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# Integrated Sugarcane Trash Management: A Novel Technology for Sustaining Soil Health and Sugarcane Yield

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## Abstract

With the raising concern on soil conservation and health in the context of depleting traditional organic manures, efforts are required to harness the potentiality of crop biomass wastes effectively. Sugarcane is one such crop that produces 7-12 t ha$^{-1}$ of trash, which is a rich source of organic carbon and plant nutrients. The burning of trash would lead to environment pollution besides depleting the soil biological properties and fertility. In this context, integrated sugarcane trash management (ISTM) that conserves and decomposes trash using microbial enriched (*Trichoderma viridae*) farm yard manure and urea (75 kg/ha) serve as a novel technology in sustaining soil health and sugarcane yield.

The results revealed that intense heat generated due to trash burning has reduced the germination of sugarcane to an extent of 68 percent compared to 82 percent in ISTM. The ISTM has increased the organic carbon content, available nitrogen, phosphorus and potassium in soil to an extent of 11.2, 3.6, 8.5 and 11.2 percent respectively in three years. The increased average cane yield was 12.8 percent over trash burning. The economic analysis showed that the gross income increased to 18.2 percent with the benefit of 2.63 rupees per rupee invested over three years. Farmers surveyed indicated that the trash management technology increased soil moisture and number of earthworms, and reduced weed incidence. Farmers also expressed that buds germinated 15 days earlier in ISTM practice and that ISTM increased cane yield and did not hinder ratoon practices.

**Keywords:** Sugarcane trash; Frontline demonstration; Organic carbon; Nitrogen

## Introduction

The depleting soil health and crop productivity in the sugarcane cultivating area of Mandya district of Karnataka is a major concern because of reduced yields. This can be clearly visualized from the static average productivity hovering close to 98 ton/hectare in last five years compared to its potential yield of 150 ton/hectare. Although soil fertility is closely linked to the physical and chemical characteristics of the environment, it is strongly influenced by human management practices. One such practice followed by farmers is burning trash after the harvest of sugarcane. About 7-12 tons of trash can be obtained from 1 ha of sugarcane [1]. Every ton of sugarcane trash contains about 5.4 kg N, 1.3 kg $P_2O_5$, 3.1 kg $K_2O$ and small quantities of micronutrients [2]. However, when sugarcane trash is burnt, most of the organic matter and nutrients in the trash are lost, leading to environmental pollution [3]. Farmers usually burn the trash with the opinions that its management is laborious, will reduce germination and hinders routine ratoon cultivation practices. On the other hand farmers apply huge quantity of fertilizers to meet the nutrient requirement of crop. Hence, the present study was taken up as a frontline demonstration in the farmer's field by Krishi Vigyan Kendra, V.C. Farm, Mandya, Karnataka, India, with the objective to educate farmers on conservation of crop residue and to assess its impact on soil fertility and sugarcane yield.

## Materials and Methods

The study on integrated sugarcane trash management (ISTM) was conducted as a frontline demonstration (FLD) at Mallanayakanakatte village of Mandya district, Karnataka for three successive ratoon sugarcane crops in 1.0 hectare area. The FLD was implemented after the harvest of plant-cane crop during rabi 2007 and continued for successive three crops. The following technologies were implemented for in-situ management of sugarcane trash;

1. Irrigation of sugarcane plot for complete soaking of trash; this would soften trash and help for easy handling.
2. Mulching of sugarcane trash in alternate rows; this would help in following ratoon cultivation practices in un-mulched rows.
3. Broadcasting of 75 kg/ha urea on sugarcane trash; enhancing N narrows the wider C:N ratio of trash and helps for faster decomposition.
4. Application of 500 kg of farm yard manure (FYM) enriched with 25 kg microbial culture (*Trichoderma viridae*) on sugarcane trash; this would help in enhancing decomposition rate.
5. Stubble shaving, shoulder breaking, gap filling and following recommended ratoon sugarcane cultivation practices

The farmers practice (1.0 ha) of burning the trash after the harvest of sugarcane crop was considered as check plot. The summary of FLD and check plot is depicted in Table 1.

### Collection and analysis of soil samples

Composite soil sample was collected after the harvest of each crop, from a depth of 0-15 cm, between the crop rows in check plot and

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| Tangential contact behavior | | Parameter |
|---|---|---|
| Variety | CO-62175 | CO-62175 |
| Planting date | October 2006 | October 2006 |
| Plant-cane harvest | November 2007 | November 2007 |
| First ratoon harvest | First week of October 2008 | Second week of October 2008 |
| Second ratoon harvest | Third week of October 2009 | First week of October 2009 |
| Third ratoon harvest | First week of October2010 | Fourth week of October 2010 |
| Trash management practice | As detailed in FLD | Trash burning after each harvest |
| **Initial soil properties** | | |
| Texture | Clay loam | Clay loam |
| pH (1:2.5) | 8.23 | 8.21 |
| EC (dS/m) | 1.67 | 1.73 |
| OC (%) | 0.42 % | 0.44 |
| Available N (kg/ha) | 312.4 | 324.8 |
| Available $P_2O_5$ (kg/ha) | 31.8 | 31.2 |
| Available $K_2O$ (kg/ha) | 232.5 | 244.6 |
| Nutrient application (N: $P_2O_5$: $K_2O$- kg/ha) | 250:100:125 | 350:125:170 |
| Gap filling | Practiced | Practiced |

**Table 1:** Summary of the FLD and check plot.

between the trash mulched rows in FLD plot. Soil pH and electrical conductivity (EC) were determined in 1:2.5, soil: water suspension by using digital pH meter and Conductivity Bridge (expressed in dS $m^{-1}$ at 25°C) respectively. Chromic acid oxidation method [4] and alkaline permanganate method [5] were followed for determining organic carbon (OC) and available nitrogen content in soil. Available phosphorus from soil was extracted using Olsen's extractant and blue colour was developed by ascorbic acid method and the intensity was read at 660 nm using spectrophotometer and calculated referring to P-standard curve [6]. Available potassium was extracted from soil using neutral normal ammonium and determined using Flame photometer [6].

## Collection and analysis of trash sample

Sugarcane trash and ash (after trash burning) samples were collected after the harvest from the field and nitrogen content was determined by Kjeldhal distillation method. A known weight of sample was digested with conc. $H_2SO_4$ and digestion mixture, further distilled for estimating N-content. The total phosphorus and potassium were determined by digesting with di-acid ($HClO_4$+ $HNO_3$) and analysed by phospho-vanado-molybdate complex and flame photometer methods respectively [7].

## Other data collection

The number sets giving healthy tillers to number of sets planted in five randomly selected rows was used for measuring ratoon germination and expressed in per cent. The yield data were recorded after the harvest of each crop. Farmers usually sell the sugarcane to sugar factories and its price will be fixed by the government of Karnataka. It was Rs. 900/ton during 2007-08 and Rs. 1200/ton during 2009-10. The same prices were used for determining gross income. The cost incurred in inputs, machinery and labour were accounted for calculating cost of production. The difference in gross income and cost of cultivation was used for determine net income. The ratio of net income to cost of cultivation was used for calculating benefit to cost ratio (B: C). The other data on relevant parameters were collected and pooled for scientific interpretation.

# Results and Discussion

## Nutrient content of sugarcane trash

The samples of raw trash and the ash of the burnt trash were collected randomly after the harvest. The analysis results (Table 2) showed that the trash contain 0.51% total N that signifies the need of external nitrogen source for reducing its wider C:N ratio and for enhancing decomposition rate [8]. The trash ash samples showed more total phosphorus and potassium compared to raw trash, but the quantity of ash produced after the burning is quite low (~0.75 - 1.0 ton/ha) compared to raw trash (7-12 ton/ha) which, ultimately results in low input for one hectare area.

## Impact of ISTM on soil properties

**Organic carbon:** Organic carbon (OC) content in soil is a key factor for its health and fertility. The impact of ISTM on soil organic carbon is presented in Table 3. The ISTM resulted in increased OC content of soil from 0.42 to 0.58 per cent over the three years, which amounts to an average increase of 11.2 per cent. Further, intervention of application of N and lignolytic microbial culture (*Trichoderma viridae*) might have enhanced the faster decomposition of trash resulting buildup of organic carbon in ISTM plots [9]. Trash burning decreased the organic carbon content, such that at the end of third year the organic carbon content was to 0.40 per cent compared to 0.44 percent in the initial period. This may be due to loss of dry matter and carbon during the burning processes of trash. According to Mitchell et al., depending on the severity of the fire, 77-97 per cent of the dry matter and carbon may be lost by burning sugarcane trash. On contrary, the retention of trash in the field will increase the organic carbon through decomposition process in the long term [10].

**Available nitrogen:** The available nitrogen in the soil depends mainly on the sources of nitrogen supply, crop removal and organic carbon content of the soil. The increase in the available nitrogen in ISTM soil was low (3% on an average), while, the trash burnt soil showed decreased N content over the years even after excess N application through fertilizers (350 kg/ha) (Table 3). This may be due to loss of N during burning of trash. The inorganic N supplied through fertilizer is prone to more loss than retention. The low buildup of N in ISTM

| Season | Sample | Total N (%) | Total $P_2O_5$ (%) | Total $K_2O$ (%) |
|---|---|---|---|---|
| **Rabi 2008** | Raw trash | 0.53 | 0.09 | 0.42 |
| | Trash ash | Traces | 0.11 | 0.56 |
| **Rabi 2009** | Raw trash | 0.49 | 0.13 | 0.51 |
| | Trash ash | Nil | 0.21 | 0.62 |
| **Rabi 2010** | Raw trash | 0.51 | 0.14 | 0.50 |
| | Trash ash | Nil | 0.22 | 0.58 |
| **Average** | **Raw trash** | **0.51** | **0.12** | **0.48** |
| | **Trash ash** | **-** | **0.18** | **0.59** |

**Table 2:** Major nutrient content of sugarcane trash and burnt trash ash.

| Year | Organic carbon | | % difference in OC over years | | Available N | | % difference in Avail. N over years | |
|---|---|---|---|---|---|---|---|---|
| | ISTM | Check | ISTM | Check | ISTM | Check | ISTM | Check |
| Before | 0.42 | 0.44 | - | - | 312.4 | 324.8 | - | - |
| Rabi 2008 | 0.45 | 0.42 | 6.3 | -4.3 | 319.6 | 306.4 | 2.3 | -5.7 |
| Rabi 2009 | 0.50 | 0.40 | 11.3 | -4.1 | 330.5 | 297.3 | 3.4 | -3.0 |
| Rabi 2010 | 0.58 | 0.40 | 16.0 | -1.5 | 347.3 | 284.7 | 5.1 | -4.2 |
| **Average** | **0.49** | **0.41** | **11.2** | **-3.3** | **327.4** | **303.3** | **3.6** | **-4.3** |

**Table 3:** Impact of ISTM on soil organic carbon and available nitrogen.

may be attributed to wider C:N ratio in trash and might have resulted in immobilization by microbes. The immobilization was higher during the initial year and in the later years the N builds up was comparatively higher. Robertson and Thorburn [11] reported similar results of slow N buildup in wider C:N crop residue management.

**Available phosphorus:** The impact of ISTM on available phosphorus (P) content of soil is presented in Table 4. The results revealed that there was a trend of increased available P content in soil in ISTM plot, while, the check plot recorded decreasing trend. This increased available P may be attributed to inoculation of *Trichoderma viridae,* which mobilizes the unavailable P content in the soil through production of organic acids [12] and also P from sugarcane trash. Even though trash ash had higher P content and farmers usually applied more P than the recommendation (125 kg/ha), there was decrease in the P content in check plot. This might be due to alkaline soil which turns P into unavailable form.

**Available potassium:** The available potassium (K) also recorded the similar trend as that of the P (Table 4). The effective management of trash results in increased potassium content as the trash is a rich source of K. The results are in line with findings of Graham et al., [13]. Though the trash ash contained more potassium, the volume of ash generated through burning was not sufficient to meet the potassium requirement of the sugarcane crop.

## Impact of ISTM on sugarcane germination and yield

**Sugarcane germination:** The pre-knowledge test conducted on sugarcane trash burning by farmers revealed that the farmers had an opinion that trash mulching will reduce germination and come in the way of routine ratoon cultivation practices. However, the results showed higher germination percentage in ISTM compared to trash burning (Table 5). The excess heat generated during burning might have resulted in reduced germination per cent and time taken for germination. Also, the maturation of sugarcane was 15-20 days earlier in ISTM than the burnt plot (Table 1).

**Sugarcane yield:** The average yield of first ratoon sugarcane crop of Mallanayakanakatte village, Mandya district, Karnataka was taken as base data to assess the impact of ISTM on sugarcane yield, as the yield of main crop will be always higher than the ratoon crops. The yield data revealed that the cane yield increased substantially in second and third ratoon crop compared to first ratoon and base year in ISTM and the average increase in yield was 8.5 per cent. While in the check plot, the yield showed the decreasing trend. The increased cane yield might be attributed to increased germination percent, increased soil fertility and over all positive effect of trash mulching on soil health. Research results on trash mulching in sugarcane revealed that the trash mulching had an added advantage of moisture conservation, weed control, increased soil biological activity and increased number of earthworms, which eventually resulted in increased yield [14]. Thorburn et al., [11] also determined that the trash mulching sustains the sugarcane productivity and soil health.

**Impact of ISTM on sugarcane economics:** The economics of sugarcane cultivation are described in Table 6 and 7. The results revealed that though the average cost involved in ISTM was marginally higher (3.2 %) than the check, the gross income realized was 13.9 per cent greater than the check. The net income obtained in ISTM plot over the years trended higher, while the net income in the check plot showed a decreasing trend. This could be attributed to increased cane yield and price per ton over the years (Rs. 900/ton during 2007 to Rs. 1200/ton during 2009). The increase in the Benefit to cost ratio (B:C) was 8.5 per cent in ISTM plot, while in the check plot the difference was negative. ISTM recorded a benefit of Rs. 2.63 over rupee invested.

| Year | Available $P_2O_5$ | | % difference in Avail. $P_2O_5$ over years | | Available $K_2O$ | | % difference in Avail. $K_2O$ over years | |
|---|---|---|---|---|---|---|---|---|
| | ISTM | Check | ISTM | Check | ISTM | Check | ISTM | Check |
| Before | 31.8 | 31.2 | - | - | 232.5 | 244.6 | - | - |
| Rabi 2008 | 34.2 | 29.6 | 7.4 | -5.1 | 248.3 | 236.8 | 6.8 | -3.2 |
| Rabi 2009 | 37.0 | 29.2 | 8.3 | -1.4 | 277.1 | 228.4 | 11.6 | -3.5 |
| Rabi 2010 | 40.6 | 27.6 | 9.8 | -5.5 | 319.2 | 230.3 | 15.2 | 0.8 |
| **Average** | **35.9** | **29.4** | **8.5** | **-4.0** | **269.3** | **235.0** | **11.2** | **-2.0** |

**Table 4:** Impact of ISTM on soil available phosphorus and potassium.

| Year | % S. cane germination | | S. cane yield (ton/ha) | | % difference in yield over years | |
|---|---|---|---|---|---|---|
| | ISTM | Check | ISTM | Check | ISTM | Check |
| Before* | | | 104.3 | 104.3 | | |
| Rabi 2008 | 86 | 73 | 110.9 | 97.3 | 6.3 | -6.7 |
| Rabi 2009 | 73 | 65 | 121.0 | 95.4 | 9.1 | -2.0 |
| Rabi 2010 | 87 | 66 | 133.2 | 91.4 | 10.1 | -4.2 |
| **Average** | **82** | **68** | **117.3** | **97.1** | **8.5** | **-4.3** |

*The average yield of first sugarcane ratoon crop of Mallanayakanakatte village, Mandya ditrict, Karnataka.

**Table 5:** Impact of ISTM on sugarcane germination and yield.

| Year | Gross cost (Rs.) | | % difference in GC over years | | Gross income (Rs.) | | % difference in GI over years | |
|---|---|---|---|---|---|---|---|---|
| | ISTM | Check | ISTM | Check | ISTM | Check | ISTM | Check |
| Before* | 41720 | 39113 | | | 96750 | 96750 | | |
| Rabi 2008 | 44348 | 40380 | 6.3 | 3.2 | 110871 | 97300 | 14.6 | 0.6 |
| Rabi 2009 | 48384 | 42930 | 9.1 | 6.3 | 133056 | 104940 | 20.0 | 7.9 |
| Rabi 2010 | 53271 | 45700 | 10.1 | 6.5 | 159813 | 109680 | 20.1 | 4.5 |
| **Average** | **46931** | **42031** | **8.5** | **5.3** | **125122** | **102168** | **18.2** | **4.3** |

* Economics calculated for average first ratoon crop.

**Table 6:** Impact of ISTM on sugarcane economics-Gross cost and income.

| Year | Net income (Rs.) | | % difference in NI over years | | B:C Ratio | | % difference in B:C over years | |
|---|---|---|---|---|---|---|---|---|
| | ISTM | Check | ISTM | Check | ISTM | Check | ISTM | Check |
| Before* | 55030 | 55030 | | | 2.32 | 2.32 | | |
| Rabi 2008 | 66523 | 53515 | 20.9 | -2.8 | 2.50 | 2.22 | 7.8 | -4.2 |
| Rabi 2009 | 84672 | 57240 | 27.3 | 7.0 | 2.75 | 2.20 | 10.0 | -1.0 |
| Rabi 2010 | 106542 | 54840 | 25.8 | -4.2 | 2.96 | 2.00 | 7.6 | -9.1 |
| **Average** | **78192** | **55156** | **24.7** | **0.0** | **2.63** | **2.19** | **8.5** | **-4.8** |

*Economics calculated for average first ratoon crop.

**Table 7:** Impact of ISTM on sugarcane economics-Net income and B:C ratio.

## Conclusion

The present study, indicated that ISTM technology of trash mulching in alternate rows along with application of urea (75 kh/ha) and microbial enriched (*Trichoderma viridae*) farm yard manure is effective in enhancing the soil health and sugarcane yield. This technology was popularized to farmers through field visits, trainings, demonstration, group discussion and field days. The Farmers stated that ISTM is highly beneficial and helped in conserving the soil moisture which decreased the number and frequency of irrigations to the sugarcane crop. The trash mulching helped in improving soil health which can be realized with increased number of earthworms in soil. This technology can be adopted without hampering the ratoon sugarcane cultivation practices. Also, ISTM resulted in increased cane yield and allowed farmers to harvest the crop 15 days earlier compared to their usual practice.

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