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A New Proposal for Sugar Cane Fertilization Based on Sustainable Land Management Practices.

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ABSTRACT

A new sugar cane fertilization method based on the principles of sustainable land management is suggested. Accordingly, a study was conducted at the Mid-Eastern Sugar Cane Local Research Station (ETICA) in the province of Camagüey, Cuba. The single or combined effects of FitoMas- E and Enerplant phytostimulants, using 50% of the mineral fertilizer dose recommended by the Service of Fertilizer Recommendations and Amendments (SERFE) for this particular type of soil for variables crop yields and industrial yields. The stumps used for evaluation belonged to a third generation. The results demonstrated that the mixture of Enerplant and FitoMas-E with 50% of the dose for mineral fertilizers had a positive effect on the crop and industrial yields evaluated for sugar cane. Moreover, the economic assessment showed that the three treatments that applied the phytostimulants, either separately or together, combined with 50% of the dose recommended by SERFE, were more productive than the application of the whole dose. These criteria should be considered due to the environmental benefits observed in this study.

KEY WORDS/: Phyostimulants, fertilization, nutrients, sugar cane, sustainable land management.

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INTRODUCTION

The large extensions of land used for sugar cane agriculture in Cuba, along high demands of nutrients and low nutrient deposit by fertilizing, have brought about a remarkable decrease in the fertility of most soils engaged in the culture of this poacea. The nutritional deficit of crops must be compensated by fertilization efforts to achieve sustainability and competitiveness of the productive system. It is important to pay attention to crop nutrition, since in tropical conditions soil degradation processes are intense. This practice is critical to achieve stable and proper yields, using mineral fertilizers, toward a more balanced nutrition of the crop and high cost-effective productions. The high costs of fertilization demand timely and effective application to make the best use of nutrient per plant.

Since the 1990s, the Center for Sugar Cane Research (INICA) has conducted studies on the application of biostimulants to sugar cane, and their response, first based on lab samples in small experimental plots. By 2001, production was scaled up for commercial purposes, extending to all the edaphoclimatic conditions of the country. These extensions demonstrated that different biostimulants combined with the recommended mineral fertilization produced higher yields, than by using mineral fertilizing alone. The application of biostimulants alone reduces the negative effects of stress caused by variations in the occurrence of precipitations, a factor that should be considered when adapting to climate changes.

Based on these antecedents, it is important to study the effects of biostimulants in order to gather important criteria that could be used as relevant elements in the use of such alternatives.

MATERIALS AND METHODS

A randomized block design was made with four treatments and five repetitions in 20 plots. The treatments were based on a control (N), with 100% application of mineral fertilizer recommended by the Recommendation Service of Fertilizers and Amendments (SERFE-Azcuba), without biostimulants. A second treatment (En) was based on the application of biostimulant Enerplant, and 50% of SERFE recommendation. The third treatment (Fi) was similar to the previous, but Enerplant was substituted with FitoMas-E. The fourth treatment (En+Fi) combined the two biostimulants with half the dose of mineral fertilizers recommended by SERFE (Table 1). The experimental plots had four 7.5 m long rows, with 1.6 m separation, making a total harvest surface of 48 m^2. The stump evaluated was the third shoot of variety C86-12.

Table 1. Treatments evaluated in the research

Treatments		kg ha^{-1}		mL ha-1	L ha-1	mL ha-1 + L ha-1
N		P	K	Enerplant	FitoMas-E	Enerplant + FitoMas-E
N	100	50	100			
En	50	25	50	2.6		
Fi	50	25	50		4.0	
En+Fi	50	25	50			2.6 + 4.0

N: Control En: Enerplant Fi: FitoMas-E

Table 1 shows the treatments evaluated in the research. Mineral fertilization was made manually, 45 days after cutting, 10 cm deep, approximately. The biostimulants were applied to foliage with manual sprinkler in a final solution of 200 L ha^{-1}. Enerplant applications were made on the 90^{th} and 120^{th} days after cutting; FitoMas was applied once, 90 days after harvest.

The main components of yields were evaluated eight months after. Grinding stem count was performed in the two main rows of each plot to estimate stem population per hectare. Stem diameter and length were estimated from 10 stems per plot; inter-knot +7 diameter was determined with a gauge caliper. Length was measured from the stem base to the first visible dewlap with a ruler (Jorge *et al*., 2011).

Brix, Pol in sugar cane and juice purity were determined from a sample of 10 stems a week prior to harvest, according to Jorge *et al*. (2011). Harvest was made manually, according to the technical norms, at 12 months of age.

To achieve that, the production of each plot was directly weighed used SALTER 599, coupled to a mechanical crane. Two-way data analysis of variance was performed. STATISTICA, version 6, for Windows was used for data analysis. The significant differences among the treatments were determined by Duncan's multiple range ($p<0.05$) to set up the differences among the means.

RESULTS AND DISCUSSION

Table 2 shows the results of multivariate analysis of variance for potassium for crop yields, according to the treatments evaluated. No statistical differences were observed in stem diameter between treatments N and En+Fi, but they did differ from the other treatments. These results demonstrated that the plant was capable of assimilating every necessary nutrient, according to SERFE, with the application of half the dose of the mineral fertilizer combined with the biostimulants studied, to achieve proper development of the main target organ with economic relevance in sugar cane production. This corroborated the findings of León *et al.* (2009), who claimed that biostimulants have a positive effect on growth and development. They increase the efficiency of biosynthesis, which stimulates the plants to fix more CO_2, and favor the development of microorganisms that release nutrients into more assimilable forms and growth stimulating substances. It contributes to improved assimilation of fertilizers, especially on the positive properties of these two biostimulants when they combine.

The results of analysis of variance for stem length, number of stems per hectare, and tons of sugar cane per hectare, evidence the lack of statistically significant differences among the treatments (Table 2).

Table 2. Influence of treatments on crop yield components

Treatments	SD (cm)	SL (cm)	NT ha^{-1} x 10^3	SCTH
N	2.85a	197.8	74.92	101.25
En	2.35c	194.4	67.42	103.33
Fi	2.56b	194.2	70.5	100.83
En+Fi	2.87	200.4	69.42	106.67
$\bar{X}$ ± SE	2.66 ± 0.05	196.7 ± 1.87	70.56 ± 17.0	103.02 ± 2.56
Sig.	*	ns	ns	ns

In an article published by Pino *et al*. (2017) at Manuel Fajardo Basic Production Unit (UEB), in the province of Mayabeque, the authors found significant differences in terms of stem population per hectare in the treatments evaluated, which differed from the results of this experiment.

Meanwhile, Martínez *et al*. (2017) did not find any significant differences in their studies on FitoMas-E and the dose of fertilizers used, and the stem population depended on the results of this research, which are remarkable (very high, considering they came from a third generation stump). It demonstrates the importance of proper crop management between harvest periods. The results achieved in this paper coincided with the findings of Díaz (2007), who claimed that the combination of biostimulants with mineral fertilization enhanced energetic processes in plants efficiently; production may be increased even when mineral fertilization is cut down by 50%.

Villar *et al*. (2011) in research done at Pablo Noriega UEB, in Mayabeque, found no statistically significant differences related to yields in the treatment with 100% application of the dose recommended by SERFE (50%), plus FitoMas-E, which were similar to the results of this paper.

Besides, Molinet *et al*. (2012) did a study on vertisol soils at the Andres Cuevas Heredia cooperative (UPC) to corroborate the agronomic effectiveness of FitoMas-E + biostimulants, and mineral fertilization levels recommended by the agro-chemical service. No significant differences were observed in the research for treatments one and three, using 100% of the dose of fertilizers without biostimulants, and 50% of the dose plus the biostimulant, which coincided with the results of this paper. However, Nápoles *et al*. (2017) found that when the dose recommended by SERFE was reduced to 50% and mixed with FitoMas + Enerplant, statistically significant differences were observed in comparison to 100% of the dose recommended by SERFE without stimulants. The results were 7.4 and 8.96 t ha^{-1} higher, which differed from the results of this research, but corroborated the importance of a 50% reduction of mineral fertilizer mixed with biostimulants. An article published by Pino *et al*. (2017) found that the FitoMas-E (4 L ha^{-1})+ Enerplant (0.052 L ha^{-1}) combined with the dose recommended by SERFE, reached statistically significant increases in crop yields between 4.83 and 7.83 t ha^{-1}, which was different from the results of this study.

These causes may be allegedly caused by the different edaphoclimatic conditions of the experiments, with different agronomic managing practices. Moreover, the most important factor to be considered was that the sugar cane cultivars were different.

The mean yield value from the combination of biostimulants was higher than the rest of the treatments. Therefore, it may be inferred that for the conditions of this research, 50% the mineral fertilizer dose (NPK) recommended by SERFE did not affect crop yields, which would generate environmental benefits by reducing the volume of chemicals in the soil. Overall, the crop yields of this experiment may be considered high, since the average yield for a third generation stump in the province accounted for 33.5 t ha^{-1} after the previous harvest, which showed the importance of proper crop management, with timely and quality actions.

Table 3 shows the results of analysis of variance for industrial yields, according to the treatments evaluated. No statistically significant differences were observed among the treatments for the variables studied. This is a relevant result, whose final goal was sugar cane production. Therefore, a 50% substitution of mineral fertilizers by biostimulants FitoMas-E and Enerplant did not affect the industrial parameters. Similar results were reported by García (2004); Mayor (2009); and Gallego *et al.* (2017).

Table 3. Influence of treatments on the components of industrial yields.

Treatments	Brix	Pol % sugar	Pol t ha^{-1}
N	23.49	18.64	18.87
En	23.74	18.65	18.9
Fi	23.78	18.75	19.27
En+Fi	23.23	19.05	20.35
$\bar{X}$ ± SE	23.56 ± 0.21	18.78 ± 0.10	19.35 ± 0.51
Sig.	ns	ns	ns

These results coincided with the reports published by Gallego *et al*. (2017), where they demonstrated that the FitoMas dose was a determining Pol factor in sugar cane, though it did not act negatively for this indicator. On their part, García (2004) and Mayor (2009) also published similar results; they found no significant effects for this indicator using biostimulants FitoMas-E and Vitazyme.

The Pol percentage values achieved in this study may be considered high, which corroborated the importance of proper crop management; *i.e.*, giving the plant the required quality care at the proper time, so it can express all its productive potential, which will be turned into more sucrose production.

Table 4 shows the results of the financial analysis. The three treatments that used biostimulants (either separately or combined using 50% of the recommended dose) had the lowest expenses

during the production process, but they also produced the highest profits and lowest values of cost per Cuban Peso, which may be considered low (only $ 0.16 per peso produced). It demonstrated the economic feasibility of the results with the use of biostimulants combined with a 50% decrease in the dose of mineral fertilizers recommended by SERFE.

Table 4. Financial analysis of results

Treat.	Expenses ha^{-1}	Income ha^{-1}	Profits ha^{-1}	Cost per	Point of balance
N	6 396.64	20 042.44	13 645.80	0.32	32.31
En	3 285.50	20 454.17	17 168.67	0.16	16.60
Fi	3 266.34	19 959.29	16 692.95	0.16	16.50
En+Fi	3 293.00	21 115.33	17 822.33	0.16	16.64

N: Control **En:** Enerplant **Fi:** FitoMas-

CONCLUSIONS

The combination of biostimulants Enerplant and FitoMas-E, plus 50% of the mineral fertilizer dose, had a positive effect on the components of industrial and crop yields. The financial assessment demonstrated that the three biostimulant treatments, either separately or combined in 50% of the dose recommended by SERFE, were better compared to the 100% application of the recommended dose.

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