THE EFFECT OF BAGASSE FURNACE ASH APPLICATION ON SUGARCANE RESISTANCE TO TOP BORER *SCIRPOPHAGA NIVELLA INTACTA* SNELLEN (LEPIDOPTERA: PYRALIDAE)

By

SAEFUDIN SAEROJI, SUNARYO and HERU GUNITO

PT Gunung Madu Plantations, Lampung, Indonesia
saefudin@risetgmp.com

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Abstract

SUGARCANE top borer, *Scirpophaga nivella intacta* Snellen, is a major pest of sugarcane at PT Gunung Madu Plantations, Lampung, Indonesia. Infestation on several commercial varieties is alarming despite an integrated control program. Many studies have been done in South Africa, Hawaii, Florida, India, and Taiwan on use of the element silicon to improve plant resistance to pest and disease. Bagasse furnace ash, plentiful at a cane sugar factory, is known as an important silicon source. A field trial was conducted in the plantation to study the effect of bagasse furnace ash application on sugarcane resistance to top borer infestation. A susceptible variety TC4 was used. Treatments comprised a control and 40, 80, and 120 t/ha of pre-plant broadcast application. In the 120 t/ha treatment, the number of top borer larvae successfully boring into the leaf spindle was 20.7% fewer than the control. Also 19.2% fewer larvae bored into the growing point and the internodes. Similarly, the length of boring tunnels (measured from the growing point) in this treatment was shorter than in the control. In addition, stalk population, height, and diameter increased with the rate of ash application. Application of 120 t/ha bagasse furnace ash of approximately 7.97 ± 0.58% silicon content increased the resistance of susceptible variety TC4 to top borer infestation and increased the cane yield by 39.89%.

Introduction

Sugarcane moth borers (Lepidoptera: Pyralidae) are predominant pests in Gunung Madu sugarcane plantation, Lampung, Indonesia. The borer complex consists of white top borer (*Scirpophaga nivella intacta* Snellen), and spotted- and glossy- stem borers (*Chilo sacchariphagus* Boj. and *C. auricilius* Dudg.). Borer population cycles overlap under the tropical conditions found here. Infestation pressure is exacerbated by the massive size of the plantation (> 25 000 ha) and uninterrupted mono-cropping practices applied therein (Sunaryo, 2005).

Stem borers have been acceptably controlled by augmented natural enemies reared in the laboratory such as egg parasitoid *Trichogramma chilonis* Ishii and larval parasitoids *Cotesia flavipes* Cam. and *Sturmiopsis inferens* Tns.

Top borers have been controlled through recolonisation and preservation of natural enemies in the field and soil application of granular insecticide on selective fields of young canes adjacent to heavily damaged mature canes. At the peaks of moth flight, a combination of light trappings and manual collection has been occasionally done to reduce moth populations. However, the overall infestation in the last decade reached 7.80% (3.04 – 13.52%) and was 9.61% (3.47 – 18.77%) on susceptible variety TC4. Other approaches are explored to improve the overall result.

Top borers lay eggs on the uppermost leaves; the hatched larvae then penetrate the leaf spindle through the midrib. They move to the growing point, kill it and bore further downward into the internodes. They feed and transform into pupae inside the internodes.

Field and greenhouse trials in Florida, Hawaii, and Mauritius indicated that the application of silicon fertiliser had a positive effect on sugarcane resistance to pests, diseases, and frost tolerance (Matichenkov and Calvert, 2002). This knowledge is potentially useful, as silicon is concentrated in bagasse ash (furnace- and fly-ash), which is abundantly available at most sugar mills. In India, sugarcane varieties which are resistant to shoot borer were found to contain higher silicon per leaf area unit, and a study in Taiwan showed that borer infestation on silicon-treated sugarcane was lower compared with untreated cane (Meyer and Keeping, 2005). Keeping and Meyer (2006) compared the efficacy of several silicon sources, including fly ash, on controlling boring by *Eldana*. Also from South Africa, Kvedaras *et al.* (2007) reported a comprehensive study on soil applied silicon, sugarcane cultivars, and borer feeding sites in the stalks.

The objective of the present study is to find out the effect of the application of bagasse furnace ash on sugarcane resistance to top borer *S. nivella intacta.* This material is abundantly available at most sugar mills. The use of bagasse to fuel mill boilers at Gunung Madu sugar mill (12 000 TCD) leaves up to 23 000 t bagasse furnace ash annually, and therefore it is potentially a good and practical silicon source for this purpose.

Materials and method

The present study was carried out at Gunung Madu sugarcane plantation, Lampung, Indonesia (approximately 4°42' S/105°12' E), from August 2005 to July 2006. The study used field plots 20 m long x 40 m (26 sugarcane rows) wide, with 5 m inter-plot spacing. In each plot, 16 rows were selected for pest observation and 10 other rows for agronomy observation.

The treatments consisted of one control (no-ash application) and 40, 80, and 120 t/ha–of bagasse ash application, each replicated three times in a complete randomised design. The bagasse ash, supplied from Gunung Madu sugar mill, was pre-plant broadcasted as in Keeping *et al.* (2004). Silicon content of the material, analysed at the Soil and Plant Analysis Laboratory of the plantation using a yellow silico-molybdic acid method, was 7.97 ± 0.58%. TC4 variety, which is highly productive but susceptible to top borer, was planted.

Resistance was assessed on artificially-infested plants. Three newly hatched top borer larvae were laid on top of leaf number –1 of each of 80 sugarcane stalks in each plot. This was done on 9 month old plants, the same plant age chosen by Kvedaras *et al.* (2005). These stalks were marked for spindle and internode observations. Observations were made 14 and 27 days after infestation with 40 infested plants for each observation (where at least one larva was already in the midrib). The first observation was to assess larval penetration and position in the leaf spindle while the second was to assess the extent of boring into internodes.

Infestation success rate in the spindle and internodes was used to describe plant resistance. An infestation was considered successful when the larva was still alive. The distance of larvae from the growing point when they were in the spindle (14 days after infestation) and when they were in the internodes (27 days after infestation) was measured to find out the movement and position of larvae.

The larval infestation success rate (%) within both spindle and internodes was calculated by the number of successful infestations relative to the total samples artificially infested. The infestation success rate (%) in the spindle was formulated as:

$$(s/40) \times 100$$

where s = number of successful infestations in the spindle,

40 = total samples infested.

As for larva success rate in the internodes, the following formula was used:

$(i/40) \times 100$

where i = number of successful infestations in internodes,

40 = total samples infested.

Data on stalk population, height, and diameter of millable stalks from 10 through 12 month age (harvest time) were also recorded to give a general idea on the effect of bagasse ash application on cane agronomy. Samples for agronomic evaluations were collected from the specifically assigned 10 rows as described before, ignoring natural top borer infestation that might have occurred therein. In each plot, a row sample equal to 1/1000 ha was used for population counts, out of which 20 stalks were randomly selected for height and diameter measurement. Adequate size of sub-plots were sampled and weighed to estimate cane yield per hectare.

Results and discussion

Larva penetration in leaf spindle (14th day after infestation)

There was significantly lower initial success rate of infestation in the control compared to the treatment with 120 t/ha ash application, with a reduction (compared to control) of 20.7%. Treatments with 80 and 40 t/ha ash application reduced the success rate by 15.0 and 3.9% respectively (Table 1). The lower success rate of larval penetration into the spindle with higher rate of ash application may be attributed to the increased silicon supply to the plant. The same table shows that larvae were closest to the growing point in the controls and significantly further away in the 80 and 120 t/ha ash treatments. It suggests that the movement of larvae to the growing point was significantly hindered with 80 and 120 t/ha ash applications which presumably contributed to plant resistance.

Table 1—Infestation success rate and distance of top borer larvae from growing point in the spindle.

Treatment (t/ha)	Infestation success rate (%)	Distance (cm)
0	83.7 a*	2.9 c
40	79.8 ab	3.3 ab
80	68.7 ab	4.3 bc
120	63.0 b	4.9 c

* means within the same column followed by the same letter are not significantly different (P = 0.05, HSD- test).

Larva boring in the internodes (27th day after infestation)

The application of bagasse furnace ash decreased the infestation success rate into top internodes, similar to the increase of application rate. The 120 t/ha treatment gave the lowest success rate (58.0%) with a tunnel length (treatment average) of 4.1 cm. It means that only 58.0% larvae were found alive and arriving at the growing point or further through the internodes.

Some of the larvae were just at the growing point and 1st internodes (each 10.0%), the remainder have been further down in the lower internodes, but none at 4th internodes. In controls, the success rate was 77.2%, significantly higher by 19.2% compared to 120 t/ha treatment and all larvae have bored further down to 2nd and lower internodes with a total 83.3% at 3rd and 4th internodes (Table 2).

These findings suggest that ash application resulted in lower infestation success rate and may constitute plant resistance. With the increasing rate of ash application, the hindrance to larval movement was greater as indicated by the shorter tunnel length and larval position. It confirms the earlier observation taken on the 14th day.

Table 2—Infestation succsess rate, tunnel length and larva positon in the internodes.

Treatment (t/ha)	Infestation success rate (%)	Tunnel length (cm)	Larva position (%)				
			Growing point	1st Internode	2nd Internode	3rd Internode	4th Internode
0	77.2 a*	5.7 a	0.0 a**	0.0 a	16.7 b	50.0 d	33.3 c
40	69.8 ab	5.3 ab	0.0 a	0.0 a	26.6 b	46.7 c	26.7 b
80	64.3 ab	4.3 bc	6.7 a	3.3 a	50.0 c	36.7 b	3.3 a
120	58.0 b	4.1 c	10.0 a	10.0 a	56.7 c	23.3 b	0.0 a

* means within the same column followed by the same letter are not significantly different (P = 0.05, HSD- test).
** means within the same row followed by the same letter are not significantly different (P= 0.05, HSD- test).

Deposition of silicon in surface cell layers, and especially the epidermis, has a bearing as well on physical surface properties (Epstein, 1999). Pan *et al.* (1979), using similar bagasse furnace ash as silicon provider, also found that borer damage was lower when compared to no-ash application. The increased presence of silicon crystals in sugarcane plant tissues hinders the feeding of the larvae, which at their early instar has rather fragile mandibles (Meyer and Keeping 2005).

On a different crop, Ukwungwu and Odebiyi (1985) found that silicon increases hardness of plant tissue, interferes with insect larval boring and feeding activity, and constitutes a strong factor in resistance to rice striped borer.

The present results conform to those of Keeping *et al.* (2004), who assessed the effect on *Eldana* borer of fly-ash application containing 10% silicon. They reported a similar reduction of borer infestation from 45 per 100 stalks in control plots to 18 per 100 stalks in ash treated plots. Further, Keeping *et al.* (2008) stated that silicon is accumulated in the epidermis tissues of sugarcane internodes, root bands, and also contained in the internal tissues.

This silicon accumulation obstructs the penetration and larval feeding of *Eldana* borer, and adversely affects the feeding mechanism. As a result of their slower movement, there will be more time for larvae to be exposed to natural predators, weather stress, or pest control measures (Kvedaras *et al.*, 2008).

The application of silicon fertilisers (based on various silicon sources) has been considered as worth including in the integrated pest management scheme as they do not leave unwanted residues in the sugarcane products and environment, and yet are compatible with any other pest control technique including biological control (Pan *et al*., 1979).

Cane agronomy

Bagasse furnace ash application gave a positive effect on sugarcane stalk population. Stalk population at 10-month age with 120 t/ha ash application was 97 000/ha as compared to 85 000/ha of no-ash application. Statistical analysis showed a significant difference between no-ash application with either 80 or 120 t/ha ash application treatment, where the latter two had higher stalk population (Table 3).

There was also a significant difference on the height of millable stalks between the control and the 120 t/ha ash application treatment, the latter being 13.7 cm longer at 10-month age. Similar effect was observed on stalk diameter, which was only 2.3 cm for no-ash but 3.0 cm for 120 t/ha ash application treatment.

Eventually, at harvest time (12-month age), the total sampled stalks weight was higher on all ash application treatments. The estimated yield with 120 t/ha ash application was 39.9% higher compared to no-ash treatment (Table 3).

Table 3—Population, height, stalk diameter and cane yield.

Treatment (t/ha)	Population (x 1000)	Height (cm)	Stalk diameter (cm)	Cane yield (t/ha)
0	85.8 a*	316.9 ab	2.3 ns**	82.9 a
40	86.3 a	304.4 a	2.4 ns	88.7 a
80	95.9 b	330.1 b	2.5 ns	104.5 b
120	97.0 b	330.6 b	3.0 ns	116.0 b

* means within the same column followed by the same letter are not significantly different (P= 0.05, HSD- test).
** ns = Non-significant.

It appears that, in addition to the potential benefit of improved plant resistance and possible lower borer damage, the ash application under local soil condition, especially at higher rates, has increased stalk population, stalk length and diameter, and eventually the cane yield. This could be due to improved status of silicon in the plant. Elawad (1982), Allolerung (1989), and Matichenkov and Calvert (2002), using various silicon materials, reported a similar cane yield improvement.

Although no biochemical role for Si in the development of plants has been positively identified, it has been proposed that enzyme-Si complexes form in sugarcane that act as protectors or regulators of photosynthesis and enzyme activity. Si can suppress the activity of invertase in sugarcane, resulting in greater sucrose production. A reduction in phosphatase activity is believed to provide a greater supply of essential high-energy precursors needed for optimum cane growth and sugar production. Si additions have improved the growth of sugarcane in Florida, Hawaii, Mauritius, Puerto Rico, and Saipan (Tisdale *et al*., 1993).

Conclusion

Under the conditions of this trial, the application of bagasse furnace ash has resulted in improved resistance of a susceptible variety to top borer infestation. The ash application at 120 t/ha has significantly lowered the success rate of larval penetration into the leaf spindle and hindered further penetration into the growing point and top internodes. On top of the potential benefit of plant resistance and reducing borer damage, the ash application had the positive effect of improving stalk population, plant height (length), and stalk diameter, which resulted in 39.9% increase in cane yield.

Future studies need to include measurement of silicon content in plant tissues, probably in the midribs, spindle leaves, and the meristem tissues of growing points and top internodes. This is to know the extent of hindrance that silicon may be responsible for the penetration of the top borer. Growth observations, such as periodical plant height measurement, may be worthwhile to learn if there is any improved growth rate due to silicon application that may eventually be responsible for changes in top borer penetration. Also, measurement of larva and pupa weight will be useful to confirm the role of silicon in constituting plant resistance.

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EFFET DE CENDRE DE BAGASSE SUR LA RÉSISTANCE DE LA CANNE À SUCRE CONTRE LE FOREUR APICAL DE LA CANNE *SCIRPOPHAGA NIVELLA INTACTA* SNELLEN (LEPIDOPTERA: PYRALIDAE)

Par

S. SAEROJI, SUNARYO et H. GUNITO

PT Gunung Madu Plantations, Lampung, Indonésie
saefudin@risetgmp.com

MOTS-CLÉS: Canne à sucre, Cendre de Bagasse,
Foreur Apical de la Canne à Sucre, Résistance, Silice.

Résumé

LE FOREUR apical de la canne à sucre, *Scirpophaga nivella intacta* Snellen, est un ravageur majeur de la canne à sucre au PT Gunung Madu Plantations, Lampung, Indonésie. L'infestation de plusieurs variétés industrielles est alarmante malgré un programme de lutte intégrée. Plusieurs études en Afrique du Sud, Hawaï, Floride, Inde et Taiwan ont démontré que l'utilisation de la silice peut améliorer la résistance de la plante contre les ravageurs et les maladies. La cendre de bagasse, produit en abondance aux sucreries, est connue pour être une source importante de silice. Un essai a été effectué à la propriété susmentionnée pour déterminer l'effet de la cendre de bagasse sur la résistance de la variété TC4, qui est sensible au foreur. L'essai comprenait un témoin non-traité ainsi que des traitements de 40, de 80, et de 120 t/ha, de cendre appliqués à la volée avant la plantation. Pour le traitement de 120 t/ha, le pourcentage de la feuille du fuseau attaqué était de 20.7% de moins que le témoin. De plus, 19.2% moins de larves ont pénétré le point de croissance et les entrenœuds. La longueur des tunnels forés (mesurée du point de croissance) était aussi réduite pour ce traitement que le témoin. De plus, il a été constaté que le nombre, la longueur et le diamètre des tiges étaient supérieurs en fonction de l'augmentation du taux d'application de cendre. Il a été conclu qu'une application de 120 t/ha de cendre de bagasse avec un taux approximatif de 7.97 ± 0.58% de silice augmente la résistance de la variété TC4 au foreur et occasionne un rendement de canne supérieur par 39.89%.

EL EFECTO DE LA APLICACIÓN DE CENIZAS DE BAGAZO EN LA RESISTENCIA DE LA CAÑA AL BARRENADOR DEL COGOLLO *SCIRPOPHAGA NIVELA INTACTA* SNELLEN (LEPIDOPTERA: PYRALIDAE

Por

SAEFUDIN SAEROJI, SUNARYO y HERU GUNITO

PT Gunung Madu Plantations, Lampung, Indonesia
saefudin@risetgmp.com

PALABRAS CLAVE: Cenizas de Bagazo de Caña, Barrenador del Cogollo, Resistencia, Silicio.

Resumen

EL BARRENADOR del cogollo, *Scirpophaga nivella intacta* Snellen, es una plaga importante de la caña de azúcar en las plantaciones de PT Gunung Madu, Lampung, Indonesia. La infestación en diferentes variedades comerciales es alarmante, pese a que se tiene un programa de control integral. Muchos estudios se han realizado en Sudáfrica, Hawai, Florida, la India y Taiwán sobre el uso del elemento silicio para mejorar la resistencia de las plantas a las plagas y enfermedades. Las cenizas de bagazo, abundante en las fábricas de azúcar, son conocidas como una fuente importante del silicio. Por tanto, se realizó un ensayo de campo en una plantación de caña de azúcar tendiente a estudiar el efecto de las cenizas de bagazo sobre la resistencia de la caña a la infestación por el barrenador del cogollo. La variedad TC4 susceptible fue utilizada. Los tratamientos comprendieron un control y aplicaciones en el campo de 40, 80 y 120 t/ha antes de la siembra. En el tratamiento de 120 t/ha, el número de larvas del barrenador del cogollo emergidas fue de 20.7% inferiores al control. También el número de larvas fue inferior al 19.2% entre el punto de crecimiento y los entrenudos. Del mismo modo, la longitud de los túneles del barrenador (medidos desde el punto de crecimiento) en este tratamiento fueron más cortos que en el control. Además, la población de tallos, altura y diámetros fueron mayor en este tratamiento. La aplicación de 120 t/ha cenizas de bagazo con aproximadamente 7.97 ± 0.58% de silicio aumentó la resistencia de la variedad susceptible TC4 a la infestación del barrenador del cogollo y el aumento de los rendimientos de caña en 39.89%.