Insights into the Application of Co-composting for Soil Nutrient Stability – A Review

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Abstract. The recycling of waste organic materials for energy and nutrient recovery has gained immense attention over all spheres of life especially during the past few years. There is an increasing trend of opting co-composting as a feasible technology for easy conversion of organic wastes into nutrient-rich manure. However, their success on direct field application still suffers from nutrient instability, volatility, pathogenic infection, etc., leading to the unprecedented nutrient loss and environmental contamination. Despite these limitations, co-composting offers a sustainable soil amending system whereby the bio-chemical ecology of the soil and crops can be synergistically preserved with enhanced productivity. In this review, a critical comparison is presented to comprehend the need for changing agricultural practices in view of modified soil nutrient dynamics by analyzing (i) the soil characteristics before sowing and after harvesting, (ii) the role of emerging wastes in composting processes, (iii) the methods of field application, and (iv) the agronomic characteristics of sugarcane crop in a composted soil. The study shows that the co-composting of sludge and agricultural waste resulted in maximum cane yield per hectare (150 to 315 tonnes). The sludge-based co-composting is found to retain soil nutrients for a prolonged duration thus promising nutrient sequestration and minimizing subsurface contamination.

1. Introduction

The hiked attention on research and development for sustainable agriculture unprecedentedly demands a practical implementable approach for the middle class farmers of the developing countries. The demand for food is estimated to be double by 2050 due to rapid population growth and associated social changes which will exert enormous pressure for intensive cultivation [1]. As an inevitable consequence, the continuous cropping pattern can in turn consume the available nutrients present in the soil. This leads to remarkable price hike for the fertigation. In a contrasting scenario, we find that around 34% global populations are not able to get good sanitation and the improper disposal of human excreta (faecal sludge) exposing to the environment and posing serious threat to health [1]. As an integrated approach, faecal sludge based fertigation practice for agriculture can not only solve these two distinct problems, but also can enhance recovery of valuable resources such as bio-energy and nutrients. Traditional practices in many place especially rural areas utilized the faecal sludge as nutrient enhancer for agriculture [2].

Considering the scope of resource management in agriculture for a diversified country like India, it is imperative to identify the most demanding cropping patterns and practices. Sugarcane is one such crop cultivated as a cash crop by largest fraction of farmers in India. Next to Brazil, India is the second...
The largest global sugar producer (around 15% sugar and 25% sugarcane globally). The associated sugar industry comprises of numerous sugar mills, co-generation plants, distilleries, paper, pulp and chemical units. India is producing nearly 300 – 350 metric tonnes (MT) of cane within the 3% agricultural coverage area of 5 million ha [3]. Apart from sugar production, sugarcane is projected as the future crop for its vast application in bio-energy production (bioethanol, bioelectricity and compost etc.) [4].

Indian farmers and sugarcane mill owners face various issues related to the production, yield, market, and pricing [5]. India’s yield is just 64.5 tons/hectare when contrasted with 90 tons in Java and 121 tons in Hawaii. Endeavours are being made to take care of this issue through the presentation of high yielding, early developing and high sucrose content assortments of sugarcane and additionally by controlling sicknesses and irritations which are hurtful for sugarcane. One conceivable technique to expand the devastating season is to sow and collect sugarcane at appropriate interims in various regions connecting the mill processes. This will expand the term of supply of sugarcane to sugar plants.

Co-composting of faecal sludge along with other organic solid waste such as market waste and domestic waste is the best way to recycle nutrients. These mixtures together provide rich organic matter and nutrients essential for agriculture. The faecal sludge amended compost is free from pathogens and sanitized well [6]. Zhao et al. [7] studied that compost utilization presented savings on freshwater eutrophication because of phosphorus substitution. With the application of fewer woodchips, impacts to acidification and terrestrial eutrophication decreased because more ammonium was reserved rather than released. The impacts to human toxicity were not significant because the compost was used for urban landscaping rather than farming. Trace gaseous compounds showed marginal impacts to global warming and toxicity categories. The results provided a new perspective and offered evidence for appropriate sludge treatment selection. However, the selection of waste materials for reuse and recycle largely depends on their physical-chemical nature and economic feasibility. In order to critically evaluate these interconnected bands of the spectrum, the present study aims at providing a systematic review (i) to compare the feasibility of different organic wastes for co-composting and it’s suitability for sugarcane cultivation, (ii) to compare the methods of compost preparation and strategies for effective field application, (iii) to evaluate the need for changing agricultural practices in view of modified soil nutrient dynamics, and (iv) to suggest the need for sustainable agriculture practices for maximizing the cane yield using co-compost.

2. Selection of co-substrates for sludge composting

2.1. Implications of physico-chemical properties of substrates

Physico-chemical properties of the substrates are the key elements affecting the preparation and performance of composting. On a comparison about the percentage of maximum moisture available in various co-composted substrates, meat packing waste water sludge showed high moisture content 85.4% and saw dust was least 8.92%. But the saw dust is very rich in organic matter (87.23%) carbon-nitrogen (C/N) ratio (581.25). Paper mill sludge showed least percentage of organic matter (0.045%) and total nitrogen (43%) whereas meat packing waste water sludge has maximum total nitrogen 5.81% and filter cake has minimum C/N ratio of 14. Details of the ranges of constituents in preparing sludge-based compost are given in (Table 1.).

| S.No | Co-composted Substrates | Code | Ref. |
|------|------------------------|------|-----|
| 1    | Water Treatment Sludge +Corncorb | S1   | [8] |
|   | Water Treatment Sludge + Bulk |   |   |
|---|-------------------------------|---|---|
| 2 | Sunflower Stalks S2          |   | [8]|
| 3 | Wheat Straw S3                |   | [8]|
| 4 | Plane Leaf S4                 |   | [8]|
| 5 | Filter Cake + Distillery Stillage S5 |   | [9]|
| 6 | Filter Cake S6                |   | [10]|
| 7 | Compost (Filter Cake + Vinasse) + Nitrogen S7 |   | [11]|
| 8 | Paper mill sludge S8          |   | [12]|
| 9 | Green seaweed + Sugarcane bagasse S9 |   | [13]|
| 10| Organic fraction of MSW S10   |   | [14]|
| 11| Meat-packing wastewater sludge S11 |   | [14]|
| 12| Grass S12                    |   | [14]|
| 13| Saw dust S13                 |   | [14]|

It is observed from many researchers that, for an ideal compost material, the moisture content of 50-55% is essential, the pH value should be in the range of 6 to 8 and a minimum of 40% organic content must be present, while the C/N ratio may preferably exist below 50 for rapid composting (about 30:1 at the beginning and about 20:1 at the end). The temperature range of 65-70°C is found to be suitable for ensuring sufficient inoculation against the pathogens present in the compost. In addition, frequent turning of windrows is essential to provide sufficient aeration for the microorganisms to yield good compost. The preferred ranges of organic matter %, nitrogen% and C/N ratio obtained in combinations of water treatment sludge with various bulking agents (sunflower stalks, plane leaf, corncob, wheat straw) are shown in (Figure 1).[8-14]

![Figure 1. Comparison of characteristics of co-composted substrates](image-url)
2.2. Combinations of composting substrates for the cane cultivation

Ucaroglu and Alkon [8] conducted experiments using water treatment sludge with four bulking agents such as wheat straw, plane leaf, corncob and sunflower stalks. Nasir et al. [9] carried out comparison studies on the cane yield and sugar using different proportions of bio-compost, derived from distillery units in combinations with Sodium-Phosphorous-Potassium (NPK) fertilizer. Wongkoon et al. [10] studies showed that the combined use of compost prepared from distillery slop and filter cake with NPK fertilizers showed good results. Teshome et al. [11] conducted experiments to determine the optimum rates of nitrogen and compost (Filtercake and Vinasse) for clay soil. Lakshmi et al. [15] studied effect of nutrient concentration and yield of both cane and sugar in clay loam soil upon addition of recommended dose of fertilizers in combination with different organic manures (Farm Yard Manure (FYM), vermicompost, press mud cake). Wuri et al.[16] used chicken manure and biochar from biogas sludge for their study. Refilda et al. [17] utilized coconut waste as potential fertilizer. Nawaz et al. [18] analyzed with locally prepared compost (Tiger compost - using Filter cake, Nitrogen source, Rock phosphate, Sludge, Microbial culture, Humic acid, Ash) and NPK fertilizers in various proportions. Felix et al. [19] did comparative studies using four rates of sugarcane foam and chemical fertilizer and reported that they obtained maximum of 100 tonnes per hectare of cane yield. Singh et al. [20] cultivated 76 millable canes per hectare using the substrates farmyard manure, sulphitation pressmud cake, biogas slurry, vermicompost and chopped sugarcane trash. Yeh T.P [21] compared compost, solid and liquid manure on sugarcane yields and reported that compost dressings increased the cane yield. S.K. Sinha et al. [22] studied the effect of the combination of bio-compost (N) prepared from pressmud and spent wash with inorganic fertilizer (N) in varying proportions on the cane and sugar yield under calcareous soil conditions. Showler [23] showed that high compost rate (compost and chicken litter) led to increased soil nutrients. Sarwar et al. [24] were experimented using press mud and inorganic fertilizer. A.K.Gana [25] showed that cow dung mixed inorganic fertilizers given good results. Strauss et al. [26] reviewed publications discussed various materials for co-composting such as faecal sludge, solid waste, animal manure, saw dust, wood chips, bark, slaughter house waste, sludge or solid residues of food from beverages industries. Vasudevan et al. [27] performed aerobic in-vessel composting using sewage sludge mixed with other municipal wastes such as food waste, vegetable waste, paper, cardboard, green leaves, dry leaves and woodchips.

2.3. Feasibility of co-composting using faecal sludge

Strauss et al. [26] reported that any organic material can be used as co – compost with faecal sludge in optimum conditions. Based on type of organic bulking material the mixing proportion of co-compost varies widely. They also discussed that fresh faecal sludge and bulking material can be mixed in ratios of 1:5 – 1:10 and dewatered sludge with bulking material can be mixed ratios of 1:2 – 1:4. Narrey [28] studied the co-composting effects of agricultural wastes and faecal sludge on tomato transplant and growing in humid tropical conditions. Particularly they co-composted dewatered faecal sludge with empty fruit bunches and cocoa pod husks in different combinations. Their composting period was around three months. Dry faecal sludge contains rich nutrients such as nitrogen and phosphorous. Their study suggested that increase in dewatered faecal sludge leads to higher nitrogen values. Yadav [2] achieved co-composting using faecal slurry over the time period of 135 days. The experiment suggested the integration of composting and vermicomposting with faecal slurry. Grau et al. [29] made a trial for radish crop growth using faecal sludge and municipal solid waste co-compost in pelletized form as one of their combination and proved that as best for radish.

3. Strategies for compost preparation and sugarcane field application

The field preparation and application strategies to amend co-composts for sugarcane crop is tabulated (Table 2). The composting process can be carried out in both aerobic and anaerobic conditions. However, aerobic process enhances the oxygen supply and in turn degrades the substrates quickly. Air can be supplied by natural means or artificially using blowers/air supply instruments. One of the ways
to supply oxygen for a prototype study can be made using a solenoidal valve [8]. As of now, mostly pile and windrow composting method widely preferred in fields over the in-vessel composting method. This might be due to the economical approach. In-vessel composting also can be preferred by many researchers where space availability is insufficient. In addition, field also can limit the space requirement for composting effectively through in-vessel composting method. The duration for composting varies from few weeks (21 days) to few months (180 days) based mainly on the C/N ratio, other physico-chemical properties and prevailing field condition. Some of the studies reported that they have applied the compost before 15 to 30 days of sugarcane cropping in the field [20, 22, 25]. This reveals that, the compost application have to ensure the conversion of organic nutrients into mineralized available form. It is notable that the approximate sampling depth for soil analysis varies from (0 – 25) cm [18, 19, 22, 25]. A typical sugarcane cropping can be done in the field as 5 furrows or more than that starting from 30 m² of plot area and around 1.2 m row spacing. After the incorporation of compost, it is better to rototill. Generally, few studies reported that inorganic fertilizers were incorporated while planting (basal application).

### Table 2. Comparison of compost preparation and sugarcane field application strategies

| S.N | Co-composting substrates | Soil sampling depth (cm) | Compost types, application and processing | Plot size | Ref |
|-----|--------------------------|--------------------------|------------------------------------------|-----------|-----|
| 1   | 60% Water treatment sludge+40% Bulking agents | 0-30 | 21 days batch process. Manually introduced into the top and 15 minutes aeration for each 1 hour using solenoidal valve | - | [8] |
| 2   | Tigercompost (Filtercake+nitrogens source+rockphoshphate+sludge+microbial culture+humicacid+ash) | 0-30 | Randomized complete block design trial (RCBD) of two years study period | (4.9x9) m and 1.20 m apart | [18] |
| 3   | Filter cake+Stillage (1:2) | - | 2 to 4 months anaerobic humification. 45 days pile composting | 5 rows 1.067 m apart and 12.80 m long | [9] |
| 4   | Biocompost+N | 0-30 | Biocompost applied 30 days before cropping | 9.24x5.40 m | [22] |
| 5   | Filtercake+vinasse | - | windrow composting | 52.2 m² | [11] |
| 6   | Chicken litter 119kg N/ha+pressmud+ash | - | (Chicken litter 119kg N/ha) Manual broadcast application and then disked into soil. Other organic materials rototilled into the top 30 cm of soil. | 6 furrows of each 6 m long and 1.45 m wide 24 plots, 4 rows, each plot 1.52m row spacing and 18.2 m long arranged in 6 blocks. 4 plots in Each block, separated by 3m. | [23] |
Foam + inorganic fertilizer: 10mx7.5m, 5 furrows length 10m, height 0.3m and 1.5m apart [19]

Cowdung + inorganic fertilizer: Cow dung incorporated 2 weeks before planting and inorganic fertilizer incorporated while planting (basal application). 5mx6m [25]

Farmyard manure, sulphitation pressmud cake, biogas slurry, vermicompost and chopped sugarcane trash: Under NPK treatment half of N (75 kg/ha) and full dose of P₂O₅ & K₂O (60kg/ha) basal applied. Remaining N top dressed at 85 days after planting. Furrows 75cm apart [20]

4. Comparison of cane productivity with compost application

Nasir et al. [9] reported that with the usage of NPK in combination with bio-compost increased the yield (31%) when compared to the use of chemical fertilizer alone. It is also evident from the results that bio-compost (BC) being rich in organic matter improves the physiochemical characteristics of soil. He also observed that the leaf tissue contained high concentrations of K with the usage of highest level of bio-compost. Wongkoon et al. [10] findings suggest that using compost inoculated with KKU microbes in combination with inorganic fertilizers would result in highest gain in sugarcane shoot. More surprising was that, inoculating the compost with Khon Kaen University (KKU) microbes showed much better results when compared to using commercial compost microbes. Yeh [21] reported that compost dressing was increased cane stalks length of 10 cm higher, 2 – 5% increased millable canes per ha and 12 – 18% increased sugar yield per ha. S.K.Sinha et al. [22] monitored the yield at different percentages of N through bio-compost. Their results showed that 50% N through (BC) bio-compost + 50% N through inorganic fertilizers gave higher cane and sugar yield in the sugarcane plant-ratoon system. But the application of 150% N through BC helps in sustaining the productivity of sugar cane plant-ratoon system and maintains the physiochemical and biological properties of the soil. Teshome et al. [11] concluded that the use of 46 Kg N/ha with 15 tonnes/ha of compost for clay soil is best suited. It was also suggested that the compost should be applied before furrowing while nitrogen fertilizer should be applied at 2.0-2.5 of after planting and also that the application of compost to fields that are prone to water logging should be avoided. Lakshmi et al. [15] study revealed that highest N uptake by the crop was achieved upon the application of recommended dose of fertilizer (RDF) + vermi-compost, Highest phosphorus uptake was recorded with the treatment of RDF + mud cake, better juice quality was obtained with the usage of RDF alone, Highest cane yield was achieved on the soil that received RDF + Farm Yard Manure. Allan T. Showler [23] experiment eventually resulted in the yield of mist marketable sugarcane stalks per stool but was followed by Mexican rice borer (Eoreumaloftini) infestation. He then concluded that despite the positive effects on the soil there was a substantial negative effect (pest attack) on sugar cane production and hence soil quality should be
maintained along with pest control. Felix et al. [19] reported that 18 t/ha sugarcane foam suggested to perk up soil fertility and targeted cane yield of 100 t/ha (9.6% of extractable sugar).

Comparative review of cane yield reveal that (Table 3) 15 t/ha compost (filter cake (FC)+Vinasse) + 46 kg/ha N showed maximum cane yield of 315.6 t/ha and Sulphitation pressmud showed minimum yield of 73.1 t/ha but pressmud in various proportions with other substrates as co-compost showed good yield up to 146.60 t/ha. Review also divulges that most of the sugarcane research carried out in loam and clay soil.

Table 3. Effect of co-composted substrates on agronomic characteristics of cane crop

| Co-composted substrates | Soil type            | Germination % | Tillers/plant | Millable canes/ha | Yield t/ha | Ref. |
|-------------------------|----------------------|---------------|---------------|-------------------|------------|------|
| 50 t/ha Biocompost (sugarcane filtercake+ distillery stillage)+NPK | Loam soil | 58.33 | 3.747 | 130.7 | 146.60 | [9] |
| 0 t/ha Pressmud+168-112-112 NPK kg/ha inorganic fertilizer | - | 47.40 | 1.72 | 114 | 93.77 | [24] |
| 50%N by Biocompost (pressmud+spent wash)+50%N inorganic fertilizer | Calcareous soil | - | - | 90.7 | 74.14 | [22] |
| 15 t/ha Compost(FC+Vinasse)+46 kg/ha N | Clay soil | - | - | - | 315.6 | [11] |
| 1124 kg/ha compost+42:28:28 kg/ha NPK | - | - | - | 140 | 141.6 | [18] |
| Vermicompost(2.5 t/ha)+RDF | Clay loam soil | - | - | 94.46 | 93.88 | [15] |
| Chewing sugarcane+cowdung (120N-60P2O5-90 K2O kg/ha) | Ultisol and sandy loam | 100 | - | - | 83.1 | [25] |
| Sulphitation Pressmud Cake 10 t/ha | Sandy loam | - | - | 76 | 73.1 | [20] |
| Sugarcane foam 18 t/ha | Loam-clayed | - | - | - | 100 | [19] |

5. Modified soil nutrient dynamics due to compost application

Soil physico-chemical characteristics are compared before sowing and after harvesting to comprehend the modification in soil nutrient dynamics due to the compost application. It is also much important for the productivity. There is no significant variation reported in the pH of soil. A minimum decrease reported for the EC values of soil after sugarcane harvesting. This may be hypothesized that heavy fed crop sugarcane consumed the available nutrients. However, few works reported that, other vital
chemical parameters such as Nitrogen%, Organic matter%, Organic Carbon%, Phosphorous, Potassium and C/N values are improved. Especially, 10 t/ha sulphitation pressmud showed maximum increase of 60.52% Nitrogen and 93.07% of phosphorous after sowing cane. Similarly, 12 t/ha pressmud cake + RDF showed maximum potassium increase 9.95% (Figure 2.). These soil nutrient values reveal that co-composting is the best technique to retain soil nutrients for prolonged duration. In addition low fertile soil can be replaced by sewage treatment plant proximity soil to make use of nutrients [30, 31].

**Figure 2.** Comparison of soil parameters. BS1 - Before Sowing [18], AH1 – After Harvesting [18], BS2 - Before Sowing [11], AH2 – After Harvesting [11], BS3 - Before Sowing [15], AH3 – After Harvesting [15], BS4 - Before Sowing [20], AH4 – After Harvesting [20]

6. Conclusion
The present review highlights the different organic waste materials for co-composting and its feasibility for sugarcane cultivation. Based on the literature, it is observed that, due to the compost amendments the cane yield varies from 73.1 to 315.6 tonnes per hectare. The sludge and other agricultural waste amendment as co-compost resulted in maximum cane yield per hectare. Any organic material can be used as co – compost with faecal sludge in optimum conditions. Based on the type of organic bulking material the mixing proportion of co-compost varies widely. Upon different methods for compost amendment, due to the abundance of microorganisms in the air, the aerobic methods preferred widely to enhance degradation quickly. The field composting includes pile, windrow and in-vessel techniques. Compost amendments applied before 15 to 30 days of sugarcane cropping. A typical sugarcane cropping can be done in the field as 5 furrows or more than that starting from 30 m² of plot area and around 1.2 m row spacing. After the incorporation of compost, it is better
to rottolill. Generally, few studies reported that inorganic fertilizers were incorporated while planting (basal application). In order to investigate the soil – compost interaction, the soil samples were taken in the top soil (15 to 30) cm. The increase in the nutrients after harvesting sugarcane crop reveals that, compost amendments are the much preferred sustainable techniques to retain nutrients in the soil.

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