

## The Role of Sugarcane Trash in Soil Fertility and Plant Growth: A Review

### Abstract

Sugarcane needs a hot and humid climate and can be grown on a variety of soils that can retain moisture. Owing to its long life cycle it heavily depletes soil nutrients during its growth period. Sugarcane, being a heavy feeder requires nearly 208 kg N, 53 kg P<sub>2</sub>O<sub>5</sub>, and 280 kg K<sub>2</sub>O from the soil to produce 100 t ha<sup>-1</sup> sugarcane. Sugarcane, being a C<sub>4</sub> plant, produces a large quantity of biomass. Approximately 10-15 t of trash, constituting 10-12% weight of cane harvested, is produced by the sugarcane crop. Generally, cane trash contains 68% organic matter, 0.42% N, 0.15% P, 0.57% K, 0.48% Ca, and 0.12% Mg, besides 25.7, 20.45, 236.4, and 16.8 ppm Zn, Fe, Mn and Ca, respectively. Trash conserves soil moisture, C, and N in the soil and provides energy to increase the yield. The trash application conserves the nutrients in the soil, also aids their availability to the plant, and reduces the fertilizer requirements through recycling nutrients in the soil from residue. Organic mulches also create a better physical, chemical, and biological environment of soils and in turn, improve crop productivity. Burning of trash deteriorates the fertility as well as soil health. It also reduces the soil microbial activity and destabilizes soil aggregates. Significant N losses from residues can occur during burning by high temperature volatilization. In the burnt system, >70% of the organic matter and nutrients in the trash are lost to the atmosphere.

### Introduction

Sugarcane (*Saccharum officinarum* L.) is a widely grown commercial crop worldwide and is cultivated in more than 105 countries. It belongs to the family Gramineae and has its center of origin in New Guinea. *Saccharum officinarum* and its hybrids account for about 70% of the sugar produced globally. Sugarcane is the main source of sugar in India and holds a prominent position as a cash crop. India is the world's largest consumer and the second-largest producer of sugar after Brazil. It employs about one million people directly or indirectly. Additionally, it contributes significantly to the national economy through the export of sugarcane processed products, especially white sugar. In 2016-17, India exported 2542 thousand metric tons of sugar worth 8639 crore rupees (Anonymous, 2017a), proving its pivotal role in India's economy.

Traditionally, sugarcane residues are burnt after harvest. Usually, farmers burn sugarcane residues due to scarcity of labor to remove trash from the field and lack of knowledge regarding the potential use of trash as a source of organic carbon and nutrients (Chandra *et al.*, 2008). When sugarcane is retained on the soil as mulch, it conserves soil moisture and inhibits the growth of weeds. Incorporating residues elevates the level of organic matter and may decrease soil pH by releasing hydrogen ions (Mthimkhulu *et al.*, 2018). High C:N ratio, high fiber content and lack of proper composting techniques prolong the decomposition of trash in the field. Besides the loss of organic

matter and plant nutrients, burning of crop residues results in atmospheric pollution due to the emission of toxic gases like methane and carbon dioxide. Disposal of crop residues by burning is often criticized because trash burning accelerates the losses of soil organic matter, increases C emissions, **causes** intense air pollution and reduces soil microbial activity (Dhar *et al.*, 2014). If organic carbon is decreased it affects the properties of soil and richly affects the productivity of the soil. Burning of trash **deteriorates fertility** as well as soil health. It also reduces the soil microbial activity and **destabilizes soil** aggregates (Mithimkhulu *et al.*, 2016). Significant N losses from residues can occur during burning by **high-temperature** volatilization (Smith and Bowes, 1974). In the burnt system, >70% of the organic matter and nutrients in the trash are lost to the atmosphere. Retention of crop residues has been shown to increase soil organic matter and soil nutrient contents in other cropping systems (Robertson *et al.*, 2007). Therefore, in situ trash management can be a good **alternative to mitigate** these problems. **Retaining** trash as a mulch can reform the **soil's** organic matter content compared to the traditional burnt trash practices.

**The use of** trash as mulch also reduces soil temperature in the topsoil and favor meso and microflora present in the soil (Tortora *et al.*, 2013; Kumar *et al.*, 2019). **After incorporating trash into** soil, it tends to **increase** the soil bacterial population by 10-100 times and fungal and actinomycetes population by 10 times (Chandra *et al.*, 2008).

When **harvested** sugarcane residue is returned to the soil, nutrients and organic matter increase and soil structure improves (Kumar and Sagwal, 1998). This management system allows the return of an **essential** quantity of crop residues to the soil, favoring nutrient recycling, reducing both water and wind erosion, diminishing soil water evaporation, increasing infiltration and allowing a better conservation of soil moisture. The straw blanket also reduces evaporative losses of water **and creates** beneficial environment for plants and soil biota, **decreases soil** temperature and improvement in soil structure. The study of the effect of sugarcane trash on soil physical, chemical, and biological properties is essential for the management of **waste and balanced nutrient** management in agriculture. So, a brief resume of research work carried out at different locations in India and abroad on different aspects relevant to the present investigation has been reviewed and presented in this chapter. The relevant work done is reviewed under the following headings:

➤ **Effect of different trash management practices on the physical properties of soil**

The different trash **management** practices and crop residue retention change the physical properties of soil, like soil **structure and soil** moisture and inhibit the growth of weeds. The successful burning of trash and **removal from** the field increased the bulk density of soil (1.4 to 1.55 g cm<sup>-3</sup>) in the second ratoon system (Ball *et al.*, 1993). **On the other hand,**

Yadav *et al.* (1994) observed a fall in bulk density under the trash retained plot (1.45 to 1.40 g cm<sup>-3</sup>). In green cane trash blanketing treatment, Noble *et al.* (2003) reported an increase in bulk density with depth (1.13 to 1.25 g cm<sup>-3</sup>), but it was recorded lowest than the burnt treatment (1.187 to 1.26 g cm<sup>-3</sup>). The bulk density was decreased from 1.50 to 1.44 (Mg m<sup>-3</sup>) after the crop residue management practices in the wheat cropping system and also observed a decrease in bulk density with the increasing crop residue retention (6 Mg ha<sup>-1</sup>) (Yadav *et al.*, 2016). Ghuman and Sur (2010) argued that simultaneous implementation of minimum tillage practices and crop residue trash mulch significantly decreased bulk density at 0-0.1, 0.075 and 0.125 m depth, soil aggregation with increased mean weight diameter and cumulative infiltration rate. Sidhu and Beri (1989) reported decreased trend in bulk density in addition to chopped and un-chopped crop residue in soil. Black (1973) witnessed a fall of 8% in erodible soil fraction for each 1100 kg ha<sup>-1</sup> of straw incorporation in soil, along with a decrease in bulk density of 0 to 7.5 and 7.5 to 15 cm soil depth with increase in residue level. Davari *et al.* (2012) observed similar trends in bulk density value on crop residue incorporation in soil for two years. Bulk density of 2-4 and 4-10 cm is lowered by addition of crop residue as per the findings put forward by Walia and Dick, (2018). Salahin *et al.* (2018) argued that keeping residue in three cropping cycles leads to more reduction in bulk density compared to retaining residues in two cycles. Similar observations were recorded by Nagar *et al.* (2016) in their experiment in which reduction in bulk density was exerted by the application of crop residue.

The pre-harvest burnt to residual green trash shifting system increased the soil aggregation and macroaggregates from 17, 24, and 39 % at typic Hapudult, Quartzpsamment, and typic Hapludox sites, respectively (Luca *et al.*, 2018). Graham *et al.* (2002) pointed out that long-term application of fertilizer and trash increased the percentage of large aggregates (78%) more in the trash application relative to the trash burnt treatment (60%). The crop residue significantly increases total water-stable aggregates (15.65%) in 0-15 cm surface soil and 7.53% in subsurface soil (15-30 cm) compared to the without residual incorporation treatments (Kumari *et al.*, 2019).

Removing trash caused a significant reduction in the infiltration rate in conventional puddling systems in rice. It may be due to the modification of overall pore structure and shrinking of soil during wetting and drying in absence of soil mulch, as pointed out by Tripathi *et al.* (2007). The integrated and organic nutrients affect the soil bulk density in the ratoon crop. The integrated use of a recommended dose of N with organic and bio-fertilizer

increased the bulk density as well as infiltration rate from 5.4 mm hr<sup>-1</sup> against the initial infiltration rate of 4.1 mm hr<sup>-1</sup> (Singh *et al.*, 2011) and the recycling of sugarcane trash also affects the physio-chemical properties of the soil.

The residual management affects the sugarcane's physical properties. The ratoon cane has high soil temperature than the plant cane during the ripening time. In the residue burning, temperature was higher (26.09 °C) in the ratoon crop and lower (25.38 °C) in the cane plant cane. The different stage of decomposition of different organic waste shows the lower temperature of 28-30 °C at the starting of decomposition and highest 46 °C temperature was observed after 14 days of sugarcane trash composting (Goyal *et al.*, 2005). Shen *et al.* (2018) observed linear negative relationships between soil temperature and residue retention in soil. The decrease in soil temperature may be due to the insulating effect of residue provided to soil from solar radiation. *In situ* sugarcane trash management practices buffer the soil temperature at 25.1-27.2 °C in the top 5 cm soil layer and control treatment fluctuation was wide (26.9-34°C) and shows higher soil moisture content (0.70-5.92%) over control. And sugarcane trash kept moisture at field capacity for a longer period of time than the no-mulch treatments (Tayade *et al.*, 2016). Residue incorporation and composting increased the soil moisture from 36.50% to 38.55%, respectively (Basit *et al.*, 2018). The soil moisture content at a given potential was more in the mulch of residual than in burnt treatments. The capillary pore space is more in mulch (12.2%) than in the burnt treatment (5.2%) (Ball *et al.*, 1993). Sidhu and Beri (1989) also noticed an improvement in water holding capacity of soil with the addition of both chopped and unchopped wheat crop residue in soil. The long-term sugarcane trash management affects the sugarcane water stress index. Due to trash covering, it directly affects soil water. Reducing an average water stress index reduces the photosynthesis rate in response to restricted water supply from the soil. The lowest (0.4) average water stress occurred in green cane trash burnt compared to the trash management system, and trash removal increased water stress (Marin *et al.*, 2014).

#### ➤ **Effect of different trash management practices on chemical properties of soil**

According to Liu *et al.* (2018), the trash blanket placement increased labile carbon in sugarcane. In the alternate year of trash application, it enhanced the soil's electrical conductivity by 12% compared with the 100% trash application treatment. The long-term addition of residue decreased the soil pH by the acid formation and by promoting Al solubility in burnt + residues scattered and fertilized treatments (Mthimkhulu *et al.*, 2018). The soil pH decreased in green trash blanketing treatment related to burnt (Noble *et al.*,

2003). The application of trash for a long period did not bring any significant change in EC and pH; however, in the unfertilized plot, the pH was 3.5 at top of the soil (0-15 cm) and 4.5 (10-30 cm) at depth. The application of mulch with fertilizer lowered the pH (3.4) compared with the burnt plot (3.5). The application of trash in soil decreased the soil pH and increased the macro and micronutrients in the soil (Thourburn *et al.*, 2012; Mthikhulu *et al.*, 2016; Tayade *et al.*, 2016). On top of the surface, application of trash retention leads to decrease in the soil pH from 5.5 to 5 (Page *et al.*, 2014). After applying rice straw mulch in the sorghum plot, the pH was 7.94 and lowest 7.77 recorded after wheat harvesting. Mulch reduced the salt load up to 7.35 dS m<sup>-1</sup> compared to the no mulch (7.92 dS m<sup>-1</sup>) in the soil after harvest of wheat (Soni *et al.*, 2021).

The pH and electrical conductivity were significantly reduced from 8.27 to 8.03 and 0.36 to 0.28 dS m<sup>-1</sup>, respectively after the application of crop residue in maize and wheat cropping systems (Madar *et al.*, 2020). The fall in soil pH may be attributed to production of weak organic acid by the decomposition of crop residue. Sidhu and Beri (1989) reported this statement from their findings from crop residue experiments. Dhar *et al.* (2014), when incorporated crop residue with green manure noticed the largest reduction in soil pH compared to all other treatments. The addition of organic matter aids in improvement of soil buffering capacity, which improves the soil pH status of soil (Ogbodo *et al.*, 2011). Fu *et al.* (1987) reported an increase in pH from 4 to 5 and decrease from 8 to 7 in two different soils with addition of crop residue obtained from sorghum and alfalfa. Degradation of added organic residue in soil releases organic ligands in soil along with higher concentration of carbon dioxide gas which contribute to the lowering of soil pH. Kabirinejad *et al.* (2014) reported a decline of 0.3 units in soil pH on average due to addition of crop residue in fallow soils.

In the long-term experiment of adding residue, the soil organic carbon increased from 36 to 48 g kg<sup>-1</sup> in burnt plot + green top residue compared to the mulched plot and burnt plot (Mthimkhulu *et al.*, 2018). The effect of sugarcane harvesting with burning enhanced the chemical properties of soil. The TOC was higher (12.45 g kg<sup>-1</sup>) in the trash without burnt than trash burnt (8.10 g kg<sup>-1</sup>). In the inter rows, the organic carbon increased and microbial biomass carbon decreased due to trash retention (Graham *et al.*, 2002). And due to a combination of inorganic fertilizer and sugarcane trash as organic amendments increased the soil organic carbon and labile carbon (Eustice *et al.*, 2009). According to Chandra *et al.* (2008), the sugarcane trash with green manure practices was superior in increasing soil

organic carbon as compared to trash removal and trash burning. Mthimkhulu *et al.* (2016) studied the effect of green cane burnt in the field, application of residue as a mulch, and removal from the plot and the results revealed that total C was slightly higher ( $42 \text{ g kg}^{-1}$ ) in trash mulch as compared to the removal of the trash plot ( $36 \text{ g kg}^{-1}$ ) at 0-10cm topsoil. Organic carbon was higher in trash removal (0.79%) over trash burning (0.78%) in ratoon crop of sugarcane. Trash incorporation + cellulolytic microbial culture performed better in increasing organic carbon in soil (5.1 to 8.9%) at 75 DAR and (2.6 to 3.6%) after the harvest of ratoon (Chandra *et al.*, 2002).

The soil organic carbon and nitrogen were 21% more under trash blanketing than burning on top 0 to 25 cm depth. The soil net mineralization did not change significantly, but the post-analysis of different treatments at a different time of experiments revealed net mineralization to be lower in green cane trash blanketing treatments than in burnt treatment. The C: N ratio of the top surface (0-10cm) was higher in green trash treatment than burnt (Marin *et al.*, 2014).

The SOC increased on top 0-5 cm soil ( $25 \text{ g kg}^{-1}$ ) in green cane trash burnt and lowest in burnt ( $13.6 \text{ g kg}^{-1}$ ). The Organic Carbon increased by  $20.9 \text{ g kg}^{-1}$  under the green cane trash blanket treatment and  $16.1 \text{ g kg}^{-1}$  in burnt treatment after 9 years. With the incorporation of maize crop residue, reported a high level ( $13500 \text{ kg ha}^{-1}$ ) of soil organic carbon. The soil organic matter increased with increased the incorporation of straw, *i.e.*, directly proportional to the incorporation of straw (Kumari *et al.*, 2019). The total organic carbon found higher ( $12.45 \text{ g kg}^{-1}$ ) in the trash incorporation than intrash burnt ( $8.10 \text{ g kg}^{-1}$ ). The organic carbon increased by  $2 \text{ g kg}^{-1}$  after 6 years,  $5 \text{ g kg}^{-1}$  after 8 years and  $9.2 \text{ g kg}^{-1}$  after 55 years of residue incorporation. The concentration of total carbon was increased in the retained residue compared to burnt residue in top 20-50 mm of soil (Thornburn *et al.*, 2012). The green cane trash blanketing increases the organic carbon by 8-15%. And the organic carbon increased from the 2.53 to  $3.99 \text{ g kg}^{-1}$  in 9 trash mulch treatments over the  $3 \text{ t ha}^{-1}$  ( $2.47$  to  $3.666 \text{ g kg}^{-1}$ ) (Basset *et al.*, 2021; Robertson *et al.*, 2007). The trash burning reduced the organic carbon by 0.02 % (Yadav *et al.*, 1994). The dissolved organic carbon was 154 % higher in the fertilizer, followed by residue treatment related to the control and 47% higher than the fertilizer treatment (Zhang *et al.*, 2020). The application of different residue rates increased the soil organic carbon content *i.e.*  $6 \text{ Mg ha}^{-1}$  residue increased the SOC (0.49-0.52%) and the lowest (0.43-0.4%) were recorded in the no residue retention. In long-term experiments, no adding of residue more tillage practices reduced the SOC 20-50% (Madar *et*

*al.*, 2020).

The addition of crop residue as mulch significantly increased the soil organic carbon content in the layer 0.02 m deep than surface of soil (Ghuman and Sur, 2001). The findings of crop residue experiment by Karlen *et al.* (1994) revealed that total soil carbon content on 0 to 25 mm and 25 to 75 mm depth was significantly improved by double-crop residue treatment (40 g kg<sup>-1</sup>) and standard residue treatment (24 g kg<sup>-1</sup>) compared to removal (16 g kg<sup>-1</sup>). Organic Carbon content is significantly increased by the incorporation of crop residue in soil. The addition of crop residue as surface mulch adds the organic matter in soil which increase the soil organic carbon content (Dhar *et al.*, 2014). Organic matter is the major decomposition product of crop residue decomposition, which explains the detection of higher level of organic carbon content in soil in a crop residue study conducted by Ogbodo (2011). Salahin *et al.* (2018) found a significantly high content of organic carbon in treatments retaining crop residue for three crop cycles compared to treatments retaining residue just for two cycles. Kabirinejad *et al.* (2014) reported an increase in dissolved organic carbon in soil as a result of residue retention in soil.

The sugarcane trash applied as mulch increased the available N and available P by 37 kg ha<sup>-1</sup> and 10 kg ha<sup>-1</sup>, respectively, over control and it helps in the conservation of the nutrients in the soil. The trash burning reduced the available N by 15 kg ha<sup>-1</sup> and available P by 16 kg ha<sup>-1</sup> over control (Yadav *et al.*, 1994). Yadav *et al.* (2009) also reported a decrease in available N (261-246 kg ha<sup>-1</sup>) and available P (55-39 kg ha<sup>-1</sup>). On the other side increase in P from 161 to 168 kg ha<sup>-1</sup> was observed in trash application plot and available N, P, and K, all three nutrients were increased from 261-299, 55-65, and 161-165 kg ha<sup>-1</sup>, respectively. The trash recovered and recycled the soil N (40 kg N ha<sup>-1</sup>) and yielding (65.5 kg N ha<sup>-1</sup>) from the trash. In the second cycle 62 kg N ha<sup>-1</sup>, yielding a total of 127.5 Kg N ha<sup>-1</sup>. And in the second cycle, the total N increased 168.8 kg N ha<sup>-1</sup> in the long-term experiment after adding sugarcane residue to the soil (Trivelin *et al.*, 2013). Black (1973) observed significant increase in available N content in 0 to 7.6 and 7.6 to 15 cm and available P content in 0 to 15 cm soil depth, respectively, after four crop fallow cycles and one year fallow and this increase was directly proportional to quantity of crop residue added throughout the experiment. The addition of surface mulch gave higher values of available P and total N in soil than the control (Mbah and Nneji, 2011).

Devari *et al.* (2012) noticed a significant increase in Kjeldahl N and sodium bicarbonate extractable P content in soil when crop residue was incorporated in soil for two

years. Similar trends were observed by Dhar *et al.* (2014) which may be attributed to addition of N and P from crop residue into soil. Ogbodo (2011) reported highest levels of total soil N and available P in crop residue-treated plots, which can be ascribed to the fact that organic matter acts as a reservoir of plant nutrients which, on decomposition, releases them in soil. The addition of crop residue stimulates the multiplication of microorganisms which convert N bound in organic matter to inorganic form (Nagar *et al.*, 2016). Similar trends in total soil N were observed by Sidhu and Beri (1989). The trash blanket placement increased nitrogen availability in sugarcane. The  $\text{NH}_4^+$ -N concentration was higher (4.5 to 4.8  $\text{mg kg}^{-1}$ ) in trash application than no trash application (3.2  $\text{mg kg}^{-1}$ ) (Liu *et al.*, 2018). The integrated trash management practices, trash burnt direct effect on the available N, it decreased after the trash burning. Applying fertilizer and fertilizer with residue increased the total nitrogen by 43% compared to the control treatment (Zhang *et al.*, 2020).

Using sugarcane residue as a biochar fertilizer increased phosphorus use efficiency and plant yield. After 120 days of using biochar fertilizer, it increased by 10% phosphorus efficiency in most clayed soil related to the controlled condition. But in triple superphosphate treatment, the plant phosphorus content was higher (339  $\text{mg kg}^{-1}$  soil) compared to the fertilized with biochar in sandy soil and clay soil (1375  $\text{mg kg}^{-1}$ ). The total P was higher (19735  $\text{mg l}^{-1}$  P) after 120 days of biochar fertilizer addition and lowest in TSP treatment (14697  $\text{mg/l}$  P) (Borges *et al.*, 2020). The trash also affected the magnesium content at 0-10cm topsoil. The Mg was higher in unfertilized treatment (3.61  $\text{cmol kg}^{-1}$ ) compared to the fertilized plot (1.69  $\text{cmol kg}^{-1}$ ) (Mthimkhulu *et al.*, 2016).

The trash retention increased the P, K, Ca and Mg range from 0.09- 17.17  $\text{mg dm}^{-1}$ , 0.04-0.10  $\text{cmol dm}^{-1}$  0.44-1.27  $\text{cmol dm}^{-1}$  and 0.14 to 0.38  $\text{cmol dm}^{-1}$  respectively (Souza *et al.*, 2012; Noble *et al.*, 2003). The pre-harvest burning versus trash conservation on the soil after 14 years, low availability of  $\text{Al}^{3+}$  and conserving  $\text{Ca}^+$  and  $\text{Mg}^+$  at 40 cm depth. And the total carbon stock after 14 years of trash conservation at a depth of 0-10 cm, 4  $\text{Mg ha}^{-1}$  was greater than the burned treatment (Pinheiro *et al.*, 2010). The highest Ca concentration (6.37  $\text{cmol}(+)\text{kg}^{-1}$ ) was observed in burnt with residue scattered and fertilized treatment and lowest (4.83  $\text{cmol kg}^{-1}$ ) in mulch and burnt treatment, respectively (Mthimkhulu *et al.*, 2016). The liming improves the soil microbial growth, but trash blanket placement increases the labile carbon and nitrogen availability in sugarcane. The alternate trash application increased the microbial biomass carbon and microbial biomass nitrogen concentration related to the no trash application (Liu *et al.*, 2018).



The addition of sugar cane trash increased the sulphur mineralization significantly up to 24.2 and 26.87% with the incorporation of pine needles and press mud waste. The pattern of sulphur mineralization from different amendments was in the order of paper mill bagasse > sugarcane trash > press mud > pine needle. The paper mill bagasse showed 19.44, 51.54 and 48.4% more sulphur mineralization than sugarcane trash, press mud and pine needle, respectively. Sulphur mineralization was increased up to 45 days of incubation and declined after 90 days. The maximum sulphur mineralization of 31.26% was registered at 45 days of incubation. Sugarcane trash increased the sulphur mineralization on 30<sup>th</sup> day of incubation and maximum at 60 days of incubation. The preservation of crop residue for the long term in the soil increased 78% of the total soil sulphur. However, no burning effect was observed in the lower layer of soil. In the top soil layer, the total-S was 441 and 247 mg kg<sup>-1</sup> for the without and with burning treatments, respectively. The SO<sub>4</sub><sup>2-</sup> content of soils without burning was the 3 times higher than the burnt treatments. The organic S was the main pool, containing 88-97% of the total S, showing the higher in the soil in the treatments without burning (Canellas *et al.*, 2010; Mishra *et al.*, 2016).

The trash application sharply releases potassium, which occurs in the plant in ionic form. It was also leached in the soil after 1 year of trash application because of the formation of weak complexes with Ca, Mg, S and P, and 40-80% released after 1 year of decomposition of trash residue (Thornburn *et al.*, 2012). The addition of trash in the soil enhanced the soil organic matter and also increased the K content in the soil which reduced the K dose *i.e.* 25-30 kg ha<sup>-1</sup> in the next succeeding crop (Tayade *et al.*, 2016). The concentration of neutral ammonium acetate extractable exchangeable K in soil exhibited an increasing trend in the incorporation of crop residue in soil, as revealed by independent investigations by Dhar *et al.* (2014) and Davari *et al.* (2012). But, in many research findings, the potassium content was higher (0.8 cmol kg<sup>-1</sup>) in the burning treatment relative to the mulch treatment (0.7 cmol kg<sup>-1</sup>) (Mithikhulu *et al.*, 2016). The sugarcane trash application @ 9t ha<sup>-1</sup> significantly increased K level from 0.43 to 0.50 cmol kg<sup>-1</sup> while lowest K content of 0.26 to 0.36 mol kg<sup>-1</sup> was recorded in the less trash @ 3 t ha<sup>-1</sup> in two years of experiment (Bassey *et al.*, 2021).

➤ **Effect of different trash management practices on biological properties of soil**

The sugarcane trash with green manure practices was superior in soil organic carbon compared to trash removal and burning. After 75 days of ratooning, the soil that was treated with trash incorporation and trash incorporation + cellulolytic treatment showed more dehydrogenase activity as compared to the trash burning and trash removal treatment. The

accumulation of organic matter and fertilizer-induced acidity in the soil microbial and energy activity of long-term sugarcane. The microbial activity *i.e.*, Fluorescein Diacetate hydrolysis rate: Arginine ammonification and Dehydrogenase activity were increased in green cane harvest with retention of residual treatment with the residual burnt. The increased order of FDA:  $0.45 < 0.55 < 0.80 \mu\text{mol g h}^{-1}$ , Arginine ammonification:  $0.3 < 0.5 < 0.8 \mu\text{mol g h}^{-1}$  and Dehydrogenase activity:  $0.03 < 0.06 < 0.08 \mu\text{mol g h}^{-1}$  respectively in treatments BF0 (pre-harvest burnt and harvest residue remove with no fertilizer) < pre-harvest burnt with residue left with no fertilizer and retention of trash with no fertilizer (Graham *et al.* 2005; Chandra *et al.* 2008).

In the long-term experiment, the urease and dehydrogenase activity decreased by an average 58 and 38% in row and inter-row, respectively. After the sixth harvest, dehydrogenase activity continually reduced. Urease activity decreased up to the third harvest and then increased. Acid phosphatase activity decreased until the third harvest and increased close to the first crop harvest. The application of rice straw increased the dehydrogenase activity 98 in sorghum and 95 ( $\text{mg TPF kg}^{-1} \text{soil day}^{-1}$ ) in the wheat crop after harvesting and less than 88 and 80 ( $\text{mg TPF kg}^{-1} \text{soil day}^{-1}$ ) in no mulch treatment of sorghum and wheat respectively. Urease was recorded 60 and 61 ( $\text{mg NH}_4^+ \text{N kg}^{-1} \text{soil h}^{-1}$ ) after sorghum and wheat harvesting, with lowest values 59 and 56 ( $\text{mg NH}_4^+ \text{N kg}^{-1} \text{soil h}^{-1}$ ) recorded in no mulch, respectively (Soni *et al.*, 2021).

The conventional tillage, zero tillage in the rainy season with residue, had 16-38% higher urease activity over conventional tillage without residue after 7 years. More 7.1 ( $\mu\text{g TPF g}^{-1} \text{soil h}^{-1}$ ) dehydrogenase activity was recorded in conventional tillage, with zero tillage in the rainy season with residue over the conventional tillage in post-rainy seasons without residue (Nath *et al.*, 2021). Higher application of crop residue ( $6 \text{ Mg ha}^{-1}$ ) reported more ( $73.7 \mu\text{g TPF g}^{-1} \text{d}^{-1}$ ) dehydrogenase activity compared to  $52.4 \mu\text{g TPF g}^{-1} \text{d}^{-1}$  in the no crop residue (Madar *et al.*, 2020). Dehydrogenase activity was higher under zero tillage maize-wheat-mungbean ( $62.88 \mu\text{g TPF g}^{-1} \text{24 h}^{-1}$ ) and zero tillage rice-wheat-mungbean ( $63.16 \mu\text{g TPF g}^{-1} \text{d}^{-1}$ ) with crop residue, compared to conventional tillage ( $51.14 \mu\text{g TPF g}^{-1} \text{d}^{-1}$ ) without residue (Choudhary *et al.*, 2018). The dehydrogenase and urease activity decreased 5% and 26%, respectively, under row and inter-row. But acid phosphatase decreased ( $620$  to  $450 \mu\text{g pNP h}^{-1} \text{g DS}$ ) up to third harvest and then increased ( $450$  to  $650 \mu\text{g p-NP h}^{-1} \text{g DS}$ ) up to 6<sup>th</sup> harvest of the crop (Pupin *et al.*, 2011).

The long-term residue and N treatments directly affected the soil enzymes activity in

the 0-20 cm soil depth. With continued manuring and wheat straw incorporation showed higher ( $44 \mu\text{g soil}^{-1} \text{h}^{-1}$ ) alkaline phosphatase compared to the straw burnt ( $30 \mu\text{g soil}^{-1} \text{h}^{-1}$ ) and 190% increase in alkaline phosphatase activity over the control value (Dick *et al.*, 1988). The phosphatase enzymes were higher ( $340 \mu\text{g p-nitrophenol h}^{-1} \text{g dry soil}$ ) in 100% trash application than the alternate trash application treatment ( $120 \mu\text{g p-nitrophenol h}^{-1} \text{g dry soil}$ ) (Liu *et al.*, 2018). The application of rice straw decreases the alkaline phosphatase activity, 23 in sorghum and 22 ( $\text{mg pNP kg}^{-1} \text{soil h}^{-1}$ ) in the wheat crop after harvesting and highest 24 and 25 ( $\text{mg pNP kg}^{-1} \text{soil h}^{-1}$ ) in no mulch treatment of sorghum and wheat respectively (Soni *et al.*, 2021). The conventional tillage, zero tillage in post-rainy seasons with residue incorporation had higher alkaline phosphatase 192 and lowest 153 ( $\mu\text{g p-nitrophenol g}^{-1} \text{soil h}^{-1}$ ) in the conventional tillage without residue (Nath *et al.*, 2021). The application of 6 Mg  $\text{ha}^{-1}$  crop residue recorded the highest alkaline phosphatase ( $77.1 \mu\text{g p-nitrophenol g}^{-1}\text{hr}^{-1}$ ) compared to  $59.1 \mu\text{g p-nitrophenol g}^{-1}\text{hr}^{-1}$  in the no-crop residue (Madar *et al.*, 2020). Highest alkaline phosphatase activity was observed under zero tillage maize-mungbean-wheat ( $59.23 \mu\text{g p-NP g soil}^{-1} \text{h}^{-1}$ ) with crop residue and zero tillage rice- rice-wheat-mungbean ( $55.76 \mu\text{g p-NP g soil}^{-1} \text{h}^{-1}$ ) with residue system, and 73% and 63% higher than the conventional tillage with no residue (Choudhary *et al.*, 2018).

➤ **Effect of different trash management practice on the growth parameter of sugarcane**

Borges *et al.* (2020) and Ball Coelho *et al.* (1993) found that the use of sugarcane residue as biochar and fertilizer increased by 15% biomass yield after 120 DAP and the burning of plant crop residue decreased the dry matter (13.5 to 2.9  $\text{mg kg}^{-1}$ ). Burning and harvesting green cane also increased the root density of sugarcane. Graham *et al.* (2002) observed greater root length density on surface 0-10 cm ( $1.046 \text{ cm cm}^{-3}$ ) than the trash treatment ( $0.408 \text{ cm cm}^{-3}$ ) although the root mass density under trash burning ( $0.832 \text{ g/cm}^{-3}$ ) was greater than the trash treatment ( $0.397 \text{ g cm}^{-3}$ ). The trash application as mulch increased the plant height (176.5cm) compared to the control (170.90cm). The application of trash mulch @10 with  $80 \text{ kgP}_2\text{O}_5 \text{ ha}^{-1}$  increased the numbers of tillers  $89.15 \text{ 000 ha}^{-1}$  over the control  $79.46 \text{ 000 ha}^{-1}$  (Kumar *et al.*, 2015).

The application of high doses of nitrogen ( $210 \text{ kg ha}^{-1}$ ) increased the number of tillers ( $130940\text{-}137540 \text{ ha}^{-1}$ ) and the number of millable canes ( $109.67\text{-}112.61 \text{ 000 cane ha}^{-1}$ ) in ratoon crop (Dev *et al.*, 2013). Vermicomposting with nitrogen increased the no of tillers, stem diameter, and stalk length after 2, 3, and 4 months of planting. The stalk length ( $10.7$

cm) was observed in the 20t vermicomposting + 75 kg N ha<sup>-1</sup> treatment. After the 4 months, with the increased dose of vermicomposting and N, it increased the number of tillers (11.27 000 ha<sup>-1</sup>) and lowest (10.1 000 ha<sup>-1</sup>) tillers were recorded in the 45 kg N ha<sup>-1</sup> with no vermicompost (Djajadi *et al.*, 2020). The spring cultivar with N dose increased the millable canes by 163.3% compared to the late spring (Saini *et al.*, 1996). In the first ratoon crop, the drained treatment shows the highest plant population (83800 stalks ha<sup>-1</sup>) and lowest (77600 stalks ha<sup>-1</sup>) in the variable water table depth treatment. The plant population for the bedded treatment was higher than that for flat-planted treatments (Camp *et al.*, 1982).

The number of millable canes increased with the application of trash mulch. The 10 t ha<sup>-1</sup> trash application produced more (70.47 000 ha<sup>-1</sup>) number of millable cane compared to the control (64.05 000 ha<sup>-1</sup>). The trash as mulch and trash chopped increased the number of millable cane (81.3 000 ha<sup>-1</sup>) over the control. The number of millable canes also increased (68889 ha<sup>-1</sup>) in trash incorporation with the green manuring treatment in relation to the control (64444 ha<sup>-1</sup>) (Tayade *et al.*, 2016). The use of organic biofertilizer and intercropping of legumes with a recommended dose of N enhances the number of millable cane (131 000 ha<sup>-1</sup>) in planted cane and lowest were recorded in ratoon crop (99.3 000 ha<sup>-1</sup>) (Singh *et al.*, 2011).

➤ **Effect of different trash management practices on yield and yield attributes of sugarcane**

The cane girth (2, 21 cm) and average cane weight (1.29 kg) increased in the mulch, while lowest values were observed in the control treatments (Kumar *et al.*, 2015). The application of salt of active phosphorus (15 kg) with 100% of the recommended dose increased the cane length (41.27 cm) and single cane weight (0.369 kg) compared to the control. The potassium salt of active phosphorus doses also affected the cane length (265.31cm), cane weight (0.980 kg), and cane diameter (2.70 cm), respectively (Kumar *et al.*, 2019). In ratoon crop, pre-application of 60 kg K<sub>2</sub>O ha<sup>-1</sup> increased the cane weight as compared to the less application of K<sub>2</sub>O ha<sup>-1</sup> (Singh *et al.*, 2012)

The sugarcane trash applied as mulch increased the yield of the third ratoon crop by 1.9%. The different cropping systems viz: autumn planting gave the higher cane yield (71%) than the spring season (Yadav *et al.*, 1994; Patel *et al.*, 2019). The different planting dates in north India in the first year of planting, the autumn crop yield was 37.3 and 45.9 t ha<sup>-1</sup> higher than the spring and late spring crop respectively. The application of higher dose (150 kg ha<sup>-1</sup>) of N gave 31.6% more yield than the 120 and 90 kg ha<sup>-1</sup> N (Saini *et al.*, 1996). The trash

burning + green manuring incorporation practices gave the higher (158 t ha<sup>-1</sup>) cane yield. The productivity also increased 50.6, 30.9 and 17.7% in trash removal, trash incorporation, and trash burning treatments, respectively (Chandra *et al.*, 2008). The residue burning increased the cane yield of planted cane over the control and 83.7% (116.3 t ha<sup>-1</sup>) higher cane yield was obtained in ratoon, compared to the planted cane (63.3 t ha<sup>-1</sup>). The long-term trash management practices and application of a high dose of N (150 kg N ha<sup>-1</sup>), increased the yield of sugarcane in the green cane trash retained system relative to the 100 kg N ha<sup>-1</sup> and trash incorporation. High doses of urea, from 50 to 200 kg N ha<sup>-1</sup>, increased the sugarcane fresh mass (Marin *et al.*, 2014). After the addition of trash, the cane yield increased from 104.3 to 133.2 t ha<sup>-1</sup> in the second and third ratooning compared to the base year in integrated sugarcane trash management and on average 8.5% yield increased in the third ratoon season (Suma *et al.*, 2015). In the third ratoon, the sulphitation press mud cake application increased the sugar yield from 5.77 to 7.22 t ha<sup>-1</sup> (Singh *et al.*, 2012).

➤ **Effect of different trash management practices on Juice quality of sugarcane**

Kumar *et al.* (2015) found that the mulch @ 10 t ha<sup>-1</sup> increased the brix, pol and CCS % (20:17.62:11.06%) of cane juice over control (19.06:17.19 and 11.85%), respectively. The application of trash as a mulch 0 or 9 t did not significantly increase the brix content. But the mulch with pre-emergence herbicide application increased (18.15%) the brix content than the no mulch treatment (Bassey *et al.*, 2021). After the 10 months of planting, the brix and sucrose % were higher compared to the control *i.e.* 18.53 and 16.11%, respectively. After the 12 months of trash incorporation, the Commercial Cane percentage was higher (13.08%) in trash treatments than in the control (Tayade *et al.*, 2016). Maximum sucrose synthesis (16.9%) and CCS (1.5 t ha<sup>-1</sup>) were recorded in the autumn season than in spring and late spring. With the increase of N dose, the sucrose content was (16.3%) increased in 120 kg N ha<sup>-1</sup>, 16.2% in 150 kg N ha<sup>-1</sup>, and 16% in 90 kg N ha<sup>-1</sup>, respectively (Saini *et al.*, 1996).

## **Conclusion**

Organic mulches also create a better physical, chemical, and biological environment for soils and, in turn, improve crop productivity. Burning of trash deteriorates fertility as well as soil health. It also reduces the soil microbial activity and destabilizes soil aggregates. Significant N losses from residues can occur during burning by high-temperature volatilization. In the burnt system, >70% of the organic matter and nutrients in the trash are

lost to the atmosphere.

#### Disclaimer (Artificial intelligence)

##### Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

##### Option 2:

Author(s) hereby declare that generative AI technologies, such as Large Language Models, etc., have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology, as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

- 1.
- 2.
- 3.

#### References

- Anonymous 2017. Sugar Annual (2017). Global Agricultural Information Network. United States Department of Agriculture Foreign Agricultural Service.
- Anonymous, 2017, a. Department of Commerce, Ministry of Commerce and Industry, Government of India. [https://sugarcane.icar.gov.in/images/sbi/charts/import\\_export.pdf?phpMyAdmin=11c501a2a5dt8788ed6](https://sugarcane.icar.gov.in/images/sbi/charts/import_export.pdf?phpMyAdmin=11c501a2a5dt8788ed6)
- Ball-Coelho, B., Tiessen, H., Stewart, J.W.B., Salcedo, I.H., and Sampaio, E.V.S.B. (1993). Residue management effects on sugarcane yield and soil properties in Northeastern Brazil. *Agronomy Journal*, **85(5)**: 1004-1008.
- Basit, A. (2018). Effect of Residue Management and N and S Fertilisation on Cane and Sugar Yield of Plant and Ratoon Cane. *Pertanika Journal of Tropical Agricultural Science*, **41(1)** :249-256
- Bassey, M.S., Kolo, M.G.M., Daniya, E., and Odofin, A.J. (2021). Trash Mulch and Weed Management Practice Impact on Some Soil Properties, Weed Dynamics and Sugarcane (*Saccharum officinarum* L.) Genotypes Plant Crop Productivity. *Sugar Tech*, **23(2)**: 395-406.
- Beri, V., Sidhu, B.S., Bahl, G.S. and Bhat, A.K. (1995). Nitrogen and Phosphorus transformations as

- affected by crop residue management practices and their influence on crop yield. *Soil Use and Management*, **11**: 51-54
- Black, A.L. (1973). Soil Property changes associated **withcrop** residue management in a wheat fallow rotation. *Soil Science Society of America Journal*, **37(6)**: 943-946
- Borges, B.M., Strauss, M., Camelo, P.A., Sohi, S.P., and Franco, H.C. (2020). Re-use of sugarcane residue as a novel biochar **fertilizer-increased** phosphorus use efficiency and plant yield. *Journal of Cleaner Production*, **262**: 121406.
- Camp, C.R. (1982). Effect of Water Management and Bed Height on Sugarcane Yield. *Soil Science*, **133(4)**: 232-238.
- Canellas, L.P., Busato, J.G., Dobbss, L.B., Baldotto, M.A., Rumjanek, V.M., and Olivares, F.L. (2010). Soil organic matter and nutrient pools under long-term non-burning management of sugar cane. *European Journal of Soil Science*, **61(3)**: 375-383.
- Casida, L.E.J., Klein, D.A. and Santoro, T. (1964). Soil dehydrogenase activity. *Soil Science*. **98**: 371-376.
- Chandra, R., Rana, N. S., Kumar, S. and Panwar, G. S. (2008). Effects of sugarcane residue and green manure practices in sugarcane-ratoon-wheat sequence on productivity, soil fertility and soil biological properties. *Archives of Agronomy and Soil Science*, **54**: 651-664.
- Chen, H., Liang, Q., Gong, Y., Kuzyakov, Y., Fan, M., and Plante, A.F. (2019). Reduced tillage and increased residue retention increase enzyme activity and carbon and nitrogen concentrations in soil particle size fractions in a long-term field experiment on Loess Plateau in China. *Soil and Tillage Research*, **194(4)**: 104-296.
- Choudhary, M., Sharma, P. C., Jat, H.S., McDonald, A., Jat, M.L., Choudhary, S., and Garg, N. (2018). Soil biological properties and fungal diversity under conservation agriculture in Indo-Gangetic Plains of India. *Journal of Soil Science and Plant Nutrition*, **18(4)**: 1142-1156.
- Choudhary, R.L., Wakchaure, G.C., Minhas, P.S., and Singh, A.K. (2017). Response of ratoon sugarcane to stubble shaving, off-barring, root pruning and band placement of basal **fertilizers** with a multi-purpose drill machine. *Sugar Tech*, **19(1)**: 33-40.
- Davari, M.R., Sharma, S.N. and Mirzakhani, M. (2012). Effects of cropping systems and crop residue incorporation on production and properties of soil in an organic agroecosystem. *Biological Agriculture and Horticulture*, **28(3)**: 206-222
- de Oliveira Bordonal, R., Menandro, L.M.S., Barbosa, L.C., Lal, R., Milori, D.M.B.P., Kolln, O.T., Franco, H.C.J. and Carvalho, J.L.N. (2018). Sugarcane yield and soil carbon response to straw removal in south-central Brazil. *Geoderma*, **328**: 79-90.
- Dev, C.M., Singh, R.K., Meena, R.N., Kumar, A., and Singh, K. (2013). Production potential and soil fertility status of ratoon sugarcane (*Saccharum officinarum* L.) as influenced by time and level of earthing up and nitrogen levels in North-Eastern Uttar Pradesh, India. *Sustainable Agriculture Research*, **2** (526-2016-37903).
- Dhar, D., Datta, A., Basak, N., Paul, N., Badole, S. and Thomas, T. (2014). Residual effect of crop residues on growth, yield attributes and soil properties of wheat under rice wheat cropping system. *Indian Journal of Agricultural Research*, **48(5)**: 373-378
- Dick, R.P., Rasmussen, P.E., and Kerle, E.A. (1988). Influence of long-term residue management on

soil enzyme activities in relation to soil chemical properties of a wheat-fallow system. *Biology and Fertility of Soils*, **6(2)**: 159-164.

- Djajadi, D., Syaputra, R., Hidayati, S.N., and Khairiyah, Y. (2020). Effect of Vermicompost and Nitrogen on N, K, Na Uptakes and Growth of Sugarcane in Saline Soil. *Agrivita*, **42(1)**: 110.
- Fu., M.H., Xu, X.C. and Tabatabai, M.A. (1987) Effect of pH on nitrogen mineralization in crop residue treated soils. *Biology and Fertility of Soils*, **5**: 115-119
- Ghuman, B.S. and Sur, H.S. (2001). Tillage and residue management effects on soil properties and yields of rainfed maize and wheat in a subhumid subtropical climate. *Soil and Tillage Research*, **58**:1-10
- Goyal, S., Dhull, S.K., and Kapoor, K.K. (2005). Chemical and biological changes during composting of different organic wastes and assessment of compost maturity. *Bioresource Technology*, **96(14)**: 1584-1591.
- Graham, M.H., and Haynes, R.J. (2005). Organic matter accumulation and fertilizer-induced acidification interact to affect soil microbial and enzyme activity on a long-term sugarcane management experiment. *Biology and Fertility of Soils*, **41(4)**: 249-256.
- Graham, M.H., Haynes, R.J., and Van Antwerpen, R. (2002). Size and activity of the soil microbial biomass in the row and inter-row of a sugarcane field under burning and green cane harvesting. *South African Sugar Technologists' Association*, **76**: 186-195.
- Kabirinejad, S., Kalbasi, M., Khoshgoftarmansh, A.H., Hoodaji, M. and Afyuni, M. (2014). Effect of incorporation of crop residue into soil on some chemical properties of soil and bioavailability of copper in soil. *International Journal of Advanced Biological and Biomedical Research*, **2(11)**: 2819-2824
- Karlen, D.L., Wollenhaupt, N.C., Erbach, D.C., Berry, E.C., Swan, J.B., Eash, N.S. and Jordahl, J.L. (1994). Crop residue effect on soil quality following 10 years of no till corn. *Soil and Tillage Research*, **31**: 149-167
- Kumar, V. and Sagwal, O. P. (1998). Effect of sugarcane trash and fertilizer nitrogen applications on the nutrient status and soil physical properties in Haryana soil. *Indian Sugar*, **47(12)**, 967-971.
- Kumar, S., Chand, G., Manai, D., Kumar, A., and Kumar, S. (2015). Effect of trash mulching on quantitative and qualitative parameters of sugarcane. *Ecology, Environment and Conservation*, **21**, 141-143.
- Kumar, S., Singh, S.C., Yadav, S.P, and Singh, P. (2018). Effect of doses of potassium salt of active phosphorus on productivity and quality of sugarcane (*Saccharum* sp. Hybrid). *Indian Journal of Sugarcane Technology* **33(02)**:85-87.
- Kumar, S., Srivastav M. L., and Singh P. (2019). "Economically dose of potassium salt of active phosphorus for growth, purity and economic of sugarcane crop (*Saccharum* sp. Hybrid) In Eastern UP." *Indian Journal of Sugarcane Technology* **26(2)**:110-114.
- Kumari, R., Singh, R., and Kumar, N. (2019). Effect of crop residue management on soil organic carbon, soil organic matter and crop yield: An overview. *Journal of Applied and Natural Science*, **11(3)**: 712-717.
- Liu, X. Y., Rashti, M.R., Esfandbod, M., Powell, B. and Chen, C.R. (2018). Liming improves soil microbial growth, but trash blanket placement increases labile carbon and nitrogen availability in a sugarcane soil of subtropical Australia. *Soil Research*, **56(3)**: 235-243.



- Madar, R., Singh, Y.V., Meena, M.C., Das, T.K., Gaind, S. and Verma, R.K. (2020). Potassium and Residue Management Options to Enhance Productivity and Soil Quality in Zero till Maize–Wheat Rotation. *CLEAN–Soil, Air, Water*, **48(3)**: 1900316.
- Marin, F. R., Thorburn, P.J., da Costa, L.G. and Otto, R. (2014). Simulating long-term effects of trash management on sugarcane yield for Brazilian cropping systems. *Sugar Tech*, **16(2)**: 164-173.
- Mbah, C.N. and Nneji, R.K. (2011) Effect of different crop residue management techniques on selected soil properties and grain production of maize. *African Journal of Agricultural Research*, **6(17)**: 4149-4152
- Mishra, A., Kumar, N., Kumar, R., Kumar, R. and Tomar, D. (2016). Mineralization of carbon, nitrogen, phosphorus and sulphur from different organic wastes in silty clay loam soils. *Journal of Applied and Natural Science*, **8(1)**: 16-22.
- Mthimkhulu, S., Miles, N., van Antwerpen, R. and Elephant, D. (2018). Effect of residue and fertiliser management on soil fertility in a long-term sugarcane trial in South Africa. *South African Journal of Plant and Soil*, **13**: 1-9.
- Mthimkhulu, S., Podwojewski, P., Hughes, J., Titshall, L. and van Antwerpen, R. (2016). The effect of 72 years of sugarcane residues and fertilizer management on soil physico-chemical properties. *Agriculture, Ecosystems & Environment*, **225**: 54-61.
- Nagar, R.K., Goud V.V. Kumar, R. and Kumar, R. (2016). Effect of organic manure and crop residue management on physical, chemical and biological properties of soil under pigeonpea based intercropping system. *International Journal of Farm Sciences*, **6(1)**: 101-113
- Nath, C.P., Kumar, N., Das, K., Hazra, K.K., Praharaj, C.S. and Singh, N.P. (2021). Impact of variable tillage based residue management and legume based cropping for seven years on enzymes activity, soil quality index and crop productivity in rice ecology. *Environmental and Sustainability Indicators*, **10**: 100107.
- Noble, A. D., Moody, P., and Berthelsen, S. (2003). Influence of changed management of sugarcane on some soil chemical properties in the humid wet tropics of north Queensland. *Soil Research*, **41(6)**: 1133-1144.
- Ogbodo, E.N. (2011). Effect of crop residue on soil chemical properties and rice yield on an Ultisol at Abakaliki, Southeastern Nigeria. *World Journal of Agricultural Sciences*, **7(1)**: 3-18
- Page, K. L., Bell, M., and Dalal, R. C. (2014). Changes in total soil organic carbon stocks and carbon fractions in sugarcane systems as affected by tillage and trash management in Queensland, Australia. *Soil Research*, **51(8)**: 608-614.
- Patel, D., and Chaudhari, M. (2019). Production potential and economics of sugarcane based cropping system. *Journal of Pharmacognosy and Phytochemistry*, **8(3)**, 2387-2389.
- Pinheiro, É.F. M., Lima, E., Ceddia, M.B., Urquiaga, S., Alves, B.J., and Boddey, R.M. (2010). Impact of pre-harvest burning versus trash conservation on soil carbon and nitrogen stocks on a sugarcane plantation in the Brazilian Atlantic forest region. *Plant and Soil*, **333(1)**: 71-80.
- Pupin, B., and Nahas, E. (2011). Impact of successive sugarcane harvests and trash management practices on soil microbiological properties. *Soil Research*, **49(2)**: 183-189.
- Robertson, F. A. and Thorburn, P. J. (2007). Management of sugarcane harvest residues: consequences for soil carbon and nitrogen. *Soil Research*, **45(1)**: 13-23.

- Saini, S.K., Singh, R.K., Singh, T.P. and Sinha, S.K. (1996). Response of Sugarcane Cultivars to Nitrogen Under Different Dates of Planting in North India. *Cooperative Sugar*, **27**, 903-908.
- Salahin, N., Alam, K., Mohammad, A.T., Mondol, A.I., Islam, M.S., Rashid, M.H. and Hoque, M.A. (2017). Effect of tillage and residue retention on soil properties and crop yields in wheat-mungbean-rice crop rotation under sub humid climate. *Open Journal of Soil Science*, **7(14)**: 1-14
- Shen, Y., McLaughlin, N., Zhang, X., Xu, M. and Liang, A. (2018). Effect of tillage and crop residue on soil temperature following planting for a Black soil in Northeast China. *Scientific Reports*, **8**: 4500
- Sidhu, B.S. and Beri, V. (1989). Effect of crop residue management on yields of different crops and on soil properties. *Biological Wastes*, **27**: 15-27
- Singh, S.N., Singh, A.K., Singh, S.C., Sharma, M.L., and Kumar, R. (2011). Enhancing sugarcane (*Saccharum* spp. Hybrid) productivity by integrating organic, inorganic and biological sources of N in sub-tropical India. *Indian Journal of Sugarcane Technology*, **26(1)**: 1-15.
- Singh.K., Singh. H., Sandhu. R.S., and Bhullar. M.S. (2012), Improving productivity of winter initiated ratoon of sugarcane in sub tropical India. *Indian Journal of Sugarcane Technology* **27(02)**: 62-64.
- Smith, D.W., & Bowes, G.C. (1974). Loss of some elements in fly-ash during old-field burns in southern Ontario. *Canadian Journal of Soil Science*, **54(2)**: 215-224.
- Soni, P.G., Basak, N., Rai, A.K., Sundha, P., Narjary, B., Kumar, P., and Yadav, R.K. (2021). Deficit saline water irrigation under reduced tillage and residue mulch improves soil health in sorghum-wheat cropping system in semi-arid region. *Scientific Reports*, **11(1)**: 1-13.
- Souza, R.A., Telles, T.S., Machado, W., Hungria, M., Tavares Filho, J., and de Fatima Guimaraes, M. (2012). Effects of sugarcane harvesting with burning on the chemical and microbiological properties of the soil. *Agriculture, Ecosystems and Environment*, **155**: 1-6.
- Srivastava, T.K., Singh, K.P., and Singh, P. (2014). Organic Sugarcane Production Systems for Enhanced Soil Health and Crop Productivity. *Indian Journal of Sugarcane Technology*, **29(02)**: 41-50.
- Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for the determination of available nitrogen in soils. *Current Science*, **25**:259-60.
- Suma, R., and Savitha, C.M. (2015). Integrated sugarcane trash management: a novel technology for sustaining soil health and sugarcane yield. *Advances in Crop Science and Technology*.
- Tayade, A.S., Geetha, P., Dhanapal, R., and Hari, K. (2016). Effect of in situ trash management on sugarcane under wide row planting system. *Journal of Sugarcane Research*, **6(1)**: 35-41.
- Thorburn, P.J., Meier, E.A., Collins, K., and Robertson, F.A. (2012). Changes in soil carbon sequestration, fractionation and soil fertility in response to sugarcane residue retention are site-specific. *Soil and Tillage Research*, **120**: 99-111.
- Tortora, M.L., Naval, N.G., Vera, L., de Ullivarri, J. F., Digonzelli, P., and Romero, E. (2013). Effect of sugar cane trash blanketing on the development of microorganisms of agronomic and environmental interest. In *Proc. Int. Soc. Sugar Cane Technol* (**28**).

- Tripathi, R.P., Sharma, P. and Singh, S. (2006). Influence of tillage and crop residue on soil physical properties and yields of rice and wheat under shallow water table conditions. *Soil and Tillage Research*, **92**: 221-226
- Trivelin, P.C.O., Franco, H.C.J., Otto, R., Ferreira, D.A., Vitti, A.C., Fortes, C., and Cantarella, H. (2013). Impact of sugarcane trash on fertilizer requirements for São Paulo, Brazil. *Scientia Agricola*, **70(5)**: 345-352.
- Walia, M.K. and Dick, W.A. (2018). Selected soil physical properties and aggregate associated carbon and nitrogen as influenced by gypsum, crop residue and glucose. *Geoderma*, **320**: 67-73
- Yadav, R.L., Prasad, S. R., Singh, R., and Srivastava, V.K. (1994). Recycling sugarcane trash to conserve soil organic carbon for sustaining yields of successive ratoon crops in sugarcane. *Bioresource Technology*, **49(3)**: 231-235.
- Yadav, R.L., Suman, A., Prasad, S.R., and Prakash, O. (2009). Effect of *Gluconacetobacter diazotrophicus* and *Trichoderma viride* on soil health, yield and N-economy of sugarcane cultivation under subtropical climatic conditions of India. *European Journal of Agronomy*, **30(4)**, 296-303.
- Yadav, R.L and Kumar, R. (2005) On Farm comparison of ring pit and **conventional** flat planting methods for yield and quality of sugarcane in northwest India. *Indian Journal of Agricultural Sciences* **75**:605-10.
- Yadav, S.P., Singh, S.C., Yadav, S., Kumar, A., Singh, S.P., Yadav, S.K., and Sharma, B.L. (2016). Effect of ethrel and gibberellic acid on growth and yield of sugarcane (cv 'CoS 03251') with recommended agronomic practices. *Indian Journal of Sugarcane Technology*, **31(02)**: 65-67.
- Zhang, L., Chen, X., Xu, Y., Jin, M., Ye, X., Gao, H., and Thompson, M. L. (2020). Soil labile organic carbon fractions and soil enzyme activities after 10 years of continuous fertilization and wheat residue incorporation. *Scientific Reports*, **10(1)**: 1-10.