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Effect of Pre-Harvest Cane Burning on Human Health, Soil Quality and Rate of Cane Weight Loss in Ethiopian Sugarcane Plantations

Alemayehu Dengia[1*] **and Egbert Lantinga**[2]

[1]*Sugar Corporation, Research and Development Center, Wonji, Ethiopia*

[2]*Department of Plant Sciences, Biological Farming Systems Group, Wageningen University, Radix West, 2nd floor, Droevendaalsesteeg, 16708 PB Wageningen, The Netherlands*

*****Corresponding author:** Alemayehu Dengia, Sugar Corporation, Research and Development Center, Wonji, Ethiopia, Tel: +251943337777; E-mail: alexdengia@gmail.com

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Abstract

Pre-harvest cane burning is one of the major practices in Ethiopian sugarcane plantations in a bid to enhance labor productivity. However, its side effects were not yet studied in Ethiopian context. Therefore, effects of pre-harvest cane burning on human health, soil fertility and rate of cane weight loss were evaluated. Accordingly, patients treated in Wonji and Metehara hospitals for upper respiratory infection over a period of seven years, during burning (January-March) and non-burning period (July-August), were compared. In addition, cane and soil samples were taken before and after cane burning to determine losses in organic matter and Nitrogen (N) as well as change in cane weight, soil pH and EC. The result showed that during the non-burning period, the numbers of patients hospitalized for upper respiratory infection were 56% and 18% less than the burning period in Wonji and Metehara, respectively. Moreover, the trash percent cane were reduced by 93% following burning. As a result, the average loss of organic matter and N were estimated to be 14.4 and 0.066 ton per ha, respectively. Soil analysis also showed that soil EC increased by 6.7% which could lead to a gradual accumulation of salts in a soil with concomitant deterioration in soil quality. The rate of moisture loss in burnt cane was also significantly higher than green harvested cane. Therefore, cane burning practices negatively affected the soil quality, caused human health problems and aggravated harvested cane moisture loss. Thus, so as to ensure sustainable sugarcane production, alternative mechanism to pre-harvest cane burning should be sought.

Keywords: Pre-harvest cane burning; Health problems; Upper respiratory infection; Soil quality; Organic matter; Nitrogen; Moisture loss

Introduction

Since the inception of the first Ethiopian sugar estate in 1954, pre-harvest cane burning has been one of the adopted practices. It was intended to get rid of cane trashes and thereby increase harvest efficiency. In addition, it reduces injury to workers from sharp foliage, insects and snakes, and improves economic returns [1].

Tropical biomass burning in forests and savannahs has long been recognized as an important factor influencing the composition of the lower troposphere [1]. Likewise, sugarcane burning results in very large increases in concentrations of CO and O_3 in the lower troposphere [2]. Burning pollutes the surrounding village with smoke and ash. The gases (CO_2, NO, NO_2 and N_2O) emitted to the atmosphere during burning contribute to the greenhouse effect and global warming [3]. The emissions of aerosol and trace gases during cane burning can affect the composition and acidity of rainwater [4]. The aerosols also cause chronic respiratory problems [5,6]. According to American Thoracic Society [7] small particulate matters (aerosols) released during burning can penetrate deep into the lungs and cause respiratory impairments.

Moreover, from an agricultural point of view, pre-harvest cane burning is exceedingly harmful and eliminates what should be returned to the soil as organic matter. The resultant loss to the ensuing crop from lack of humus is immense, besides which, trash left on the field and ploughed in, naturally helps to hold moisture and check the growth of weeds. The ash that is left after burning can affect the chemistry of the soil as it is rich in several cations and anions. Burning can be detrimental to soil structure and nutrient availability due to the loss of soil organic matter. Substantial losses of C and N due to sugarcane residue burning have been reported [8]. During burning the temperature within a moderate cane fire can quickly reach 400°C [9], sufficient to result in the volatilization and loss to the atmosphere of numerous key nutrients-nitrogen, sulphur and carbon in particular and to wipe out some of the organic matter, humus, bacteria, microorganisms and worms residing in the surface layers of the soil [10]. In addition, long range movement of atmospheric particles can result in redistribution of plant nutrients (such as NO_3, PO_3^{+4}, K^+ and trace elements) [11], while deposition of particles to leaf surfaces can affect rates of diffusion of CO_2 and O_2 between plant tissues and the atmosphere [12].

Abandoning pre-harvesting practices is controversial issue. One cane harvesting machine substitutes 80-100 workers and there has been a strong multifaceted argument between trade unions, environmentalists, sociologists and plantation owners about the phasing out of burning, but even 20 years after the debate started only very little facts are available on the long-term effects of preharvest burning on yields, soil fertility and soil organic matter content [13].

In general, the effects of cane burning can be categorized mainly into five major issues: soil and environmental deterioration; declined sugar recovery; slower, less efficient and effective processing; reduced energy potential of bagasse fibre; and easier harvesting [10]. As the sugar industries are currently expanding rapidly in Ethiopia, these issues are very challenging for the future. Hence, it is imperative to understand the effects of cane burning, in Ethiopian context, in order to design appropriate management strategies.

Therefore, this study was conducted with the objective of evaluating the effect of pre-harvest cane burring on human health, soil quality and rate of cane weight loss after burning.

Materials and Methods

Site description

The study was conducted in two state owned Ethiopian sugarcane plantations, Wonji and Metehara (Figure 1). The major characteristics of each experimental site are presented in Table 1.

Characteristic	Experimental site	
	Wonji	Metehara
Location	8°31'N & 39°12'E	8°53'N & 39°53'E
Altitude (meter above sea level)	1550	950
Average temperature (°C)	11-27	17-33
Annual rainfall (mm)	772	550
Main soil type	Grey cracking clays	Complex of vertisols
Position from Addis Ababa	112 km south east	195 km east
Total area cultivated (ha)	11000	10248
Cane harvesting capacity (Mg/day)	6500	5000
Inauguration (year)	1954	1969

Table 1: Major characteristics of the experimental sites.

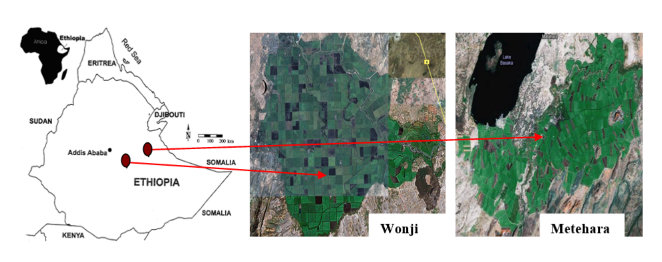

Figure 1: Location of the study areas (Wonji and Metehara sugarcane plantations).

Database survey

In order to assess the impact of cane burning on human health, the number of patients treated in Wonji and Metehara hospitals for upper respiratory infection were analyzed for a period of seven years. The data were divided into burning period (January-March) and non-burning period (July-August) and compared. The hospitals were located within each sugarcane plantation.

Soil sampling

A field with fully matured sugarcane was selected and soil samples were collected before and after cane burning. The samples were randomly taken from fourteen sites (0-30 cm soil depths). All the collected samples were composited together and divided into three subsamples. The samples were placed in a soil sample drying room for one week in open air. Since the ash left behind after burning is rich in cations/anions, it may affect soil reaction and salinity [14]. Thus, analysis was done for pH and EC.

Cane sampling

A fully matured and ready to be harvested sugarcane field (24 ha), was selected from Wonji sugarcane plantation. The age of the canes was 14 months. After 10 cane stalks along with their trashes were randomly sampled, the field was burned. Following the burning, 10 cane stalks were again sampled in the same way. The samples were carefully tied to avoid loss of the trash. Then, the trash of each cane sample was detached from the stalks, weighed separately and placed in an oven along with subsamples of the cane stalks. After drying at 105°C for 24 h, the trashes and the cane samples were weighed. Finally, total organic matter and N loss per ha was calculated according to the procedure described below.

- Change in total aboveground biomass per ha=(Total aboveground biomass per ha before burning)-(Total aboveground biomass per ha after burning) (Equation 1)
- Total aboveground biomass per ha=(Average total aboveground biomass of one cane stalk) × number of cane stalks per ha (Equation 2)
- Number of cane stalks per ha=(Fresh cane yield per ha)/(Average fresh weight of one cane stalk) (Equation 3)
- Organic matter loss/ha=(Change in total biomass per ha) × Organic matter content of cane trash (Equation 4)
- N loss/ha Change in total biomass per ha × N content of cane trash (Equation 5)

For the purpose of the calculations, cane yield per ha for the sampled field (120 ton/ha) was taken from the harvest result reports of Wonji sugar estate plantation. For estimation of organic matter and N loss due to burning, since there was no available data for Wonji plantation, the nutrient content of cane trash which was obtained from the study of Turn et al. [15] and Verma [16] was used. They stated that cane trash dry matter contains on average 92% organic matter and 0.42% N.

For cane weight losses assessment random cane samples was collected just before burning (800 cane stalks) and immediately after burning (800 cane stalks). Then the samples were brought to Wonji Research and Development Center's office yard and tied in bundles of 20 canes (88 bundles of cane in total). From each category of cane samples (green harvest and burnt harvest), 4 cane bundles were taken at 0, 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 days after harvest and weighed.

Method of soil analysis

The soil samples were analyzed in the Research Directorate of Ethiopian Sugar Development Agency laboratory located in Wonji sugar estate. Soil pH and EC were measured in a 1:2.5 soil water suspension by a glass electrode pH meter and EC meter, respectively.

Data analysis

The data were analyzed at 1% probability level using Genstat software statistical packages, 12th edition. Mean comparisons were performed for soil analytical results, for changes in biomass and for rate of cane weight loss due to burning.

Result and Discussion

Effect of cane burning on human health

The numbers of patients hospitalized for upper respiratory infection during burning period (January-March) and non-burning period (July-September) were significantly different from each other in Wonji (P=0.007) and Metehara (P=0.002) plantations (Figure 2). During the non-burning period, the numbers of patients hospitalized for upper respiratory infection were 56% and 18% less than the burning period in Wonji and Metehara, respectively.

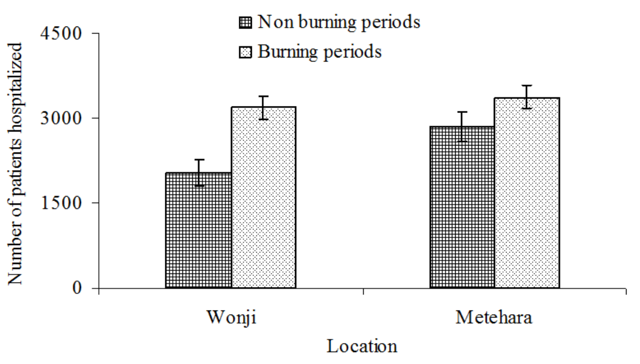

Figure 2: The number of patients hospitalized for upper respiratory infection during non-burning period (July-September) and burning period (January-March) of sugar cane. Seven years data were taken from the quarterly reports of Wonji and Metehara hospitals which are located in each sugar estate. Vertical bars indicate standard error of mean (± SEM).

The higher numbers of patients during burning period imply that the burning practices contributed substantially to respiratory problems of the residents living in the vicinity of Wonji and Metehara sugar estates. Similar finding showed that [17] a significantly higher numbers of respiratory hospitalizations during burning period in a Brazilian sugarcane plantation was observed. Ribeiro [6] also reported that the burning practice during sugarcane harvesting was the main source of inhalable particles that caused respiratory problems.

It is important to bear in mind that the observed higher respiratory cases during burning period might be also pronounced by other factors. The increase of dust and particulate matters from factories and combustions during burning period may also contribute for the observed higher number of patients. However, the concentrations of particulate matters emitted from cane burning are much higher than the other sources. According to Ribeiro [6] sugarcane burning is a source of 60% of the particulate matter while soil dust 14% and factories and combustions 12%. Therefore, cane burning plays an overriding role in contributing to the health problem.

The mechanisms of cane burning in causing respiratory problems were studied previously. According to Ribeiro [6] during cane burning incineration is incomplete that the particulate matters emitted into the air are not entirely oxidized. These particulate matters enter the alveoli, lungs and bloodstream of human in a great concentration and cause irritation of the respiratory system. The particulate matters are redox active and upon inhaling they stimulate inflammatory cells with concomitant productions of oxidants and radicals. These situations result in generation of oxidative stress and induction of pro-inflammatory responses. In addition, the interaction between particulate matters, O_3 and NO_2 results in reactive compounds such as radicals and organic compounds which can also cause proinflammatory effect [17,18].

Effect of cane burning on some soil fertility indicators

Total biomass per ha, percent trash in a cane and soil EC before and after pre-harvest cane burning were significantly different (P<0.01) while no significant difference was observed in soil pH (Table 2).

Loss of organic matter and N: The trash comprised on average 33% of the sugarcane biomass (Table 2). This fraction was slightly lower than the one observed by Barnes [19], who reported 37-44% for Mauritian, Hawaiian and South African plantations. However, it is in agreement with Stewart [20] who found 13-33% for an Australian plantation.

The total weight of biomass and the trash percent biomass in the cane were dropped by 27% and 93%, respectively, following burning (Table 2). As it was estimated by using equations 1-5, upon harvesting 120-ton fresh cane/ha, the total biomass decline due to burning was 15.6 ton/ha. The average loss of organic matter and N were also estimated to be 14.4 ton per ha and 66 kg per ha, respectively. The result is in agreement with Robertson [21] who observed a loss of about 48-55 kg N per 100-ton cane/ha in Australia. According to Alemayehu and Lantinga [22] at Wonji Sugarcane Plantation SOM and N contents of cultivated land were 53% and 56%, respectively, lower than the virgin land at 0-30 cm depth, indicating that pre-harvest cane burning plays a significant role for such a drastic plunge.

Change in soil EC: The change in soil EC was significant, despite the increment was only 6.7% (Table 2). The ash left behind after burning, which accounts generally for about 7% of the total biomass [16], might be responsible for the increase.

Parameters	Before Burning	After Burning	Change (%)
Total biomass (ton/ha)	58^{a1}	42^{b}	-27
Trash in a cane (%)	33^{a}	2.5^{b}	-93
Soil pH[2]	7.8^{a}	7.7^{a}	-1.3
EC ($mScm^{-1}$)[2]	1.5^{b}	1.6^{a}	-6.7

Table 2: Total biomass, percent of trash in a cane, soil EC and soil pH just before and after burning a sugarcane filed in Wonji plantation. [1]In rows, means followed by different letters are significantly different at P<0.01. [2]Soil samples were taken from 0-30 cm depth.

This is because of ash is rich in several cations like Fe, Mn, Zn, Cu, Ca, Mg, Na, S, K and P [14,23]. Wong and Lai [24] and Kalra et al. [25] also showed that with addition of ash, soil EC increased which likely resulted from the precipitation of soluble cationic salts in soil. Thus, the result suggests that cane burning may lead to a gradual accumulation of salts in a soil and thereby result in deterioration of soil quality. This situation may, therefore, end up in inhibition of growth in the long run, as sugarcane is moderately sensitive to salinity [26]. However, in Wonji plantation, the currently observed soil EC values are in the optimum range as the excessive irrigation leaches down the cations that would accumulate following burning.

Change in soil pH: Soil pH before and after cane burning was not significantly different (Table 2). However, the pH was expected to rise due to the ash left behind after burning. According to Singh et al. [23], ash consists of a large amount of CaO that along with water forms $Ca(OH)_2$ with concomitant increases in soil pH. The insignificant difference observed in this study might be attributed to the heavy clay soil type of the plantation which is known for its high CEC. A soil with high CEC has an eminent potential to buffer change in soil pH [27].

Effect pre-harvest cane burning on cane weight loss

For percent cane weight loss, the two-way interaction between cane burning conditions (burnt or non-burnt) and the number of days after harvest was very highly significant (P<0.001).

In both cane conditions (burnt and green harvested), there was a significant drop in cane weight with laps of time after harvest (Figure 3). The rate of moisture loss in both burnt and green cut cane was not significantly different for the first five days.

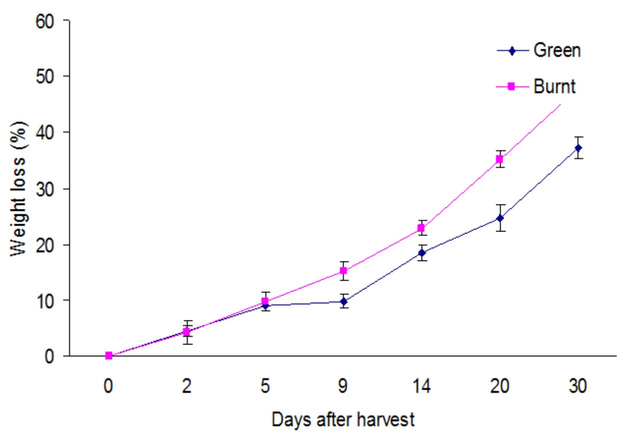

Figure 3: Effect of cane burning on percent weight loss of cane as compared to green harvested sugar cane (Average values over four replications). Bars represent standard deviations. Number of days after harvest and harvesting methods interaction effects were significant at (p<0.001) for all the parameters.

From then on, however, the loss was more rapid in the burnt cut cane than in the green cut cane. In the 9th, 14th, 20th and 30th day after harvest, the moisture loss of burnt cut cane was 36%, 19%, 30% and 22% higher than green cut cane, respectively. This result was in agreement with Davies [10] and Eggleston et al. [28]. who stated that burnt cut cane dries out more quickly than does green cut cane. According to Devis [10] burning resulted in longitudinal cracking of the stalk and wipes out its protective wax covering and make the cane to loss moisture easily. This finding revealed that harvesting green cane is beneficial in terms of reducing the rate of moisture loss and thus increasing efficiency of processing, even if the cane may delay before milling. Rapid weight loss has also an implication for farmers engaged in selling their cane to the sugar factories in a weight bases.

Conclusion

Pre-harvest burning negatively affected the major soil fertility indicators (Organic Matter, N and EC) of came plantation, impair the health of the inhabitants residing in the vicinity of the plantation and also aggravate the moisture loss of cane after harvest. The loss of the biomass and the subsequent decline in SOM and total N might, therefore, play a role for the yield decline being observed in the sugar estates.

Therefore, phasing out burning of cane is the most important issue that needs to be considered in reducing the aforementioned problems. This is also useful from environmental quality, efficient processing and sugar recovery as well as energy potential. However, the challenges associated with this regard needs further study.

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