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_2O_5, and 280 kg K_2O from the soil to produce 100 t ha^{-1} sugarcane.Sugarcane, being a C_4 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, 2045, 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.

Introduction

Sugarcane (*Saccharum officinarum* L.) is a widely grown commercial crop in the world 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 the year 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 out of 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. Incorporation of residues elevates the level of organic matter and may decrease the pH of soil 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, causing 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 deteriorate the fertility as well as soil health. It also reduces the soil microbial activity and destabilize of 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 option to mitigate these problems. The retention of trash as a mulch can reform the soil organic matter content compared to the traditional burnt trash practices.

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 incorporation of trash in soil, it tends to increases the soil bacterial population by 10-100 times and fungal and actinomycetes population by 10 times (Chandra *et al*., 2008).

When harvest 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 important 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 also create beneficial environment for plants and soil biota, decrease in 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 trash and balanced nutrients 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's practices and crop residue retention change the physical properties of soil like soil structure, soil moisture and inhibit the growth of weeds. The successful burning of trash and removal of trash from the field increased the bulk density of soil (1.4 to 1.55 g cm^{-3}) in the second ratoon system (Ball *et al*., 1993). In another hand Yadav *et al.* (1994) observed a fall in bulk density under the trash retained plot (1.45 to 1.40 g cm^{-3}). In green cane trash blanketing treatment, Noble *et al.* (2003) reported increase in bulk density with depth (1.13 to 1.25 g cm^{-3}) but it was recorded lowest than the burnt treatment (1.187 to 1.26 g cm^{-3}). The bulk density was decreased from 1.50 to 1.44 (Mg m^{-3}) after the crop residue management practices in maize- wheat cropping system and also observed decrease in bulk density with the increasing crop residue retention (6 Mg ha^{-1}) (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 at 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 on addition of both chopped and un-chopped crop residue in soil. Black (1973) witnessed a fall of 8% in erodible soil fraction for each 1100 kg ha^{-1} 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 the similar trends in value of bulk density on incorporation of crop residue 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 lead to more reduction in bulk density compared to retaining of residues in two cycles. Similar observations were recorded by Nagar *et al.* (2016) in his experiment in which reduction in bulk density was exerted by 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, Quarttzpsamment, and typic Hapludox site 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) compare to the without residual incorporation treatments (Kumari *et al.*, 2019).

Removal of trash caused significant reduction in infiltration rate in conventional puddling system in rice. It may be due to 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 recommended dose of N with organic and bio-fertilizer increased the bulk density as well as infiltration rate from 5.4 mm hr^{-1} against the initial infiltration rate of 4.1 mm hr^{-1} (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 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 ºC) in the ratoon crop and lower (25.38 ºC) in the cane plant cane. The different stage of decomposition of different organic waste shows the lower temperature 28-30 ºC at the starting of decomposition and highest 46 ºC 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 insulating effect of residue provided to soil from solar radiation.*In situ* sugarcane trash management practices buffers the soil temperature at 25.1-27.2 ºC in the top 5 cm soil layer and control treatment fluctuation was wide (26.9-34ºC) and shows higher soil moisture content (0.70-5.92%) over control. And sugarcane trash kept moisture at field capacity for a long period of time than the no mulch treatments (Tayade *et al*., 2016). Residue incorporation and composted, 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 burnt treatments. The capillary pore space more in mulch (12.2%) than the burnt treatment (5.2%) (Ball *et al*., 1993). Sidhu and Beri (1989) also noticed the improvement in water holding capacity of soil on 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. The reduction of an average water stress index reduces the photosynthesis rate in response to restricted water supply from the soil. In green cane trash burnt, the least (0.4) average water stress occurred 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 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 brought 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. 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 (Thournburn*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 the application of 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^{-1} compared to the no mulch (7.92 dS m^{-1}) in the soil after harvest of wheat (Soni *et al.,* 2021).

The pH and electrical conductivity was significantly reduced from 8.27 to 8.03 and 0.36 to 0.28 dS m^{-1} respectively after the application of crop residue in maize and wheat cropping system (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 experiment. Dhar *et al.* (2014) when incorporated crop residue with green manure noticed the largest reduction in soil pH compared to all other treatments. 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 on addition of crop residue obtained from sorghum and alfalfa. Degradation of added organic residue in soil release 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^{-1} in burnt plot + green top residue as 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 found higher (12.45 g kg^{-1}) in the trash without burnt than trash burnt (8.10 g kg^{-1}). 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 the 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 g kg^{-1}) in trash mulch as compared to the removal of the trash plot (36 g kg^{-1}) at 0-10cm top soil.

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 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 g kg^{-1}) in green cane trash burnt and lowest in burnt (13.6 g kg^{-1}). The Organic Carbon increased by 20.9 g kg^{-1} under the green cane trash blanket treatment and 16.1 g kg^{-1} in burnt treatment after 9 years. With the incorporation of maize crop residue, reported a high level (13500 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 g kg^{-1}) in the trash incorporation than trash burnt (8.10 g kg^{-1}). The organic carbon increased by 2g kg^{-1} after 6year, by 5g kg^{-1} after 8 years and 9.2 g kg^{-1} after 55 years of residue incorporation. The concentration of total carbon was increased in the retained residue with compare to burnt residue in top 20-50 mm of soil (Thornburn *et al.,* 2012*)*. The green cane trash blanketing increases the organic carbon 8-15%. And the organic carbon increased from the 2.53 to 3.99 g kg^{-1} in 9 trash mulch treatment over the 3t ha^{-1} (2.47 to 3.666 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 rates of residue increased the soil organic carbon content *i.e.* 6 Mg ha^{-1} residue increased the SOC (0.49-0.52%) and lowest (0.43-0.4%) were recorded in the no residue retention. In long-term experiment, no adding of residue more tillage practices reduced the SOC 20-50% (Madar *et al.,* 2020).

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^{-1}) and normal residue treatment (24 g kg^{-1}) compared to removal (16 g kg^{-1}). Organic Carbon content is significantly increased by on the incorporation of crop residue in soil. 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 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 $ha^{-1,}$ and 10 kg ha^{-1} 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^{-1} and available P by 16 kg ha^{-1}over control (Yadav *et al*., 1994). Yadav *et al*. (2009) also reported decrease in available N (261-246 kg ha^{-1}) and available P (55-39 kg ha^{-1}). On the other side increase in P from 161 to 168 kg ha^{-1} 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^{-1}, respectively. The trash recovered and recycling the soil N (40 kg N ha^{-1}) and yielding (65.5 kg N ha^{-1}) from the trash. In the second cycle 62 kg N ha^{-1}, yielding a total of 127.5 Kg N ha^{-1}. And in the second cycle, the total N increased 168.8 kg N ha^{-1} in the long-term experiment after the adding of sugarcane residue in 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. Addition of surface mulch gave higher values of available P and total N in soil as compared to control (Mbah and Nneji, 2011).

Devari *et al*. (2012) noticed 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 reservoir of plant nutrients which on decomposition releases them in soil. 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 NH_4^+-N concentration was higher (4.5 to 4.8 mg kg^{-1}) in trash application than no trash application (3.2 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. The application of fertilizer and fertilizer with residue was increased the total nitrogen by 43% compared to the control treatment (Zhang *et al.*, 2020).

The use of sugarcane residue as a biochar fertilizer increased phosphorus use efficiency and plant yield. After 120 days of using biochar fertilizer, it increased 10% phosphorus efficiency in most clayed soil related to the controlled condition. But in triple superphosphate treatment, the plant phosphorus content was higher (339 mg kg^{-1} soil) compared to the fertilized with biochar in sandy soil and clay soil (1375 mg kg^{-1}). The total P was higher (19735 mg l^{-1} P) after 120 days of biochar fertilizer addition, and lowest in TSP treatment (14697 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 cmol kg^{-1}) with compared to the fertilized plot (1.69 cmol kg^{-1}) (Mthimkhulu *et al*., 2016).

The trash retention was increased the P, K, Ca and Mg range from 0.09- 17.17 mg dm^{-1}, 0.04-0.10 cmol dm^{-1} 0.44-1.27 cmol dm^{-1} and 0.14 to 0.38 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 $Al^{3+,}$ and conserve Ca^+ and Mg^+ at 40 cm depth. And the total carbon stock after 14 years of trash conservation on the depth of 0-10 cm, 4 Mg ha^{-1} was greater than the burned treatment (Pinheiro *et al.,* 2010). The highest Ca concentration (6.37 cmol(+)kg^{-1}) was observed in burnt with residue scattered and fertilized treatment and lowest (4.83 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 needle and press mud waste. The pattern of sulphur mineralization from different amendments was in 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 30th 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. But no effect of burning was observed in the lower layer of soil. In the top soil layer, the total-S was 441 and 247 mg kg^{-1} for the without and with burning treatments respectively. The SO_4^{2-} 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, shows the higher in the soil in the treatments without burning (Canellas *et al.,* 2010; Mishra *et al.,* 2016).

The trash application sharply released potassium which occurs in the plant in ionic from. It was also leached in the soil after the 1 year of trash application because of formation of weak complex with Ca, Mg, S and P, and 40-80% released after 1 year of decomposition of trash residue (Thornburn *et al.,* 2012). 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^{-1} in next succeeding crop (Tayade *et al.*, 2016). The concentration of neutral ammonium acetate extractable exchangeable K in soil exhibited an increasing trend on incorporation of crop residue in soil as revealed by independent investigations carried out by Dhar *et al.* (2014) and Davari *et al.* (2012). But in many research findings, the potassium content was higher (0.8 cmol kg^{-1}) in the burning treatment relative to the mulch treatment (0.7 cmol kg^{-1}) (Mithikhulu*et al.*, 2016). The sugarcane trash application @ 9t ha^{-1} significantly increased K level from 0.43 to 0.50 cmol kg^{-1} while lowest K content of 0.26 to 0.36 mol kg^{-1} was recorded in the less trash @3 t ha^{-1} 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 as compared to the trash removal and trash burning. After 75 days of ratooning, the soil which 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 organic matter accumulation and fertilizer induced acidity on the soil microbial and energy activity on 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 µmol g h^{-1}, Arginine ammonification: 0.3<0.5<0.8 µmol g h^{-1} and Dehydrogenase activity: 0.03<0.06<0.08 µmol 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 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 decreased. Urease activity decreased up to the third harvest and then increased. Acid phosphatase activity decreased up to third harvest and then increased, close to the first harvest of crop. The application of rice straw increased the dehydrogenase activity 98 in sorghum and 95 (mg TPF kg^{-1}soil day $^{-1}$) in the wheat crop after harvesting and less 88 and 80 (mg TPF kg^{-1}soil day $^{-1}$) in no mulch treatment of sorghum and wheat respectively. Urease was recorded 60 and 61 (mg NH_4^+N kg^{-1} soil h^{-1}) after sorghum and wheat harvesting, lowest value 59 and 56 (mg NH_4^+N kg^{-1} soil h^{-1}) recorded in no mulch respectively (Soni *et al.*, 2021).

The conventional tillage, zero tillage in post rainy season with residue had 16-38% higher urease activity over conventional tillage without residue after 7 years. The more 7.1 (µg TPF g^{-1}soil h^{-1}) dehydrogenase activity was recorded in conventional tillage, zero tillage in post rainy season with residue over the conventional tillage in post rainy seasons without residue (Nath *et al.*, 2021). Higher application of crop residue (6 Mg ha^{-1}) reported the more (73.7 µg TPF g^{-1} d^{-1}) dehydrogenase activity compared to 52.4 µg TPF g^{-1} d^{-1} in the no crop residue (Madar *et al.*, 2020). Dehydrogenase activity was higher under zero tillage maize-wheat-mungbean (62.88 µg TPF g^{-1} 24 h^{-1}) and zero tillage rice-wheat-mungbean (63.16µgTPF g^{-1} d^{-1}) with crop residue, compared to conventional tillage (51.14 µg TPF g^{-1} 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 µg pNP h^{-1} g DS) up to third harvest and then increased (450 to 650 µg p-NP h^{-1}.g DS) up to 6th 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 depth of soil. With continue manuring and wheat straw incorporation showed the higher (44 µg $soil^{-1}$ h-^{1}) alkaline phosphatase compared to the straw burnt (30 µg $soil^{-1}$ h-^{1}) and 190% increase in alkaline phosphatase activity over the control value (Dick *et al.*, 1988).

The phosphatase enzymes were higher (340 µg p-nitrophenol h^{-1} g dry soil) in 100% trash application than the alternate trash application treatment (120 µg p-nitrophenol h^{-1} g dry soil) (Liu *et al.,* 2018). The application of rice straw decrease the alkaline phosphatase activity, 23 in sorghum and 22 (mg pNP kg^{-1} soil h^{-1}) in the wheat crop after harvesting and highest 24 and 25 (mg pNP kg^{-1} 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 (µg p-nitrophenol g^{-1} soil h^{-1}) in the conventional tillage without residue (Nath *et al*., 2021). The application of 6 Mg ha^{-1} crop residue, recorded the highest alkaline phosphatase (77.1 µg p-nitrophenol $g^{-1}hr^{-1}$) compared to 59.1.µg p-nitrophenol $g^{-1}hr^{-1}$ in the no crop residue (Madar *et al.,* 2020). Highest alkaline phosphatase activity were observed under zero tillage maize-mungbean-wheat (59.23 µg p-NP g $soil^{-1}$ h^{-1}) with crop residue and zero tillage rice- wheat-mungbean (55.76 µg p-NP g $soil^{-1}$ 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 15% biomass yield after 120 DAP and the burning of plant crop residue decreased the dry matter (13.5 to 2.9 mg kg^{-1}). The burning and green cane harvesting also increased the root density of sugarcane. Graham *et al.* (2002) observed greater root length density on surface 0-10 cm (1.046 cm cm^{-3}) than the trash treatment (0.408 cm cm^{-3}) although the root mass density under trash burning (0.832 g/cm^{-3}) was greater than the trash treatment (0.397 g cm^{-3}). The application of trash as mulch increased the plant height (176.5cm) compared to the control (170.90cm). With the application of trash mulch @10 with 80 kgP_2O_5 ha^{-1} increased the numbers of tillers 89.15 000 ha^{-1} over the control 79.46 000 ha^{-1} (Kumar *et al.,* 2015).

The application of high doses of nitrogen (210 kg ha^{-1}) increased the number of tillers (130940- 137540 ha^{-1}) and the number of millable canes (109.67- 112.61 000 cane ha^{-1}) in ratoon crop (Dev *et al.,* 2013). The use of 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^{-1} treatment. After the 4 months, with the increased dose of vermicomposting and N, it increased the number of tillers (11.27 000 ha^{-1}) and lowest (10.1 000 ha^{-1}) tillers were recorded in the 45 kg N ha^{-1} with no vermicompost (Djajadi*et al.*, 2020). The spring cultivar with N dose increased the millable canes by 163.3% than the late spring (Saini *et al.*, 1996). In the first ratoon crop, the drained treatment shows the highest plant population (83800 stalks ha^{-1}) and lowest (77600 stalks ha^{-1}) 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 tha^{-1} trash application produced more (70.47 000 ha^{-1}) number of millable cane compared to the control (64.05 000 ha^{-1}). The trash as a mulch and trash chopped increased the number of millable cane (81.3 000 ha^{-1}) over the control. The number of millable canes also increased (68889 ha^{-1}) in trash incorporation with the green manuring treatment with relation to the control (64444 ha^{-1}) (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^{-1}) in planted cane and lowest were recorded in ratoon crop (99.3 000 ha^{-1}) (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% recommended dose increased the cane length (41.27 cm) and single cane weight (0.369 kg) compared to the control. 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_2O ha^{-1} increased the cane weight as compared to the less application of K_2O ha^{-1} (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 dates of planting in north India in the first year of planting, the autumn crop yield was 37.3 and 45.9 t ha^{-1} higher than the spring and late spring crop respectively. The application of higher dose (150 kg ha^{-1}) of N gave 31.6% more yield compared to the 120 and 90 kg ha^{-1} N (Saini *et al.*, 1996). The trash burning + green manuring incorporation practices gave the higher (158 t ha^{-1}) cane yield. The productivity was 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^{-1}) higher cane yield was obtained in ratoon, compared to the planted cane (63.3 t ha^{-1}). The long-term trash management practices and application of a high dose of N (150 kg N ha^{-1}), increased the yield of sugarcane in the green cane trash retained system relative to the 100 kg N ha^{-1} and trash incorporation. With the application of high doses of urea from 50 to 200 kg N ha^{-1}, 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^{-1} in the second and third ratooning compared to the base year in integrated sugarcane trash management and on an 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^{-1} (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^{-1} 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 increased the brix content. But the mulch with pre-emergence herbicides 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 as compared to the control *i.e* 18.53 and 16.11%, respectively. After the 12 months of trash incorporation, Commercial Cane percentage was higher (13.08%) in trash treatments over the control (Tayade *et al*., 2016). Maximum sucrose synthesis (16.9%) and CCS (1.5 t ha^{-1}) were recorded in the autumn season than spring and late spring. With the increase of N dose, the sucrose content was (16.3%) increased in 120 kg N ha^{-1}, 16.2% in 150 kg N ha^{-1}, and 16% in 90 kg N ha^{-1}, respectively (Saini *et al.*, 1996).

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