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Yield and Extractable Sugar as affected by Foam and Inorganic Fertilizer in Intensive Cultivation of Sugare Cane (Saccharum Officinarum L. (Linnaeus)) in a Forest-Savanna Ecosystem

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Abstract: For sustaining yield and extractable sugar production of sugarcane in Cote d'Ivoire in intensive cultivation, it is required an alternative organic source of nutrients *vs.* chemical fertilizer. Comparative trial was conducted at Zuenoula (Centre West of Cote d'Ivoire) from 2011 to 2013 including 4 rates of sugarcane foam (6, 12, 18 and 24 tha^{-1}), 4 others (150, 300, 450 and 600 $kgha^{-1}$) of chemical fertilizer [N (18.5%) P (9%) K (14%) + Mg (2%) S (2.5%)] and a control plot (no fertilizer) in a randomized complete block design with 3 replications. No significant difference was observed between leave concentrations of N, P and K while increased of soil contents of N and K occurred within two-year period under foam also showing a possibility to improve soil content of P according to the rates and years of cultivation for a specific target yield. Regularly, 600 $kgha^{-1}$ of NPK induced significant difference of yield between both fertilizers but the rates of extractable sugar (9.6%) were similar and characterized by more stable yield trend for the foam treatments during the three years. Increasing rate (18 – 24 tha^{-1}) of foam induced highest yield and rate of extractable sugar contrasting with NPK fertilizer. Applying 18 tha^{-1} of foam for two year-periods was recommended for sustaining sugarcane production in the studied agro-ecosystem.

Keywords: Sugarcane foam, chemical fertilizer, yield stabilization, extractible sugar, Cote d'Ivoire

1. Introduction

Sugare cane (*Saccharum officinarum L.)* production is ranging annually from 180, 000 to 200, 000 tones in Cote d'Ivoire while 250, 000 tones are required. The gap is due to low yield (7.5tha^{-1}) in field (Li et al., 2007; Emilie & Chabalier, 2007) in spite of the use of mineral fertilizer. Among the risk factors noticed, soil physical, chemical and biological degradations under repeated land use characterized by limited restitution of up taken and/or leached nutrients (Diatta & Siband, 1997) are pointed out and cases reported are wide spread for continuous cropping in tropical agro-ecosystems (Beets, 1989 ; Ofori et al., 2010 ; Koné et al., 2013a).

For intensive production of sugar cane, combining organic and mineral fertilizer was recommended for yield stabilization at high level across year in Guinea savanna of Nigeria (Gana, 2007). However, declining yield in agricultural systems is not only function of crop and cultural practices (Pené et al., 1997; Hossner & Juo, 2009), but relevant aspects of ecosystems are involved (Baumer, 1987 ; Koné et al., 2013b). Well, declining yield was not extensively documented for the transition forest/savanna zone of West Africa, especially for sugar cane cultivation. Nevertheless, this threat is basically associated to soil compaction and acidification coupled with the loss of organic matter resulting nutrient depletion in tropical zone (Julio et al., 1995). Hence, the use of organic manure could be of interest in yield stabilization regarding to its ability to improve soil physic and chemical characteristics (Baldock & Skjemstad, 2000) as well as water holding capacity (Chiba et al., 2008; Alcantara et al., 2009). Successful experiences are reported for oxysol improvement (Alcantara et al., 2009; Franco et al., 2010) and for Cambisol under effect of sugar cane foam (Bouadou et al., 2014). But the effect on yield and extractable sugar is looking likes a black box even though success are recorded for rice production in intensive cropping (Ghosh, 1971). This situation is restricting the opportunity to improve agricultural production systems, especially, for sugar cane cultivation in Cote d'Ivoire transition zone between forest and savanna ecologies while, about 12,000 tons of foam are annually abandoned as

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industrial waste in the sugar refinery of Zuenoula instead of being used as alternative to chemical fertilizer.

Therefore, the assessment of sugar cane foam (SCF) is required for yield and extractable sugar stabilization over years of cultivar.

The actual study is initiated in the transition forest/savanna zone of Cote d'Ivoire for this purpose. The aim was, ii) to identify the optimum rates of SCF and inorganic fertilizer (IF) on the yield and extractable sugar, and ii) to explore the effect of both nutrient sources on the yield stabilization in intensive cultivation of sugar cane. Finally, the study should recommend a best practice of soil management for sustainable sugar cane production in intensive cultivation.

2. Material and Methods

2.1. Site description

Three years (2011 – 2013) study was conducted in the research station of the sugar cane refinery complex of Zuenoula (7˚33'53''N; 6˚9'46''W, 218 m asl). It is a forest/savanna transition zone characterized by a bimodal rain fall pattern with annual amount of 111.53 mm, 1295.1mm and 1413 mm as recorded in 2011, 2012 and 2013 respectively. In the same sequence, the average temperatures were 32˚9 C, 32˚4 C and 32˚7 C. The soil is a deep (> 120 cm) Cambisol plinthic with hydromorphic features induced by irrigation. The soil matrix is colored in brown (5YR 3/4) with ochre splash somewhat ruste. Loam-clayed (36 % and 33 % respectively) texture and high cation percentage (40 – 75%) were determined coupled with more than 30% of gravel content within the soil profile. This soil was continuously cultivated five years ago under influence of annual application 600 $kgha^{-1}$ of NPK + Mg+S (18.5% – 9% - 14%- 2%- 2.5%). Details of soil characteristics are presented in Table 1.

2.2. Sugar cane foam

During the extraction process for sugar from sugar beet it is necessary to separate the non-sweet substances from the beetroot juice in a refining process that consists of two steps. The colloidal substances must first be flocculated by whitewashing with lime. The flocculated substances are called foams and these, in the traditional manufacture process considered here, are swept away by water to large pools for a natural drainage. After the extraction, lime is usually added to the juice and the rest of the process continues. The sugar foam waste is therefore a relatively new and unknown organic residue that has emerged from the significant growth in the sugar beet industry (Espejo, 2001). It look likes a sludge with particle size of 1mm – 200 µm (Bouadou et al., 2014). The foam used for the experiment was characterized as presented in table 1.

2.3. Tested cultivar

Sugar cane cultivar named Co 997 (from India) was used as most adapted commercial variety for the pedoclimatic condition of Cote d'Ivoire (Péné et al., 2001). It is an interspecific hybrid released by crossing *Saccharum officinarum* and *S. spontaneum* (Sreenivasan et al., 1987 ; D'Hont et al., 1996). It is characterized by the ability of maintaining its average yield potential of 8 tha^{-1} approximately during ten years. According to cultural practices, the plant height and stalk circumference can range between 147 – 278 cm and 21 – 25 cm respectively (Bouadou, 2008).

2.4. Experimentation

An area of 4518 m^2 was tilled and harrowed before making furrow of planting bed in 2011, 2012 and 2013. A randomized complete block design of 13 micro-plots in three replications was laid out every year later in February. A micro-plot (10 m × 7.5 m) was composed of 5 furrows (length = 10 m; height = 0.3 m) spaced by 1.5 m apart of which 2 were considered under influence of border effect. Four rates of foam (6, 12, 18 and 24 tha^{-1}) and other four (150, 300, 450 and 600 $kgha^{-1}$) of NPK + Mg S (18.5% – 9% – 14% – 2% – 2.5%) as well as a control plot with no-fertilizer were the treatments applied every year. Forty cutting were planted at 5cm apart along a furrow of 10 m for a density of 600 plants by micro-plot of which 320 were harvested. Manual weeding was done monthly until 3 – 4 months after planting and irrigation was applied as far as necessary.

2.5. Soil Sampling and Laboratory Analysis

Before the experiment in 2011, the soil was sampled in 0 – 20 cm depth of each of the four corners and the centre of micro-plot using hand augur. The sub-samples of all the micro-plots were mixed and a composite sample (5 kg) was taken. This sample was air-dried in a room condition, grounded and sieved (2mm) before being analyzed (Pauwels et al. 1992): pHwater was determined with electrode glass in a soil/water ratio 1/2.5. Soil contents of organic carbon-C (Walkley & Black) and total nitrogen-N (Kjeldahl) were also determined. Moreover, soil contents of exchangeable cations (K^+, Ca^{++} and Mg^{++}) and the cation exchangeable capacity (CEC) were determined according to Peech (1945) while Olsen method accounted for available soil P content determination. Annually, a composite soil sample of micro-plot was also used for analysis of N, P and K after the experiment.

2.6. Yield and Extractable sugar Data Collection

Twelve months after planting the sugar cane was harvested in 45 m^2 of micro-plot and weighed for yield determination.

Thirty stalks were randomly sampled from the harvested canes of a micro-plot to be grounded and pressed (hydraulic press) to extract the cane juice. The juice content of saccharose (Pol j) was determined on the basis of angular refraction (Pol l) as described by (Hoareau et al., 1970; 2008). Then, the rate of extractable sugar (ES) was calculated:

ES (%) = [(0.84 × Pol C (%)) (1.6 – 60/PTE) – (0.05 × FC (%))] [1]

Pol C (%) = n × Pol j (%) [2]

PTE = [Pol j (%) × 100] /Pol l [3]

n is a factor determined in the table of Schmidt (1969)

F C (%) = (Weigh of residue – 4)/10 [4]

2.7. Leave sampling and analysis

The third, fourth and fifth older leave were sampled from 30 plants belonging to two medians planting lines at four months after planting. These samples were used for leaf diagnosis according to Stasm (2003) making a composite sample for each elementary plot: about 10 cm of median part of limb was cut, dried and grounded for analysis of the contents of N, P and K. Data was interpreted according to Emilie & Chabalier (2007) as exposed in Table 2.

2.8. Statistical analysis

By surface curve response analysis the optimum rates of foam (F) and inorganic fertilizer (IF) NPK were explored. The analyses of variance were used for annual average yield and extractable sugar (ES) determination and for the mean values of leave concentration of N, P and K. Yield difference between the rates of F and IF were determined by procedure of mixed model including the test of Turkey-Krammer. Pearson correlation analysis were also performed for the yield and ES regarding to soil contents of N, P, K, Ca and Mg as well as soil pH. SAS (version 8) package was used for statistical analysis considering $\alpha = 0.05$.

3. Results and Discussion

3.1. Potential and limit of the manures

Figures 1 and 2 show the mean values of yield and the rate ES according to the rates of SCF and IF respectively: whatever the source of nutrients and the studied parameters, no significant difference is observed. However, there is greater increasing (10%) of yield for 18 tha^{-1} of SCF compared with the control, which, in turn, shows greater increase of 1% for ES (Figure 1). More pronounced similar results are observed for IF treatment (NPK), especially for ES showing lowest value of 9.9% for the rates of 300 and 600 $kgha^{-1}$ (Figure 2) when compared with that of SCF (Figure 1). Significant (p<0.005) reduction of the rate of ES is observed over the successive cultivation seasons indifferently to the nutrient source treatments (9.6%) and the control plot (11%) in 2013 (Table 3) coupled with declining yield over successive seasons (p<0.05) characterized by highest magnitude for F: in 2013, the yield was 125 tha^{-1} and 111.4 tha^{-1} for NPK and F respectively. High ES rate performance noticed in the control plot associated with no response of yield to the rates of nutrient sources in the first year (Figures 1, 2; Table 4) could be related to the initial high level of soil fertility (Table 1) as consequence of the cultural practice adopted in the refinery complex of Zuenoula as early reported by Bressoud et al. (2003). In fact, the rate of 600 kgNPK ha^{-1} was annually applied and the sugar cane residue after the harvest was incorporated in the soil during land preparation. Hence, residual effect of fertilizer and the decomposition farm residue could supply the essential nutrients to the subsequence planted cane (Bressoud et al., 2003 ; Courteau, 2005) but relevant unbalanced ratio of cations (Ca:Mg and Mg:K) could occurred on going cultivation (Boyer ,1978; Bouadou et al., 2014). Nevertheless, the impact of the initial fertility of soil was likely limited to two years of cultivation (Table 3) underlining the effect of IF (NPK) in 2013 which induced the highest yield. This analysis confirms the importance of the cultural practice for sustaining agricultural production (Balu, 1980) and emphasizes two years duration for such effect in the studied agro-ecosystem when referring to the result observed in the control plot while the effect of NPK was longer for yield stabilization.

However, the yield gap was significant only for the rate of 600 $kgha^{-1}$ of NPK comparing the yields of the rates of SCF and IF, except for 6 tha^{-1} of F and 300 $kgha^{-1}$ of IF (Table 4). Yet, no significant difference is observed for ES between both sources of nutrients. These results have relevant aspect of net return concept of fertilizer recommendation (Sarkar, 2000) that can lead to foam (SCF) recommendation in the studied environment for sugar cane production instead of inorganic fertilizer (NPK).

Moreover, the response surface curve of sugar cane to the rate of different manures shows inversed trends for the yield and the ES respectively (Figure 3). There is significant increasing of yield according to the rates of SCF up to 18 tha^{-1}, and further application does not induced significant changes. But, the ES decrease simultaneously up to 12 tha^{-1} before increasing in the range of 12 – 24 tha^{-1} recording a maximum of 10.15% of ES: Lowest yield is associated with high rate of ES for the control plot while 18 - 24 tha^{-1} of foam can increase both yield and the rate of ES. There is difference between the responses of ES to both sources of nutrients when decreasing continuously according to the rates of NPK (Figure 4).

In the light of the results and relevant analysis, the yield stability as induced by NPK did not impact the rate of ES which was similar for both sources of nutrients in 2013. Roughly, NPK fertilizer has limited ability in increasing the rate of ES compared with the effect of foam applied at 18 – 24 tha^{-1}.

3.2. Mineral Nutrition of Sugar cane

According to Emelie & Chabalier (2007), leaf concentrations of N (1.4 – 1.8 gkg^{-1}) and K (1.17 – 1.35 gkg^{-1}) are ranging in normal levels respectively but, low concentrations of P (0.13 – 0.14 gkg^{-1}) are noticed whatever the treatments (Table 5). No significant difference is observed between the concentrations of specific nutrient according to the rates of SCF and IF. In other respects (Table 6), the difference P and K concentrations according to the rates of NPK vs. Foam are significantly ($p<0.005$) very low. In turn, highest differences are noticed for leaf concentration of N although for leaser significant level of 10 (α) when compared with that of the control plot and the treatment of 450 kgNPK ha^{-1}. Unbalanced ratio of cations (Ca: Mg) assumed to occurred in the soil could have reduced P up take by sugar cane (Koné et al., 2008) whatever the treatment while the high availability and solubility of N in the IF can explained the difference of leaf concentration of N meanwhile, N can be temporary fixed by micro-organisms during the decomposition process of the foam (Tiquia & Tam, 2002 ; Bressoud *et al.*, 2003) : Micro-organisms stock N as cellular protein compounds that should be released later in the soil. This was relevant to soil N depletion as noticed in 2012 in the treatments of SCF before enrichment occurred later in 2013 similarly to that of NPK treatment (Table 8). On the basis of similar analysis, Bouadou et al. (2014) identified 18 tha^{-1} of sugar cane foam for recapitalizing Cambisol fertility within two successive years of cultivation attesting annual requirement of 9 tha^{-1} instead of 12 tha^{-1} usually recommended for organic matter application in tropical soils (Ouattara, 2009). Refinery process of sugar cane (Azucarera Ebro, 2005) could have improved the quality of the resulting foam as organic source of nutrients, thereby differing to the other vegetal organic matters.

However, no significant correlation is observed for soil content of N and the yield of sugar cane (Table 7) contrasting with that concerning soil content of C (-0.60) which can increase when the yield reduction is observed, as for soil contents of Pa and K especially, for 12 tha^{-1} and 24 tha^{-1} of foam but such relationship is observed for C/N ratio when applying 6 tha^{-1}. Yet significant increase of soil content of N occurred in 2013 under both treatments and in the control plot which is also characterized by stable soil content of K contrasting with the increasing observed for foam treatment (Table 8). These results underline the importance of the slowness of foam mineralization process (Yao, 2014; Chabalier *et al.*, 2006) unavailability of nutrient but the effect of organic matter accumulation can be relevant of improving soil water holding capacity (Garcıá Navarro et al., 2008) which may of interest in plant mineral nutrition (Koné et al., 2008), hence increasing the yield.

Beside the unbalanced cation effects on sugar cane P nutrition, soil content of P is depleted from 2011 to 2013 under foam treatment in spite of the positive (1.8) linear relationship significantly (p = 0.0001) established with the increase of the rate of the foam (Table 9): The soil recapitalization of P was not as much as uptake, although minimized by cation effects. Significant contribution of year is also linearly observed for soil content of K only for the control plot but, similar result accounts for soil N and P indifferently to the treatments while, there are variance in the yield linear relationship with soil contents of N (NPK) and P (Foam) with positive and negative magnitude respectively emphasizing the importance of the target yield concept for P nutrition of sugar cane according to sugar cane foam amending strategy. Controversies effect of K nutrition as illustrated by a negative correlation with the yield could have influenced the foam effect regarding to the increase of soil content of K over years (Tables 7 and 8). In fact, the soil of the experiment site was initially richer in K (0.30 cmol kg-1) and further supplying could induce excess with antagonistic effect related against Mg and Ca nutrition of plants (Mengel & Kirkby, 1978) meanwhile, balanced ratio of these cations was required for optimizing plant mineral nutrition in the studied conditions (Bouadou et al., 2014).

In the light of these considerations, soil amendment with the sugar cane foam in the studied agro-ecology revealed the importance of the duration of organic matter decomposition, the target yield and the control of nutrient balance which required further study for enhancing this practice.

4. Conclusion

The cultural practices adopted in the refinery complex of Zuenoula characterized by farm residue incorporation appeared to be a main component of yield stabilization in intensive cultivation with limited potential within two seasons of land cultivation in the studied ecosystem.

High yield stability was accounted for inorganic fertilizer because of the slowness of organic matter decomposition but similar rates of extractable sugar were observed with the foam which in turn, has induced highest stability of this parameter justifying the use of sugar cane foam for intensive production.

Applying 18 tha^{-1} of sugar cane foam was recommended for two seasons of sugar cane cultivation in order to improve soil fertility, especially for N and P in relation with the target yield of about 100 tha^{-1} and 9.6 % of extractable sugar.

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Table 1: Soil (0 – 20 cm) and sugar cane foam chemical characteristics as determined before the experiment in 2011

Soil characteristics		**Sugar cane characteristics**	
pH_{H2O}	6.6	Nitrogen (g/kg)	5.6
pH_{KCl}	5.5	Phosphorus (g/kg)	3.6
C-organic (g/kg)	14.9	Potassium (g/kg)	1.3
N-total (g/kg)	1.3	Magnésium (g/kg)	0.8
C:N	11.5	Calcium (g/kg)	28.6
P-Olsen (mg/kg)	19.3		
Ca^{2+} (cmol/kg)	5.3		
Mg^{2+} (cmol/kg)	2.5		
K^{+} (cmol/kg)	0.3		
CEC (cmol/kg)	19.5		

Table 2. Interpretation scale of sugar cane leaf concentrations of N, P and K

Nutrients	**Periods of sampling (month)**	**deficient**	**moderate**	**Normal**	**High**	**Excess**
N (%)	4	< 1.4	1.4 – 1.37	1.37 – 1.83	1.83 – 2.06	≥ 2.06
	7	< 1.00	1.00 – 1.2	1.2 – 1.60	1.60 – 1.80	≥ 1.80
P (%)	4	< 0.15	0.15 – 0.17	0.17 – 0.21	0.21 – 0.23	≥ 0.23
	7	< 0.13	0.13 – 0.15	0.15 – 0.19	0.19 – 0.21	≥ 0.21
K (%)	4	< 1.05	1.05 – 1.25	1.25 – 1.55	1.55 –1.70	≥ 1.70
	7	< 0.80	0.80 – 0.90	0.90 – 1.10	1.10 –1.20	≥ 1.20

Table 3. Average yield and the rates of extractable sugar (ES) according to the treatments in 2011, 2012 and 2013

	Yield (tha^{-1})				ES (%)			
	2011	**2012**	**2013**	**Pr>F**	**2011**	**2012**	**2013**	**Pr>F**
Control	84.9Aa	87.7Aa	106.1Ab	0.11	10.9Aa	10.3Aa	9.4Ba	0.0028
SCF	76.8Ba	105.3Aa	111.4Ab	<.0001	10.7Aa	9.8Ba	9.6Ba	0.006
NPK	90.1Ba	98.0Ba	125Aa	<.0001	10.6Aa	9.9Ba	9.6Ba	0.04
Pr>F	0.03	0.13	0.04		0.18	0.08	0.86	

SCF *:* Sugar cane foam *;* **ES** *:* Extractable sugar ; Letters A and B are indicating mean values with significant difference in the line as well as for a and b in the colunm

Table 4. Yield and Extractable sugar differences according to the rates of sugar cane foam (SCF) and the inorganic fertilizer NPK

		Yield (tha^{-1})		ES (%)	
SCF	**NPK**	Dif	*Probability*	Dif	*Probability*
0	150	-7.4	0.38	0.19	0.42
0	300	-11.6	0.15	0.27	0.19
0	450	-7.5	0.29	0.04	0.85
0	600	-19.8	0.01	0.35	0.23
6	150	-6.8	0.25	-0.09	0.57
6	300	-11.0	0.04	-0.01	0.92
6	450	-6.9	0.19	-0.24	0.36
6	600	-19.2	0.00002	0.07	0.70
12	150	-2.73	0.69	-0.03	0.86
12	300	-2.96	0.29	0.05	0.75
12	450	-2.86	0.71	-0.18	0.40
12	600	-15.2	0.03	0.13	0.53
18	150	1.27	0.83	0.08	0.69
18	300	-2.95	0.63	0.17	0.32
18	450	1.14	0.85	-0.06	0.78
18	600	-11.2	0.02	0.25	0.33
24	150	-1.56	0.83	0.05	0.19
24	300	-5.79	0.53	0.14	0.53
24	450	-1.69	0.85	-0.09	0.68
24	600	-14.0	0.08	0.22	0.34

Dif *: difference*

Table 5. Average concentration of N, P and K in sugar cane leaf according to the rate of SCF and NPK across year

SCF				**NPK**			
Rates (t/ha)	**N (gkg^{-1})**	**P(gkg^{-1})**	**K(gkg^{-1})**	**Rates (kg/ha)**	**N(gkg^{-1})**	**P(gkg^{-1})**	**K(gkg^{-1})**
0	1.47a	0.14a	1.35a	0	1.47a	0.14a	1.35a
6	1.63a	0.13a	1.12a	150	1.80a	0.13a	1.15a
12	1.72a	0.14a	1.22a	300	1.72a	0.13a	1.20a
18	1.76a	0.13a	1.22a	450	1.76a	0.14a	1.11a
24	1.61a	0.14a	1.17a	600	1.69a	0.14a	1.20a
Pr>F	0.58	0.91	0.39		0.49	0.99	0.48
GM	1.64	0.13	1.22		1.69	0.14	1.21

GM : *Grand mean* ; Letter a is indicating mean with no significant difference

Table 6. Differences of leaf concentrations of N, P and K according to the rates of sugar cane foam (SCF) and inorganic fertilizer NPK

		N		**P**		**K**	
SCF (tha^{-1})	**NPK ($kgha^{-1}$)**	Dif **(gkg^{-1})**	Probability	Dif **(gkg^{-1})**	Probability	Dif **(gkg^{-1})**	Probability
0	150	-0.33	0.15	0.004	0.88	0.0004	0.29
0	300	-0.25	0.36	0.006	0.84	0.0004	0.30
0	450	-0.28	0.06	-0.004	0.89	0.0008	0.38
0	600	-0.21	0.25	0.0003	0.91	0.0009	0.33
6	150	-0.16	0.44	-0.007	0.45	-0.00001	0.53
6	300	-0.08	0.63	-0.006	0.54	-0.00002	0.21
6	450	-0.12	0.46	-0.02	0.23	0.0004	0.47
6	600	-0.05	0.71	-0.01	0.67	0.0004	0.37
12	150	-0.08	0.41	0.009	0.29	0.0001	0.34
12	300	-0.004	0.97	0.01	0.28	0.0001	0.34
12	450	-0.04	0.63	0.0008	0.93	0.0005	0.34
12	600	0.03	0.80	0.007	0.54	0.0006	0.27
18	150	-0.04	0.69	-0.008	0.41	0.00003	0.53
18	300	0.04	0.80	-0.007	0.49	0.00002	0.70
18	450	0.00	1.00	-0.02	0.13	0.0004	0.47
18	600	0.07	0.35	-0.01	0.36	0.0005	0.38
24	150	-0.19	0.19	0.003	0.75	0.00009	0.43
24	300	-0.11	0.53	0.004	0.66	0.00007	0.44
24	450	-0.14	0.47	-0.006	0.59	0.0005	0.35
24	600	-0.07	0.63	0.0008	0.94	0.0006	0.28

Table 7. Pearson Correlation between the yield of sugar cane and soil contents of N, C, Pa, K, Mg and Ca as well as soil pHwater and C/N ratio as affected by different rates of SCF

	Rate (tha^{-1})		pH	N	C	C/N	Pas	K	Mg	Ca
Control	**0**	R	-0.05	0.08	0.01	0.05	-0.70	-0.57	0.10	0.21
		Pr>|r|	0.88	0.83	0.96	0.89	0.03	0.11	0.79	0.59
SCF	**6**	R	-0.38	0.62	-0.64	-0.9	0.1	0.31	0.56	0.27
		Pr>|r|	0.31	0.07	0.06	0.008	0.79	0.42	0.12	0.48
	12	R	0.29	-0.21	-0.72	-0.13	-0.24	-0.68	-0.03	0.02
		Pr>|r|	0.44	0.59	0.03	0.74	0.52	0.04	0.93	0.93
	18	R	0.05	-0.37	-0.57	0.33	-0.23	0.53	0.0006	-0.47
		Pr>|r|	0.88	0.09	0.11	0.95	0.54	0.14	0.99	0.2
	24	R	-0.41	-0.22	-0.66	-0.14	-0.79	-0.17	-0.22	-0.53
		Pr>|r|	0.27	0.57	0.05	0.71	0.01	0.66	0.6	0.14

Table 8 . Soil contents of N, P and K after the trial every year (2011, 2012 and 2013) in the control plat and the treatments of sugar cane foam (SCF) and inorganic fertilizer NPK

	SCF			**NPK**			**Control**		
	N(gkg^{-1})	Pa ($mgkg^{-1}$)	K ($cmolkg^{-1}$)	N(gkg^{-1})	Pas ($mgkg^{-1}$)	K ($cmolkg^{-1}$)	N(gkg^{-1})	Pas ($mgkg^{-1}$)	K ($cmolkg^{-1}$)
2011	1.55a	55.20a	0.25ab	1.33b	15.58b	0.37a	1.47b	17.33a	0.34a
2012	1.35c	44.70ab	0.13b	1.34b	37.25a	0.18b	1.29b	18.66a	0.19a
2013	1.79a	31.42b	0.30a	1.79a	10.67b	0.37a	1.97a	16.67a	0.23a
Pr>F	<0.0001	0.017	0.046	<0.0001	0.0002	0.0009	0.03	0.917	0.364

Letter a and b are indicating mean values with significant difference in column

Table 9 . Linear regression of soil contents of N, P and K according to the rates, year and yield under the effect of sugar cane foam (SCF) and inorganic fertilizer NPK as well as in the control plot

		N		**P**		**K**	
		Coef	**P>|t|**	**Coef**	**P>|t|**	**Coef**	**P>|t|**
SCF	Rate	$3\ 10^{-3}$	0.625	1.8	0.0001	$-4\ 10^{-3}$	0.260
	Year	$7\ 10^{-4}$	<0.0001	$2\ 10^{-2}$	0.002	$1\ 10^{-4}$	0.163
	Yield	$-5\ 10^{-4}$	0.805	-0.34	0.021	$8\ 10^{-4}$	0.540
R^2			0.97		0.89		0.66
NPK	Rate	$-3\ 10^{-3}$	0.170	$7\ 10^{-3}$	0.699	$5\ 10^{-5}$	0.710
	Year	$3\ 10^{-4}$	0.006	$18\ 10^{-2}$	0.047	$7\ 10^{-5}$	0.440
	Yield	$24\ 10^{-3}$	0.001	-0.177	0.301	$16\ 10^{-3}$	0.251
R^2			0.97		0.59		0.81
Control	Rate	.	.	.	.	.	.
	Year	$7\ 10^{-4}$	0.07	0.017	0.001	$2\ 10^{-4}$	0.015
	Yield	$1\ 10^{-3}$	0.83	-0.187	0.035	$-3\ 10^{-3}$	0.112
R^2			0.95		0.96		0.88

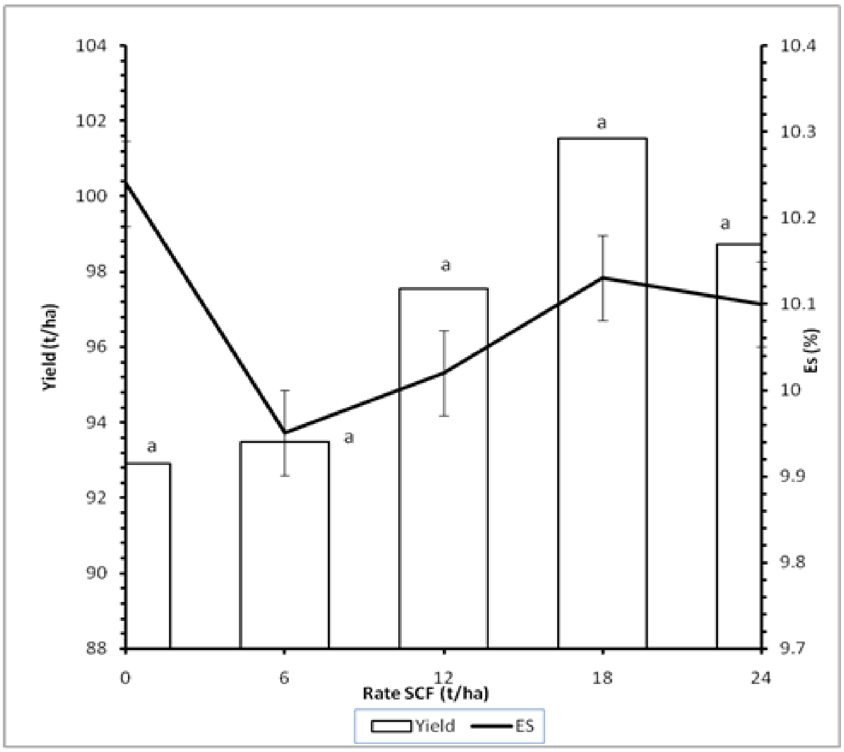

Figure 1. Mean values of sugar cane yield and the rates of extratable sugar (ES) as affected by the rates of sugar cane foam (SCF). Letter a is indicating mean values with no significant difference ($p > 0.05$) ; barre = standard error.

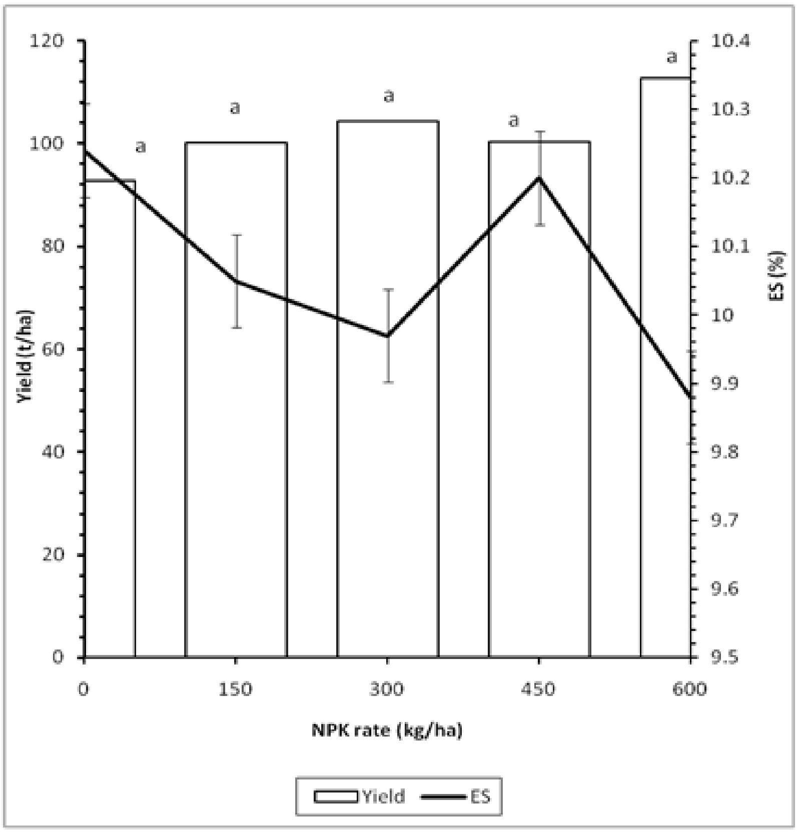

Figure 2. Mean values of sugar cane yield and the rates of extratable sugar (ES) as affected by the rates of inorganic fertilizer NPK. Letter a is indicating mean values with no significant difference ($p > 0.05$) ; barre = standard error.

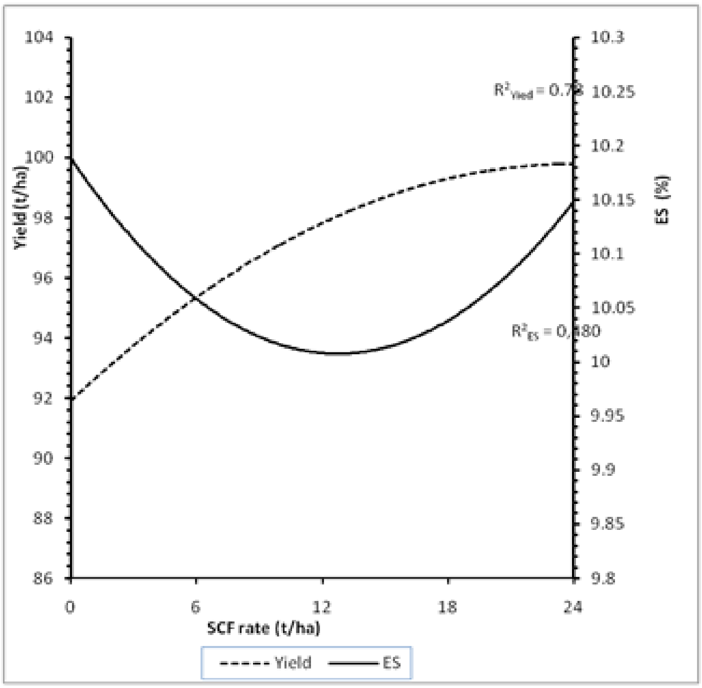

Figure 3. Response curve of sugar cane yield and the rate of extractable sugar (ES) as affected by the rate of sugar cane foam (SCF); bare = standard error

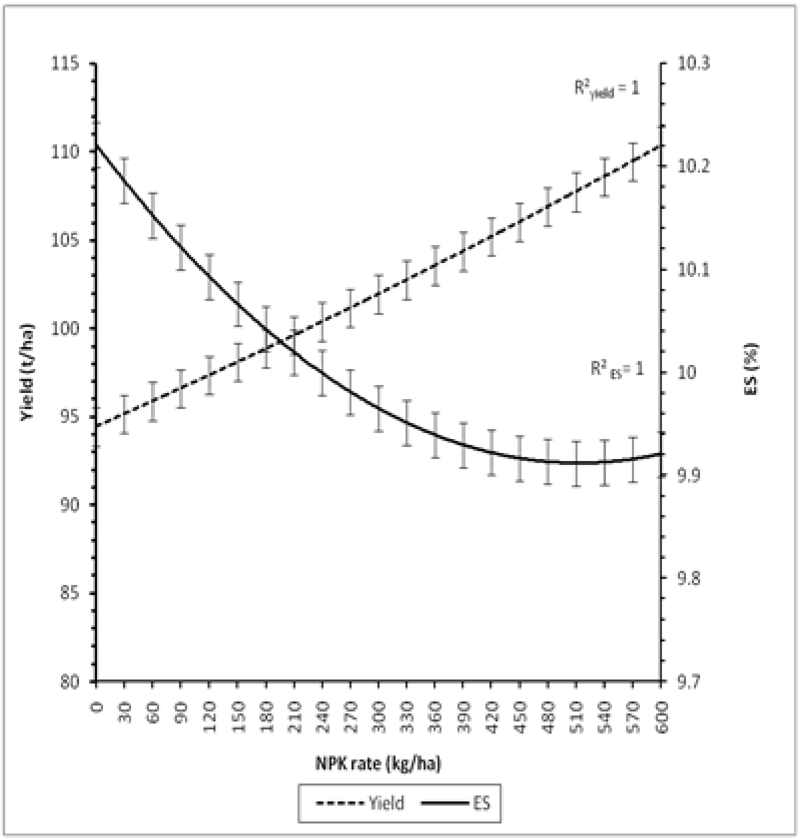

Figure 4. Response curve of sugar cane yield and the rate of extractable sugar (ES) as affected by the rate of inorganic fertilizer NPK; bare = standard error