Fertilizing Effects of Combined Application of Sugar Cane Ash with Mycorrhiza Fungi and Compost in Different Cuban Soils

Fundora, Onelio[a*], Mario Vidaurre[a], Yenny Torrecilla[a], Cristóbal Ríos[a], Bettina Eichler-Löbermann[b]

[a] Universidad Central de Las Villas, Facultad Ciencias Agropecuarias, Carretera Camajuaní, Cu 54830 Santa Clara, Cuba
[b] Universität Rostock, Agrar- und Umweltwissenschaftlische Fakultät, D-18051 Rostock, Germany

Introduction

In Cuba, sugar cane ash is produced in enormous quantities as a residue of the island's sugar industry and stored in outdoor piles, constituting an environmental risk. At the same time, a lack of research prevents the adequate use of cane ash as an amendment for soils poor in phosphorus (P) and potassium (K), which are often inadequately low fertilized due to the high prices of imported chemical fertilizers. The objective of this work was to determine the effect and the adequate fertilization dosage of sugar cane ash alone and with Mycorhiza and compost additions.

Material and Methods

Field studies and pot experiments were carried out with different soils (Eutric Oxisols and Inceptisols) and different crops. Field trials (in blocks at random) consisted of maize in small plots (4,8 m²) and sugar cane in big plots (480 m²) in production conditions. In those experiments, the effect of increasing rates of sugar cane ash, alone or accompanied with Mycorrhiza or compost, on plant and soil compared with the effect of enough NPK chemical fertilizer (150 kg N, 150 kg P_2O_5, 250 kg K_2O ha^{-1}) or with an absolute control (untreated soil), was investigated. The soil phosphorus and/or potassium contents (extraction with H_2SO_4 0,1 N) were insufficient. The method of Henin was used for the analysis of stable soil aggregates The sugar cane ash presented a content of 1.56% P_2O_5 and 3.10% K_2O, and pH value, 8,4. The Mycorrhiza (Glomus intraradices and Glomus hoi-like strains), was applied as the commercial product EcoMic, diluted at 1kg EcoMic in 600 ml water, and applied as a paste to the maize grains; once the seeds were coated, they were allowed to dry under shade until the following day. Plant growth and development were evaluated. Microorganism counting by serial dilutions was carried out according to Winogradsky methods (1949)., cited by Mayea (1982). The SPSS and CurveExpert softwares were used for the statistical analysis.

Results and Discussion

Typical compost applications of 10 t ha^{-1} in organic sugar production could be significantly improved by combining them with ash amendments (Table 1). The highest number of stalks per clump, as well as the biggest diameter and height, 6 month after plantation, were obtained with the application of 10 t ha^{-1} sugar cane ash + 10 t ha^{-1} compost. Although significantly inferior, 5 t ha^{-1} ash + 10 t ha^{-1} compost had a remarkable effect in this respect. The increase in leaf potassium as effect of compost and ash applications was noteworthy.

The best effect on soil phosphorus and potassium was obtained with the combination of ash plus compost which attained sufficient contents of both nutrients for the generality of tropical crops (Table 2).

Results considering the group of investigations carried out, indicated that adequate sugar cane ash doses vary from 2.5 to 10 t ha^{-1}, depending on soil characteristics, although, 10 t ha^{-1} dose was frequently the most favourable.

* Corresponding author. Email: ofundora@uclv.edu.cu

Table 1: Effects of ash and compost on the sugar cane (treatments with distinct letters differ significantly, Tukey HSD, $\alpha = 0,05$)

Treatment	Nr. of stalks per clump	Height of the stalks (cm)	Diameter of the stalks (cm)	Leaf K (% K in dry matter)
10 t ha^{-1} compost + 10 t ha^{-1} ash	10,0 a	177,2 a	4,01a	0,90 a
10 t ha^{-1} compost + 5 t ha^{-1} ash	8,0 b	159,6 b	3,58 b	0,85 b
10 t ha^{-1} compost	7,2 bc	152,7 b	3,29 c	0,79 c
5 t ha^{-1} ash	5,6 cd	131,2 c	3,41 bc	0,68 d
Control (non treated)	4,1d	110,4 d	2,90 d	0,62 e

In this investigation the combination of 10 t compost plus 10 t ha^{-1} ash increases the pH from a value of 6,4 to 6,9 (Table 2) but with higher ash doses until 40 t ha^{-1} in other experiments the pH value increased until 7,9, which probably affect the availability of nutrients of the soil, so relatively high ash doses should be avoided.

Table 2: Effects of ashes and compost on the Oxisol (treatments with distinct letters differ significantly, Tukey HSD, $\alpha = 0,05$)

Treatment	Soil P mg P_2O_5 100 g^- soil	Soil K mg K_2O 100 g^- soil	Soil pH (KCl 1,0 N)
10 t ha^{-1} compost + 10 t ha^{-1} ash	10,6 a	15,8 a	6,90 a
10 t ha^{-1} compost + 5 t ha^{-1} ash	9,6 a	13,8 ab	6,77 ab
5 t ha^{-1} ash	7,2 ab	11,6 ab	6,71 abc
10 t ha^{-1} compost	4,0 bc	8,2 ab	6,65 bc
Control (non treated)	2,8 c	6,0 b	6,40 d

Table 3 shows the effect of doses of sugar cane ash alone and of other treatments on maize dry matter yield as indicator plant in a pot experiment (0,5 kg soil pot^{-1}). The best result was obtained with 10 t ha^{-1} ash, above the chemical NPK fertilization. It is also very remarkable that only 5 t ha^{-1} ash, if they were accompanied with Mycorrhiza, constituted the variant with the nearest result to that of 10 t ha^{-1} ash alone, and above 5 t ha^{-1} ash alone. Seemingly, fungal hyphas, besides other possible effects, contribute to a better use of ash phosphorus and other nutrients (Hamel and Plenchette, 2007). When Mycorrhiza was applied alone with nitrogen, it had a poor performance, contrary to its application with ash. That performance could be attributed to the low content of soil PK (Larsen *et al.*, 2007). Probably, the short term pot experiment didn't allow the compost to show its potential effect as nutrients source for plants, as it did in long term field experiments. However, it manifested the greatest influence on water st able soil aggregates.

Table 3: Dry weight of the indicator plant (maize 1 month after sowing in an Oxisol) as effect of different treatments including ashes, compost and Mycorrhiza (treatments with distinct letters differ significantly, Tukey HSD, α = 0,05)

Treatments	Dry Weight (g plant^{-1})	Treatments	Dry Weight (g plant^{-1})
10 t ha^{-1} ash + N	0,60 a	10 t ha^{-1} compost + N	0,40 abc
5 t ha^{-1} ash + Mycorrhiza + N	0,58 ab	2,5 t ha^{-1} ash + N	0,36 bc
5 t ha^{-1} ash + 10t compost + N	0,50 abc	Mycorrhiza + N	0,36 bc
7,5 t ha^{-1} ash + N	0,45 abc	NK	0,35 c
5 t ha^{-1} ash + N	0,43 abc	NP	0,35 c
NPK	0,40 abc	N	0,33 c

Although much less than compost, ash also influenced positively on stable aggregates in Oxisols as well as in Inceptisols in fields experiments in small plots (Figure 1). As the quantity of its application increased, the effect on the stable aggregates grew. These results would mainly be explained as effect of the highest organic matter content in the soil as ash dose increases due to its positive influence on plant, with a bigger production of organic residuals that enrich the soil, apart from other possible effects.

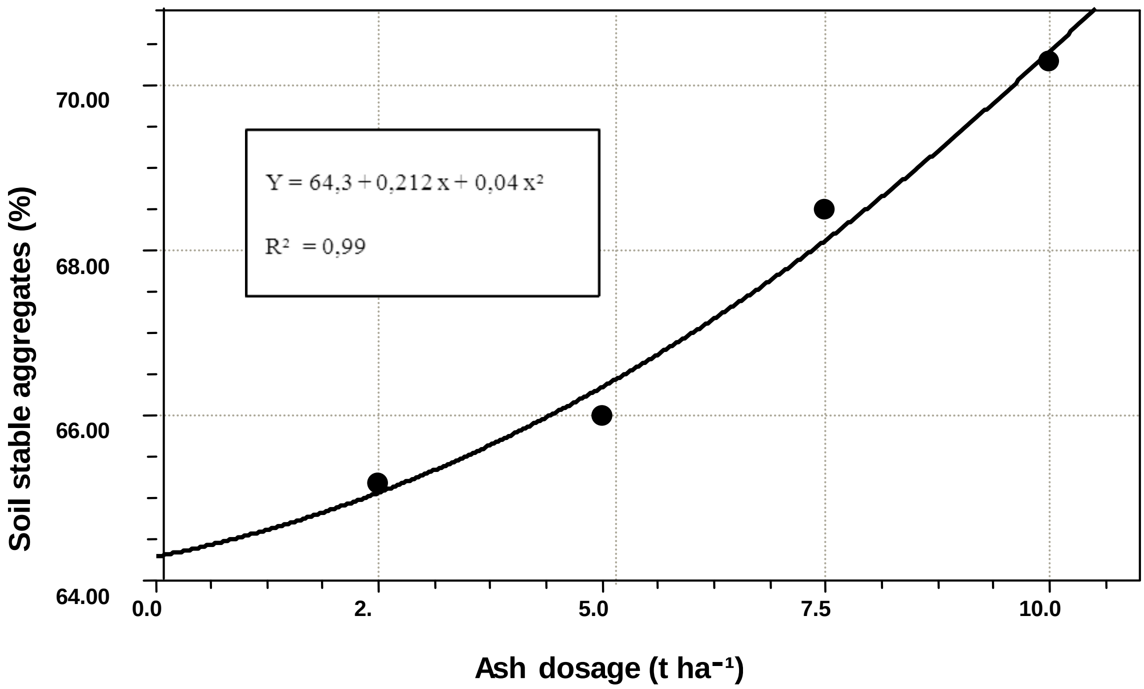

Figure 1: Stable soil aggregates in an Oxisol as effect of ash application

The treatments including ash (10 t ha^{-1}) had a remarkable influence on the phosphates solvent bacteria in a field trial with maize in small plots (Table 4). Ash probably supplies nutrients that are not present in enough concentrations for the bacteria in the soil. All treatments increased Azotobacter in relation with the control (N treatment), but the most remarkable was the one including ash and Mycorrhiza. The positive Mycorrhiza influence on Azotobacter has been reported (Fernández Martin, 2003).

Table 4. Effects of ash and Mycorrhiza application on microorganisms in an Inceptisol (physical unities of colonies g^{-1} soil)

Treatment	Bacteria	PSB*	Azotobacter	Fungi	Actinomyces
N	$5,3 \times 10^7$	$1,9 \times 10^5$	$9,0 \times 10^3$	$3,0 \times 10^5$	$9,9 \times 10^5$
Ash + N	$5,6 \times 10^7$	$4,0 \times 10^5$	$1,2 \times 10^4$	$3,4 \times 10^5$	$7,3 \times 10^5$
Ash + Mycorrhiza + N	$4,9 \times 10^7$	$3,5 \times 10^5$	$5,5 \times 10^5$	$3,8 \times 10^5$	$8,2 \times 10^5$

*Phosphate solvent bacteria

Conclusions and Outlook

Sugar cane ash can be an adequate substitute for highly soluble P and K fertilizers in Cuban soils (Oxisols and Inceptisols). Ash had notable effects on soil P and K reserves of both soil types. The addition of Mycorrhiza to ash enabled better results than ash application alone. A combined application of ash with compost resulted in higher plant yields than compost application alone. Results also showed positive effects of cane ash on physical soil properties (aggregate stability) and on soil microbial activity. Ash dosage of 2,5 to 10 t ha^{-1} , depending on the soil PK, are recommended.

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