a split-plot with spacing as main factor and five varieties as secondary factor. The new row spacing (1.2 m) significantly increases sugarcane yield by about 18%. All varieties reacted positively to narrowed spacing. However, varieties M1565/87 and M1246/84 gave the best yields, regardless of the spacing. This shows the interest of using these varieties and encouraging the new sugarcane row spacing so as to improve sugarcane productivity.***

Keywords: sugarcane, row spacing, yield, rainfed, Côte d'Ivoire

1. Introduction

Sugarcane *Saccharum officinarum L.* (Poaceae) is a perennial crop with multiple uses. It is mainly grown for its stem from which crystallized sugar is extracted sucrose **[5]**. It originates from New Guinea and might have already appeared around 15,000 to 8,000 years before Christ. Sugarcane plantations, formerly confined to a small geographical area, extended throughout the XIXth and XXth centuries, in all regions of the world where climate and soils were favorable **[16].**

The world annual sugarcane production is estimated at about 1.3 billion tons. The largest producers are Brazil with 736.11 million tons, India 752.14 million and China with 125.61 million tons **[22]**. In Côte d'Ivoire, sugarcane cultivation began with the experimental plots of Nieky, Oumé, Zuénoula, Bouaflé, Niakaramandougou and Ferkessédougou in 1964 **[13]**. Since the privatization of the Ivorian sugar industry in 1997, the sugar complexes have been managed by two private operators SUCAF-CI and SUCRIVOIRE with a yield of 180,000 t during the crop year 2011-2012 over a total surface area of about 25,000 ha. The share of village plantations initiated in order to improve incomes, create jobs especially for young people and curb rural exodus, still remains marginal with barely 17% of cultivated areas. The average yield for village cultivation is about 40 t/ha compared with 78 t/ha for industrial cultivation which benefits from irrigation **[3][11].** It is in this context that we undertook to test three spacing between sugarcane rows under village farm conditions at Ferké 2 in northern Côte d'Ivoire so as to assess their effects on the crop yield.

This study aims at determining the spacing that ensures a better yield of rainfed sugarcane cultivation and determining the variety or varieties adapted to the rainfall regimes.

2. Material and Methods

2.1 Description of the study area

The experiments were set up at the Ferké 2 sugar complex which is located in the administrative district of Tafiré. The latter is located in northern Côte d'Ivoire in the savannah zone and is subject to the tropical sub-humid or sub-Sudanian transitional climate **[4]**. The climate is characterized by two seasons: a dry season which lasts from November to March and a rainy season which runs from mid-April to October. The average rainfall in the zone is 1200 mm/year **[17].**

The soils of the Ferke 2 sugar complex, site of the study, are shallow and stem from granite or gneiss. They are hydromorphic in the slums and sandy in the alluvial terraces of the Bandama River. However, ferralitic soils are predominant, with shallow topsoil limited by duricrusts of 40-60 cm deep. The geographical coordinates of the site are: 9° 14'-9°35' N and 5°15'- 5° 24' W and 323 m altitude**[11]**.

2.2 Plant material

The plant material consisted of five varieties of sugarcane: M1176/77, M2593/92, M1565/87, M1246/84 and M1400/86. They were the fruit of research carried out by the Mauritian Sugarcane Industry Research Institute (MSIRI). They were introduced in Côte d'Ivoire in 2007 on the Ferké 2 complex.

2.3 Methods

2.3.1. Experimental design

The experiment was conducted under rainfed conditions on village plots of the Ferké 2 sugar complex. The trials were set up at the beginning of the crop year and were followed over time in virgin sugarcane followed by two (2) ratoons, that is, for three (3) years. The experimental design was a split plot type **(Figure 1)**. Spacing or inter-row was the main factor of the three-level trial, with twin rows (1.3 - 0.5 m), conventional single rows (1.5 m), which are the reference on the complex, and narrow single rows (1.2 m). The secondary factor was the plant material comprising five varieties of sugarcane (M1176/77, M2593/92, M1565/87, M1246/84 and M1400/86). The experimental plot consisted of 45 micro-plots or elementary surface areas of 270 m^2 (9m x 30m). Each elementary plot of twin rows comprised five sugarcane rows, the one consisting of single rows had six rows and seven rows for narrow single rows. Only the central rows or usable rows were weighed for determination of sugarcane yield.

2.3.2 Cropping conditions

Cultural operations, including N-P-K fertilization, pre-emergence herbicide treatment and manual weeding, were performed homogeneously for all treatments of the trial. On the trial plot, the conventional dose of NPK manure applied under rainfed conditions in the complex is provided annually. These are 300 kg/ha of NPK (16; 8.5; 23). The trials were harvested manually after burning.

2.3.3 Assessment criteria

Sugarcane harvesting was done annually. Thus, the trials were harvested after 18 months for sugarcane in virgin culture (R0) then the harvesting of the first ratoon (R1) and the second ratoon (R2) took place 12 months after the cutting of the virgin cane (R0) and 12 months after the cutting of R1, respectively. The parameter assessed was sugarcane yield expressed in tons of sugarcane per hectare (tc/ha). After burning, the usable rows were cut and the sugarcanes tied with a rope. The mass of the load was read on the screen of the weight scale. Thus, sugarcane yield (tc/ha) was calculated by dividing the yield per hectare by the usable surface area of each corresponding elementary plot.

Yield (tc/ha) = Cane Weight X 10^4/usable surface area

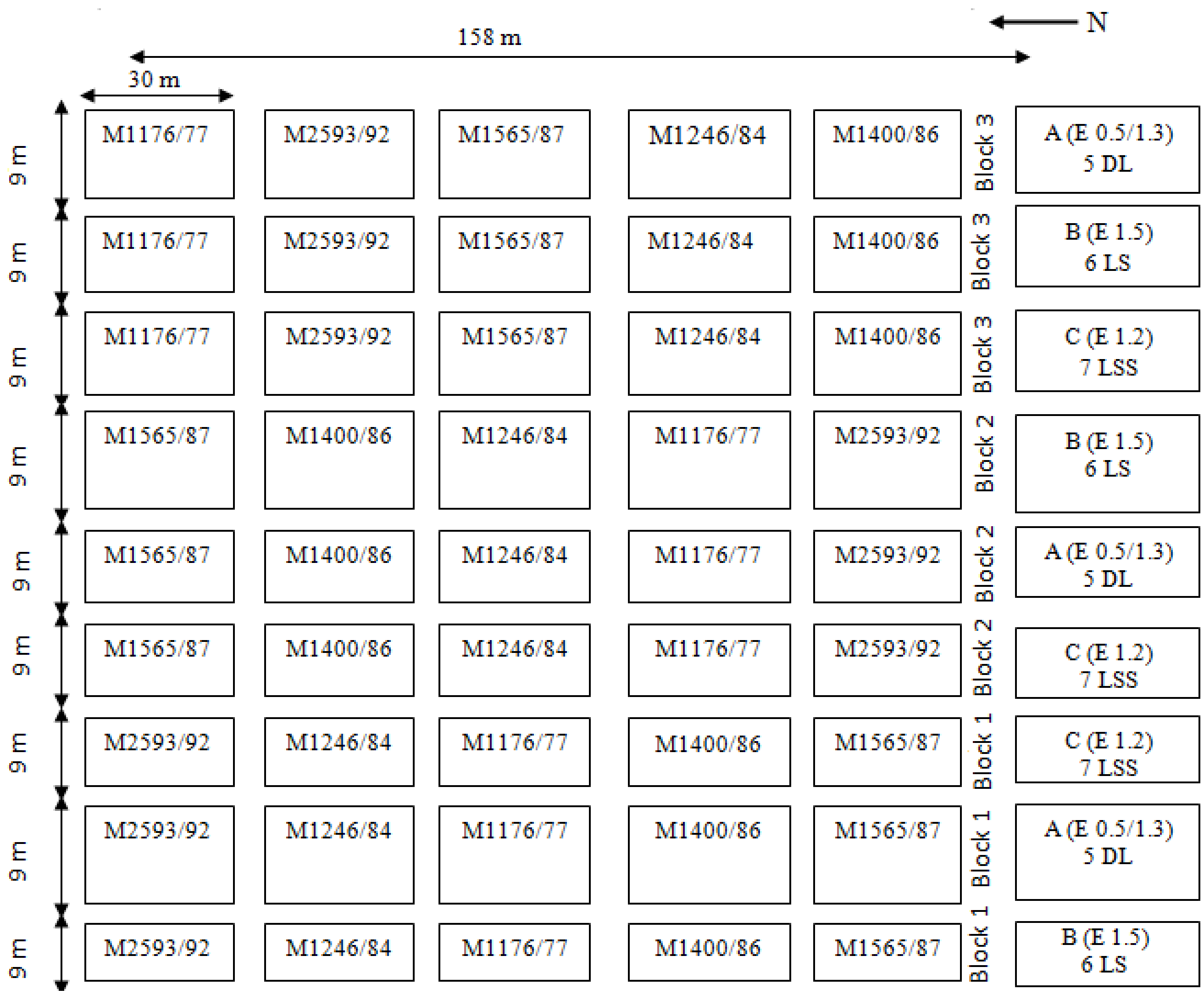

Figure 1: Experimental design plan

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Legend:
On each block are the three (3) levels of the main factor numbered A, B and C.
E = Spacing or inter-row
DL = Double Rows or Twin Rows (1.3m-0.5m)
LS = Single Rows (1.5m)
LSS = Narrow Single Rows (1.2 m)

3. Results and discussion

The statistical analysis of the trial showed that year, spacing, and year*variety interaction had highly significant effects on cane yield (P<0.01). In contrast, variety as well as year*spacing and spacing*variety interactions had no significant effect on sugarcane yield (Table 1).

Table 1: Cane yields averages over the 3 years trial

Sugarcane yields (tc / ha)				
Sources of variations	Ddl	Mean square	F	P
Years	2	1956,7	54,35	0,00**
Spacing	2	1254,9	34,86	0,00**
Varieties	4	6,1	0,17	0,95 ns
Years x Spacing	4	58,7	1,63	0,17 ns
Years x Varieties	8	121,0	3,36	0,00**
Spacing x Varieties	8	6,2	0,17	0,99 ns
Error	106	36		
Total	134			

**highly significant effect at α=0.01; *significant effect; ns: non-significant effect at α=0.05

The analysis of variance showed that spacing had a highly significant effect on sugarcane yield. The Newman-Keuls average comparison test at 5% threshold made it possible to compare the three-spacing tested and classify them. The test showed that the highest sugarcane yields were obtained on the new spacing of 1.2 m over the entire duration of the trial. In contrast, the best sugarcane yield, 61.1 tc/ha **(Figure 2)**, was obtained in the first ratoon year (R1). These yields were significantly higher than those in the conventional spacing (1.5 m) usually practiced and those of the twin rows.

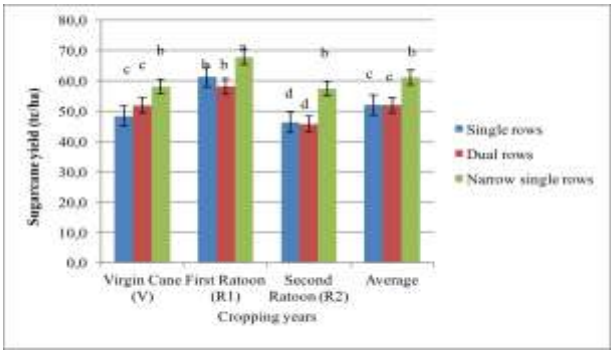

Figure 2: Average sugarcane yields depending on planting density

The new spacing of 1.2 m between sugarcane lines lead to an increase in sugarcane yields. The narrowed spacing between sugarcane rows gave the highest sugarcane yield compared to yields obtained with conventional (1.5 m) and twin (1.3 - 0.5 m) spacing. Thus, the narrowing of the interval helped obtain more sugarcane whatever the variety. According to **[19]**, temperature and water are the factors that favor growth and therefore sugarcane yield. **[15]** indicate that weeds are the only competitors of crops for mineral nutrition and water use, a limiting factor under rainfed conditions. Thus, the faster soil cover, which reduces weeding and evaporation by a higher sugarcane stem density due to narrowed planting spacing, might explain the results obtained. Such spacing limits environmental pollution by reducing herbicide applications and decreases the economic value of chemical weed control. The narrowing of sugarcane lines is therefore an opportunity for village producers to boost their incomes through increased yields and reduced production costs. These results are similar to those found by **[2]**, when reducing the spacing between sugarcane rows. In his work, this author showed an increase by more than 5% in sugarcane yield. Similarly, **[12]** showed that the narrowing of sugarcane rows caused a very significant increase in cane yield. These yield gains were 46% and 22%, respectively, in virgin and first ratoon (R1) crops compared to the conventional 1.5 m spacing.

Moreover, the works of **[7]** on the effect of spacing and traffic on sugarcane growth and yield showed that increased spacing does not result in increased yields. **[20]** also indicate that soil compaction and sugarcane stump crushing are the main impacts of agricultural machinery on the crop. They point out that the current wheel spacing of agricultural machinery, in particular harvesters and loaders, is 1.83 m. According to **[23]**, this amplitude might allow the machinery control traffic between sugarcane rows of 1.2 m leaving 0.9 m between the wheels and the stumps, which would have no significant impact on sugarcane stumps as well as on the soil. This spacing thus makes it possible to optimize sugarcane yields.

Sugarcane yields increased in the first two years of the trial before decreasing in the third year. The best sugarcane yields were all obtained in first ratoon crop. The Newman-Keuls average comparison test, at 5% threshold, showed that sugarcane average yields were statistically different **(Figure 3)**. Climatic conditions greatly influence sugarcane yields in rainfed conditions.

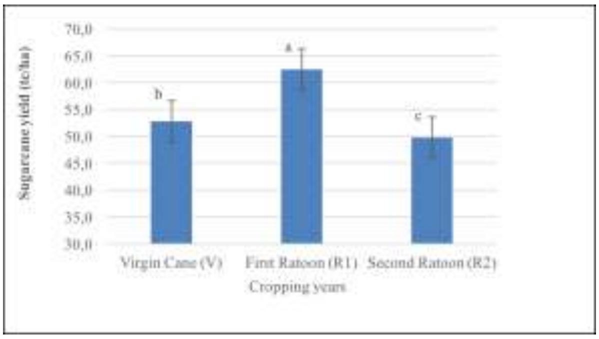

Figure 3: Average sugarcane yields per year

Varieties M1176/77, M2593/92, M1565/87, M1246/84 and M1400/86 showed average sugarcane yields with no significant difference according to analysis of variance.

The analysis of variance showed a non-significant interaction between spacing and year on sugarcane yield. This means that the ranking of varieties obtained for spacing did not change from one year to another.

The study under rainfed conditions showed an increase in sugarcane yield during the first two years followed by a fall during the second ratoon. The decline in cane yield observed during the second ratoon might be due to the depletion of the soils of the complex exploited since 1975 to date, to which is added the low use of inputs for village sugarcane as confirmed by **[14]**. The decline in productivity of a sugarcane plantation over the years has also been observed by **[8]**. However, this trend of declining yield over the years is highly variable according to soil fertility and the way in which the plantation is maintained, as reported by **[9]**. Our results are consolidated by those resulting from the works of **[18]**, obtained in other environments, which show that cane yields decline over the ratoons.

During the different years of the study, the sugarcane yields of the different varieties fluctuated. The interaction between year and variety, shown in **figure 4**, shows that the years enormously influenced the sugarcane yields of the different varieties. In fact, the varieties tested almost had the same sugarcane yield levels each year. All the varieties tested during the experiment gave the best sugarcane yields with the new spacing tested (1.2 m between the sugarcane lines). They all reacted to narrowed spacing **(Figure 5).** The Newman-Keuls post-hoc comparison test, at 5% threshold, showed the varietal classification obtained after 3 years of trial. Varieties M1565/87, M1176/1177 and M1246/84 showed the best yields compared to other varieties.

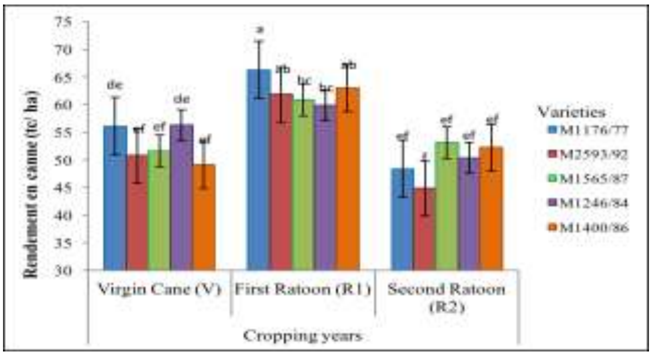

Figure 4: Year*variety interaction on the evolution of cane yields during the trial

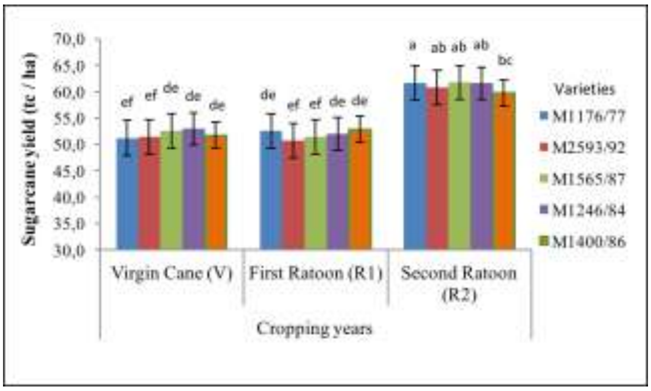

Figure 5: Spacing-variety interaction for average sugarcane yield during the trial

During the different years of the experiment the varieties reacted differently. Indeed, according to **[1],** and **[21],** the most important factors which determine sugarcane maturation are low temperatures, moderate drought, and low nitrogen content in the soil. Moreover, the accumulation of sucrose in the stems that starts as from the beginning of growth (3 months), accelerates at the end of growth (8.5 to 9 months) under the combined action of a relative cold, the high difference in night and daytime temperatures, the lack of water and nitrogen **[6].** Sugarcane yields in rainfed conditions depend greatly on the above-mentioned climatic factors. Thus, the effect of climatic variations on the environmental conditions of the study area could significantly influence the expression of the intrinsic characteristics of the varieties tested. These oscillating results from year to year are consistent with those of **[10]** on the same site.

4. Conclusion

This study was carried out with the aim of contributing to the improvement of sugarcane and sugar yields of village plantations initiated in Côte d'Ivoire in order to increase incomes, create jobs especially for young people and to curb rural exodus from savannah areas.

Thus, a village sugarcane experiment site at the Ferké 2 sugar complex was chosen to test three spacing: Twin rows (1.3 mx 0.5 m), Conventional single rows (1.5 m), Narrowed single rows (1.2 m).

The trial showed the positive effect of narrowed inter-row (1.2 m) and therefore a denser sugarcane plantation after three years of experiment. This positive effect comes to an average increase of 18 % in sugarcane yield compared to conventional single rows (1.5m) and twin rows (1.3m x 0.5m). The study also revealed the good reaction of all the varieties tested to spacing narrowing. Thus, these varieties could contribute to an improvement of the yield under uncertain hydrological conditions.

These results augur good prospects for the development of village sugarcane. The study must be completed with a cost analysis associated with the use of each spacing. Similarly, this study on sugarcane row-spacing narrowing could be conducted in irrigated conditions.

5. Acknowledgements

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