*Original Research Article*

# Effects of nutrient enriched municipal solid waste compost on yield and nutrient content of cabbage in alluvial soil


## Abstract

Composting of municipal solid waste (MSW) is a good option for solid waste recycling, but its use by the farmers is limited because of its very low nutrient status.

**Aims**: The study aimed at nutrient enrichment of marketed MSW compost by using some organic materials and evaluating the influence of nutrient enriched MSW compost on yield and nutrient content of cabbage (*Brassica oleracea* L.).

**Place and Duration of Study**: MSW compost amendment, field experiment and nutrient analysis were carried out at Bangladesh Agricultural University (BAU), Mymensingh during October 2017 to June 2018.

**Methodology**: We prepared three types of amended compost by mixing 20% mustard oil cake (MOC), and 30% poultry manure (PM) or cow dung (CD) or sugarcane press mud (SPM) with 50% MSW compost. A liquid culture of *Trichoderma viride* was inoculated to every type of compost. The field experiment was conducted to evaluate the performance of the amended MSW composts on yield and nutrient content of cabbage (cv. Atlas-70), and on soil fertility. The experimental soil was silt loam having 6.7 pH and 2.79% organic matter; according to Soil Taxonomy it belongs to Aeric Haplaquept under the order Inceptisols.

**Results**: Based on the yield and nutrient concentration (N, P, K & S) of cabbage, the treatment containing 50% fertilizers + 50% compost mixture (MSW compost + MOC + SPM in a ratio of 5:2:3) demonstrated the best result followed by poultry manure amended compost. Use of the amended composts had residual effects on soil showing an increased N, P, K & S content.

**Conclusion**: Organic amendment of MSW compost inoculated with *Trichoderma* is a noble means to increase the nutrient status of marketed MSW compost and improve the soil fertility and crop productivity. The results have significant value in fertilizer management strategies for vegetables cultivation in sub-tropical countries.



***Keywords:*** *Mustard oil cake, MSW compost, cabbage, poultry manure, sugarcane press mud.*


UNDER PEER REVIEW

## 1. INTRODUCTION

Cabbage (*Brassica oleracea* L.) is a leafy green, red (purple), or white (pale green) biennial plant grown as an annual vegetable crop for its dense-leaved heads [en.wikipedia.org>wiki>cabbage]. Green cabbage is the most commonly eaten variety of cabbage. Nevertheless, red cabbage has added nutritional benefits; the red color reflects its concentration of anthocyanin and polyphenols, which has antioxidant and anti-inflammatory properties.

Globally generation of municipal solid waste (MSW) has doubled between 2000 and 2010, from 0.68 billion tons per year in 2000 to 1.3 billion tons per year in 2010, and it is projected to reach 2.2 billion tons per year by 2025 and 4.2 billion tons per year by 2050 [1]. Composting of MSW has recently gained good attention from the point of protection of environmental degradation, saving of land filling area, cost of incineration and scope of use in agronomy to support soil fertility and crop productivity.

Unfortunately, the compost that available in the market is generally low in plant nutrients and for this reason, the crop farmers like to rely on chemical fertilizers for higher crop yield [2]. It is well agreed that neither manure nor fertilizer alone can sustain soil health and crop yield. Thus, an integrated approach with combined use of compost and fertilizers is important. The benefits of integrated compost and fertilizers in terms of improvement of crop yield and soil fertility have been widely reported [3-5]. The availability of plant nutrients may increase and heavy metal content may decrease during composting indicating that the composting might be an option for agricultural waste recycling and increased crop productivity [6]. Sustainable agriculture requires the utilization of organic fertilizers for a steady nutrients supply and improving soil organic matter, soil physical & chemical properties and crop productivity [7-9].

As the nutrient contents of MSW compost are usually, very low scope exists to enhance the nutrient value by the addition of organic amendments rich in nutrients viz. green manure, cow dung and mustard oilcake [10]. Achiba, et al. [11] reported a 5-year application of MSW compost increased the organic matter and N content, while increasing the heavy metal concentration in the soil. Thus, mixing of organic materials (e.g. mustard oil cake, poultry manure, sugarcane press mud) with MSW compost would increase the nutrient value and the decrease of heavy metals (e.g. Pb, Cd, Ni). Addition of *Trichoderma* can help rapid composting and can significantly reduce the incidence of seed and soil borne fungal diseases [12]. Organic amended MSW compost could be an appropriate material for the (nutrient)-rich MSW with less impact on the environment, lower cost operations, and reduction in the weight of compost transportable to the farmer's field. Use of compost in vegetable and fruit production is more important than in cereal production [13].

The present study aimed at nutrient enrichment of MSW compost by using locally available organic materials in a suitable proportion and evaluating the influence of nutrient enriched MSW compost on the yield and nutrient content of cabbage (*Brassica oleracea* L.) and on soil fertility.

UNDER PEER REVIEW

## 2. MATERIALS AND METHODS

### 2.1 Production of nutrient enriched MSW compost

We had procured bulk of MSW compost from the organization 'GRAMAUS' (Grameen Manobic Unnayan Sangstha) which produces and markets compost with solid wastes collected from Mymensingh City, Bangladesh. We added mustard oil cake (MOC), poultry manure (PM), cow dung (CD) and sugarcane press mud (SPM) in a suitable proportion to enrich the nutrient level of this MSW compost. The N, P, K & S contents of those organics are shown in Table 1 and their levels in four different types of amended compost presented in Table 2. To accelerate the composting process, *Trichoderma (T. viridi)* inoculum was added to the amended and unamended MSW compost at a rate of 1L of broth per ton of compost, the fungal count being $10^6$cfu $mL^{-1}$. The four types of amended MSW compost were prepared in bulk before one month of field application. The procedure for determining nutrient contents of different organic materials and MSW composts is stated later in nutrient analysis section. .

**Table 1. Nutrient status of MSW compost, mustard oil cake, cow dung, poultry manure and sugarcane press mud**

| Organic material | % N | %P | %K | %S |
|---|---|---|---|---|
| MSW compost | 1.14 | 0.23 | 0.87 | 0.27 |
| Mustard oil cake | 4.70 | 1.06 | 0.91 | 0.93 |
| Cow dung | 1.07 | 0.57 | 0.54 | 0.32 |
| Poultry manure | 1.33 | 0.80 | 0.89 | 0.42 |
| Sugarcane press mud | 1.59 | 0.091 | 0.64 | 0.51 |

**Table 2. Nutrient level of different types of compost**

| Types compost | %N | %P | %K | %S |
|---|---|---|---|---|
| Compost 1 | 1.41 | 0.33 | 1.01 | 0.41 |
| Compost 2 | 3.14 | 0.84 | 0.84 | 0.52 |
| Compost 3 | 2.91 | 0.62 | 0.77 | 0.45 |
| Compost 4 | 3.22 | 0.40 | 0.81 | 0.32 |

Compost 1 = MSW 100%; Compost 2 = MSW 50% + MOC 20% + PM 30%; Compost 3 = MSW 50% + MOC 20% + CD 30%; Compost 4 = MSW 50% + MOC 20% + SPM 30%.

### 2.2 Field experiment

#### 2.2.1 Location and site

UNDER PEER REVIEW

The field trial with cabbage was conducted at Bangladesh Agricultural University (BAU) research farm, Mymensingh (24°56.11' N, 89°55.54′ E) which belongs to Old Brahmaputra Floodplain agro-ecological zone [14] with non-calcareous dark grey floodplain soil characteristics. According to US Soil Taxonomy, the soil is Aeric Haplaquept under the Order Inceptisols and as per FAO Soil Unit it is Chromic-Eutric Gleysols. The location has a sub-tropical humid climate and is characterized by hot and humid summer and cold winter. The research field was medium high land.

### 2.2.2 Soil characteristics

The soil (0-15 cm thickness) was silt loam (14% sand, 70% silt &16% clay) having a pH of 6.7 (1 : 2.5: Soil : Water), 2.79% organic matter [15], 0.17% Kjeldahl N [16], 4.1 mg $kg^{-1}$ Olsen P [17], 0.089 cmol (+) $kg^{-1}$ $NH_4OAc$ extractable K [18], 17.1mg $kg^{-1}$ $CaCl_2$ extractable S [19]), 0.65 mg $kg^{-1}$ DTPA extractable Zn [20] and 0.24 mg $kg^{-1}$ $Ca(H_2PO_4)_2$ extractable B [21].

### 2.2.3 Treatments and design

There were 10 treatments with different combinations of chemical fertilizers (urea, triple superphosphate, muriate of potash and gypsum) and four types of compost. *Trichoderma* inoculum was added to the MSW compost one month ahead of its field application. The treatment details are given in Table 3. The experiment was laid out in a randomized complete block design (RCBD), with three replications. For $T_7$-$T_{10}$, the dose of MSW, MOC, PM, CD and SPM was calculated based on 50% nitrogen that could be mineralized in one season. The aim of the experiments was to reduce the use of chemical fertilizers by 50% through supplementing with MSW compost (50%) + MOC (20%) + PM/CD/SPM (30%). The amount of nutrient addition using fertilizers and compost is shown in Table 3.The 100% fertilizer dose for N, P, K and S was 180, 45, 60 and 25 kg $ha^{-1}$, respectively. The experiment was laid out in a randomized complete block design, with three replications.

**Table 3. Nutrient addition through fertilizers and compost (kg $ha^{-1}$)**

| Treatments | N | | P | | K | | S | |
|---|---|---|---|---|---|---|---|---|
| | CF | compost | CF | Compost | CF | Compost | CF | Compost |
| $T_1$ : Control | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $T_2$ : 100% CF | 180 | 0 | 45 | 0 | 60 | 0 | 25 | 0 |
| $T_3$ : Compost 1 | 0 | 71 | 0 | 33 | 0 | 101 | 0 | 41 |
| $T_4$ : Compost 2 | 0 | 157 | 0 | 84 | 0 | 84 | 0 | 52 |
| $T_5$ : Compost 3 | 0 | 146 | 0 | 62 | 0 | 77 | 0 | 45 |
| $T_6$ : Compost 4 | 0 | 161 | 0 | 40 | 0 | 81 | 0 | 32 |
| $T_7$ : 50% CF + $T_3$ | 90 | 71 | 23 | 33 | 30 | 101 | 13 | 41 |
| $T_8$ : 50% CF + $T_4$ | 90 | 157 | 23 | 84 | 30 | 84 | 13 | 52 |
| $T_9$ : 50% CF + $T_5$ | 90 | 146 | 23 | 62 | 30 | 77 | 13 | 45 |
| $T_{10}$ : 50% CF + $T_6$ | 90 | 161 | 23 | 40 | 30 | 81 | 13 | 32 |

$T_1$= Control, $T_2$= Fertilizers ( NPKS), $T_3$ = Compost 1 (100% MSW at 10 t $ha^{-1}$**)**, $T_4$ = Compost 2 (50% MSW + 20% MOC + 30% PM), $T_5$ = Compost 3 (50% MSW + 20% MOC + 30% CD**)**, $T_6$ = Compost

UNDER PEER REVIEW

(50% MSW + 20% MOC + 30% SPM), $T_7 = T_3$ + 50% CF, $T_8 = T_4$ + 50% CF ,$T_9 = T_5$ + 50% CF and $T_{10} = T_6$ + 50% CF; *Trichoderma* used for MSW treatments, $T_3 – T_{10}$
50% N mineralization considered from compost during one crop season

**2.2.4 Crop management**

The plots received nutrient enriched compost and/or fertilizers as per treatments. Fertilizers such as urea, triple superphosphate (TSP), muriate of potash (MoP) and gypsum were used as sources of N, P, K, S and Zn, respectively. The full dose of compost and TSP was applied during the final land preparation. Fertilizers urea and MoP were applied in two installments - the first half at 15 days and the second half at 35 days after transplanting of the cabbage seedlings.

Thirty-day old seedlings of cabbage (cv. Atlas-70) were transplanted on 13 November 2017, with a spacing of 55cm × 45cm. After planting the seedlings were lightly watered and kept under pieces of banana leaf sheath for 3 days during the day time to protect the seedlings from scorched sunlight. The crop was irrigated at 15, 35 and 55 days after transplantation. The plots were kept free from weeds and the soil was mulched by breaking the upper crust for easy aeration and to conserve soil moisture. Malathion 57 EC @ 2 ml $L^{-1}$ and rovral 50 WP @ 2 g $L^{-1}$ of water were sprayed to control mole crickets and caterpillars, and Alternaria leaf spot disease, respectively.

The crop was harvested after 90 days of planting. The growth and yield characters on each plot were recorded. The characters included plant height (cm), leaf length (cm), leaf breath (cm), head thickness (cm), head diameter (cm), individual head weight (kg) and head yield (kg $plot^{-1}$, then converted to t $ha^{-1}$). The heads (edible portion) and soils after harvest from every plot were chemically analyzed for N, P, K & S concentrations.

**2.2.5 Nutrient analysis**

For N determination, $H_2SO_4$ digestion (Kjeldahl method) and for P, K & S determination $HNO_3$-$H_2O_2$ digestion procedures were followed [22]. The amount of N, P, K and S in the acid digest was measured by the same methods used for soil analysis. Nitrogen in the digest was estimated by distillation with 10N NaOH followed by titration of the distillate trapped in $H_3BO_3$ indicator solution with 0.01N $H_2SO_4$ [16]. The K concentration in the acid digest was determined by flame photometer. The amount of P in the digest was determined by color-metrically and the S determined by turbid-metriclly, as indicated in the soil characteristics section.

**2.2.6 Statistical analysis**

All the data (plant growth, yield components, yield, nutrient content and soil analysis after harvest) were statistically analysed using “R”, version 3.4.3 software. The analysis of variance for every parameter was performed by F-test and mean comparisons of the treatments were done by Duncan’s Multiple Range test (DMRT), where P<0.05 was considered as the threshold value for significance [23].

UNDER PEER REVIEW

## 3. RESULTS AND DISCUSSION

The growth characters, yield components, head yield, nutrient concentrations, and changes in soil properties were examined as the treatment effects.

### 3.1 Head yield

Head (edible portion) yield was the principal parameter of this study. The head yield of cabbage significantly varied with the treatments, showing a range of 7.6 t $ha^{-1}$ in control ($T_1$) treatment to 69.4 t $ha^{-1}$ in $T_{10}$ treatment receiving 50% recommended dose of fertilizers plus press mud based compost (Fig. 1). The $T_{10}$ treatment produced superior yield over all the treatments. This might be due to its higher nitrogen content (3.22% N, Table 2) and also could be due to the higher capacity of this compost to increase availability of native soil nutrients through higher biological activity [24]. Next to press mud, poultry manure based compost treatments showed higher yield. The yields due to different treatments followed the order: $T_{10} > T_8 \approx T_9 > T_6 \approx T_4 > T_5 \approx T_7 > T_3 \approx T_2 > T_1$. The yield increase over control due to different manure and fertilizer treatments is 546-813% showing a 5-8 times yield benefit. Thus, the result reveals that nutrient enriched compost in combination with chemical fertilizers supplied adequate amount of nutrients for proper vegetative and reproductive growth of cabbage plants. Vimala, et al. [25] and Hasan and Solaiman [26] also reported positive effect of the conjunctive use of organic and inorganic sources of nutrients on the growth and yield of cabbage (*Brassica oleracea*). Cardoso et al. [27] studied two sources of organic fertilization in cabbage production and observed greater yield, head weight and diameter in case of use of castor bean cake compared to the organic compost. As stated by Ayilara et al. [28], addition of activators (e.g. viricides, fungicides) to raw materials can help improve the nutritional quality of compost and use of degradable organic material is advantageous to perennial or biennial crops. In the present study, we had used MSW, cow dung, poultry manure and sugarcane press mud which slowly decompose and release nutrients, and to accelerate the composting process we used *Trichoderma* (*T. viridi*) fungus.

UNDER PEER REVIEW

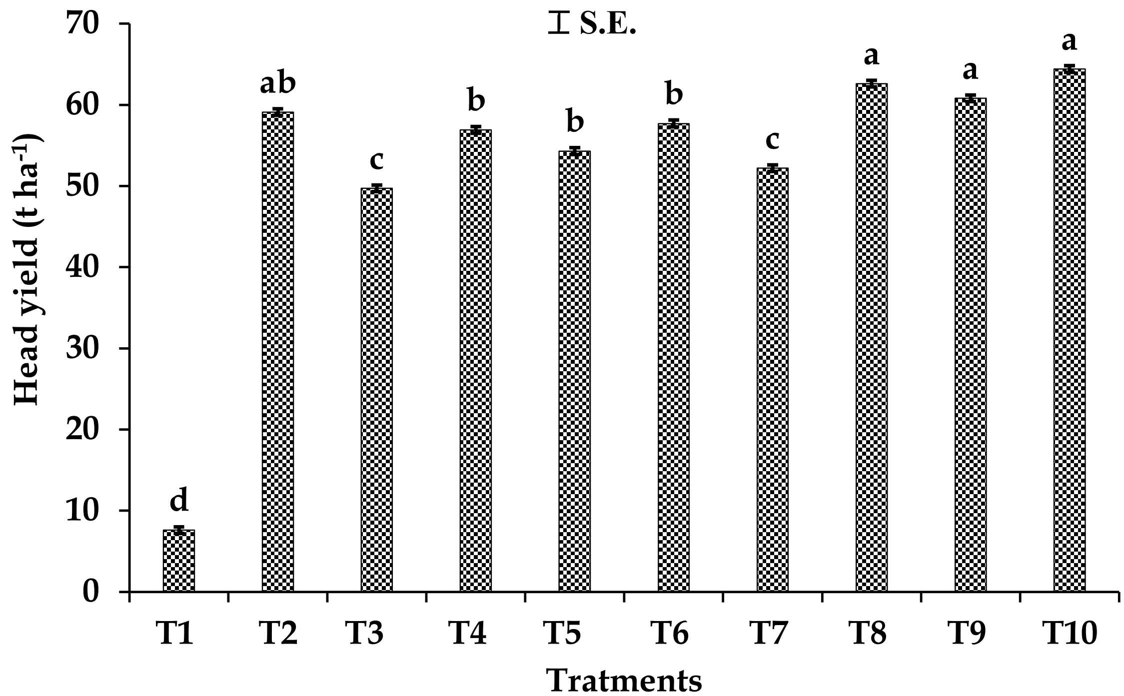


**Fig. 1.** Effects of different treatments on the head yield of cabbage

[$T_1$= Control, $T_2$= Fertilizers ( NPKS), $T_3$ = Compost 1 (100% MSW at 10 t/ha**)**, $T_4$ = Compost 2 (50% MSW + 20% MOC + 30% PM), $T_5$ = Compost 3 (50% MSW + 20% MOC + 30% CD**)**, $T_6$ = Compost (50% MSW + 20% MOC + 30% SPM), $T_7$ = $T_3$ + 50% CF, $T_8$ = $T_4$ + 50% CF ,$T_9$ = $T_5$ + 50% CF and $T_{10}$ = $T_6$ + 50% CF; *Trichoderma* used for MSW treatments, $T_3$ – $T_{10}$]

UNDER PEER

### 3.2 Growth and yield parameters

The growth parameters such as plant height ranged from 22.1-29.9 cm, leaf length from 16.6–27.4 cm and leaf breadth from 12.1-24.3 cm over the treatments. The yield parameters viz. head thickness varied from 11.3-13.5 cm, head diameter from 12.6-9.6 cm and individual head weight from 0.24–1.98 kg. For the growth parameters such as plant height, leaf length and leaf breadth the sole 100% chemical fertilizers ($T_2$) produced the best results (Table 4). However in case of yield parameters (head thickness, diameter and weight) the combined fertilizer-compost treatments showed better performances. Indeed, the sugarcane press mud (SPM) based treatment i.e. 50% CF + 50% compost mixture (MSW + MOC + SPM in a ratio of 5:2:3) ($T_{10}$) performed the best yield parameters. Higher dose of compost may inhibit crop growth, as reported by Giannakis et al. [29] that use of MSW at much higher dose (100 t $ha^{-1}$) inhibited plant growth of cabbage which they thought to be associated with immobilization of $NO_3$-N.

Analysis of correlation statistics shows that head yield (t $ha^{-1}$) was positively and significantly correlated with yield contributing characters such as individual head weight (r = 0.999, P<.001), head diameter (r = 0.939, P<.001) and head thickness (r = 0.572, P<.05). Significant relationships also exist between head yield and plant height (r = 0.784, P<.01), leaf height (r = 0.818, P<.01) and leaf breadth (r = 0.860, P<.01). Such results indicate that all the parameters had direct or indirect influence on the head yield.

**Table 4. Effects of different compost and fertilizer treatments on the growth and yield components of cabbage (cv. Atlas-50)**

| Treatments | Plant height (cm) | Leaf height (cm) | Leaf breath (cm) | Head thickness (cm) | Head diameter (cm) | Individual head wt. (kg) |
|---|---|---|---|---|---|---|
| $T_1$ : Control | 22.1 b | 16.6 e | 12.1 e | 11.3d | 12.6 e | 0.24 e |
| $T_2$ : 100% CF | 29.9 a | 27.4 a | 24.3 a | 13.8 ab | 19.4 a | 1.92 a |
| $T_3$ : Compost 1 | 22.7 b | 20.2 d | 16.6 d | 12.9 abc | 17.0 d | 1.55 cd |
| $T_4$ : Compost 2 | 30.0 a | 22.9 bcd | 21.4 b | 11.4 cd | 17.0 d | 1.78 b |
| $T_5$ : Compost 3 | 28.0 a | 24.6 abc | 20.7 bc | 13.0 ab | 18.8 abc | 1.69 bc |
| $T_6$ : Compost 4 | 28.0 a | 21.7 cd | 18.8 c | 13.0 ab | 18.6 abc | 1.80 b |
| $T_7$ : 50% CF + $T_3$ | 28.7 a | 22.5 bcd | 21.6 b | 13.5 ab | 17.9 bcd | 1.63 c |
| $T_8$ : 50% CF + $T_4$ | 29.6 a | 25.2 ab | 21.8 b | 12.3 bcd | 19.2ab | 1.95 a |
| $T_9$ : 50% CF + $T_5$ | 27.5 a | 23.8 bc | 20.3 bc | 12.7 abcd | 17.8 cd | 1.90 a |
| $T_{10}$ : 50% CF + $T_6$ | 29.8 a | 23.7 bc | 21.8 b | 13.9 a | 19.6 a | 1.98 a |
| Level of sig. | ** | ** | ** | * | ** | ** |
| CV (%) | 7.47 | 8.03 | 5.92 | 6.60 | 4.43 | 2.73 |
| SE (±) | 0.94 | 1.10 | 0.69 | 1.03 | 1.14 | 0.87 |

$T_1$= Control, $T_2$= Fertilizers ( NPKS), $T_3$ = Compost 1 (100% MSW at 10 t $ha^{-1}$**)**, $T_4$ = Compost 2 (50% MSW + 20% MOC + 30% PM), $T_5$ = Compost 3 (50% MSW + 20% MOC + 30% CD**)**, $T_6$ = Compost (50% MSW + 20% MOC + 30% SPM), $T_7$ = $T_3$ + 50% CF, $T_8$ = $T_4$ + 50% CF ,$T_9$ = $T_5$ + 50% CF and $T_{10}$ = $T_6$ + 50% CF; *Trichoderma* used for MSW treatments, $T_3$ – $T_{10}$
SE (±) = Standard error of means, CV= Coefficient of variation
*, P <0.05; **, P < 0.01
In a column means followed by same letters are not significantly different at 5% level by DMRT.

### 3.3 Nutrient concentrations of cabbage

Effects of different treatments on N, P, K and S concentrations of cabbage (head) were examined on the point of quality aspect. The results are displayed in Table 5. All the treatments showed significantly superior results over control treatment. The results are an indicative of the contribution of fertilizer and compost application to nutrient enrichment (bofortification) of cabbage (edible part).

The N concentration of cabbage depending on the treatments varied between 0.113% recorded in $T_1$ (control) treatment and 0.261% in $T_2$ treatment (100% chemical fertilizers only) (Table 5). However, the $T_2$ treatment did not differ significantly with the four treatments ($T_7$-$T_{10}$) which received 50% chemical fertilizers plus any type of compost. Further treatments $T_4$, $T_5$ and $T_6$ were not significantly different.

There was a significant variation in P concentration of cabbage due to the different treatments (Table 5). The P concentration ranged from 0.16 – 0.43%, the lowest value observed in $T_1$ (control) treatment

UNDER PEER REVIEW

and the highest value in both $T_5$ and $T_6$ treatments. Treatments $T_4$-$T_{10}$ had statistically an identical effect on cabbage P concentration.

The K concentration of cabbage markedly varied with the treatments, showing a range of 0.026 – 0.196% (Table 5). The highest K concentration was recorded by $T_{10}$ and the lowest K concentration by $T_1$ (control) treatment. After $T_{10}$, the $T_7$, $T_8$ and $T_9$ had positions in terms of cabbage K concentration. The first three treatments had significantly lower K concentration, but they were all significantly different.

In cabbage, the values of S concentration were relatively low compared to the N, P and K concentration. However, the treatment effects were similar showing that the $T_{10}$ treatment recorded the highest result and $T_1$ (control) treatment did the lowest. Treatments $T_8$-$T_{10}$ were not significantly different from each other and similarly treatments $T_4$-$T_7$ did not differ significantly between them in respect of S concentration. Although the S concentrations of the first three treatments in value were different, they were statistically identical. The S concentrations of cabbage across the treatments were 0.009-0.044% (Table 5).

There existed significant positive correlation between cabbage N with other nutrient concentrations, strongly with P (r=0.787, P<.01) and S (r=807, P<.01) and moderately with K (r=0.692, P<.05). Plant body maintains narrowly varied nutrient ratios in its tissues. We found a N:P ratio of 4.05-6.34 (mean 5.17), N:K ratio of 1.13-2.90 (mean 1.55) and N:S ratio of 6.51-12.82 (mean 9.86) in cabbage. Protein is a polymer of amino acids and sulphur is a constituent of some amino acids viz. cysteine, cystine and methionine, and RNA and DNA is a constituent of base (N), sugar and phosphate.

**Table 5. Effects of different compost and fertilizer treatments on N, P, K and S concentrations of cabbage**

| Treatments | N (%) | P (%) | K (%) | S (%) |
|---|---|---|---|---|
| $T_1$ : Control | 0.113 e | 0.018 c | 0.039 g | 0.009 d |
| $T_2$ : 100% CF | 0.241 a | 0.038 b | 0.097 f | 0.019 bc |
| $T_3$ : Compost 1 | 0.141 d | 0.033 b | 0.120 e | 0.011 d |
| $T_4$ : Compost 2 | 0.209 bc | 0.041 ab | 0.142 d | 0.019 bc |
| $T_5$ : Compost 3 | 0.159 cd | 0.039 ab | 0.138 d | 0.013 cd |
| $T_6$ : Compost 4 | 0.191 bc | 0.046 a | 0.162 c | 0.025 b |
| $T_7$ : 50% CF + $T_3$ | 0.229 ab | 0.043 ab | 0.175 b | 0.023 b |
| $T_8$ : 50% CF + $T_4$ | 0.241 ab | 0.043 ab | 0.183 b | 0.037 a |
| $T_9$ : 50% CF + $T_5$ | 0.241 ab | 0.045 a | 0.180 b | 0.037 a |
| $T_{10}$ : 50% CF + $T_6$ | 0.222 ab | 0.043 ab | 0.196 a | 0.033 a |
| Significance | ** | * | ** | ** |
| CV (%) | 5.53 | 7.12 | 6.50 | 8.17 |
| SE (±) | 0.213 | 0.123 | 0.174 | 0.117 |

$T_1$= Control, $T_2$= Fertilizers ( NPKS), $T_3$ = Compost 1 (100% MSW at 10 t $ha^{-1}$**)**, $T_4$ = Compost 2 (50% MSW + 20% MOC + 30% PM), $T_5$ = Compost 3 (50% MSW + 20% MOC + 30% CD**)**, $T_6$ = Compost (50% MSW + 20% MOC + 30% SPM), $T_7$ = $T_3$ + 50% CF, $T_8$ = $T_4$ + 50% CF ,$T_9$ = $T_5$ + 50% CF and $T_{10}$ = $T_6$ + 50% CF; *Trichoderma* used for MSW treatments, $T_3$ – $T_{10}$

UNDER PEER REVIEW

SE (±) = Standard error of means, CV= Coefficient of variation
*, $P < 0.05$; **, $P < 0.01$
In a column means followed by same letters are not significantly different at 5% level by DMRT

### 3.4 Nutrient level of post-harvest soil

The soil N content varied significantly with the treatments, showing a range of 0.11-0.19%. The $T_{10}$ treatment (50% CF + press mud based compost) demonstrated the highest N level (Table 6). Next to this treatment, it was $T_8$ (50% CF + poultry manure based compost) gave the highest N content (0.185%) that was followed by $T_6$ and $T_7$ (both 0.155%), then $T_5$ (0.15%), $T_4$ (0.135%), $T_9$ (0.133%), $T_2$ (0.131%) and $T_3$ (0.130%). It was noted that the soil N content declined in control plot while it increased in all treated plots, in comparison with initial level that was 0.12%.

The soil P level varied from 9.0-21.8 mg $kg^{-1}$, the highest level performed by the $T_{10}$ treatment (50% CF + press mud based compost) and the lowest level by the Control ($T_1$) treatment (Table 6). After $T_{10}$, the $T_8$ had the highest P availability (19.5 mg $kg_{-1}$) which was statistically similar with $T_2$ (18.7 mg $kg^{-1}$) and $T_6$ (17.9 mg $kg^{-1}$). The combined treatments (manure + fertilizer) followed the order of $T_{10}$> $T_8$> $T_9 \approx T_7$, and similarly the exclusive compost treatments showed the sequence of $T_6 \approx T_4$> $T_5 \approx T_3$. Virtually the P availability increased in all treatments including the Control, based on initial P status (6.08 mg $kg^{-1}$).

The initial K status of soil was 3.47 mg $kg^{-1}$ which went down to 3.0 mg $kg^{-1}$ in Control plot while it went up to 15.5 mg $kg^{-1}$, as recorded by $T_{10}$ treatment (50% CF + press mud based compost). After $T_{10}$, treatments $T_7$, $T_8$ and $T_9$ showed similar K status which was followed by $T_2$ and $T_6$ with an identical effect. Then, chronologically and significantly the effect was noticed in the order of $T_4$, $T_3$, $T_5$ and $T_1$ (Table 6).

Significant variation in soil S status was noticed due to different treatments. The soil S level across the treatments ranged from 6.0 mg $kg^{-1}$ in $T_1$ treatment to 11.6 mg $kg^{-1}$ in $T_{10}$ treatment (Table 6). The $T_{10}$ treatment showed the superiority of press mud amended compost over other types of amended compost. Again, $T_6$ and $T_8$ treatments had identical effects on S availability in soil. In comparison with initial status, the treatments $T_1$, $T_2$ and $T_3$ showed little lower S status in soil (6.0-6.6 mg $kg^{-1}$).

Malik and Chauhan [30] reported the higher values for soil N, P & K contents due to integrated use of organic and inorganic source of nutrients. Rekaby, et al. [31] observed higher availability of nutrients in Egypt soils after organic amendment (biochar, humic acid, compost). As noted by Demir and Gulser [32], application of rice husk compost improved the N, P & K status of soil. The increased availability of nutrients in soil in the treatments receiving both organic and inorganic sources of nutrients might be due to its direct addition through chemical fertilizers and their slow release through compost, thus enriching the available nutrients pool of the soil [33].

UNDER PEER REVIEW

**Table 6. Nutrient status of soil under different treatments after cabbage harvest**

| Treatments | Total N (%) | Available P (mg kg$^{-1}$) | Available K (mg kg$^{-1}$) | Available S (mg kg$^{-1}$) |
|---|---|---|---|---|
| $T_1$ : Control | 0.110 d | 9.0 e | 3.0 g | 6.0 f |
| $T_2$ : 100% CF | 0.133 c | 18.7 bc | 11.2 c | 6.5 ef |
| $T_3$ : Compost 1 | 0.130 c | 11.6 d | 7.1 e | 6.6 def |
| $T_4$ : Compost 2 | 0.135 c | 17.6 c | 9.5 d | 8.6 c |
| $T_5$ : Compost 3 | 0.150 b | 12.6 d | 5.3 f | 7.2 d |
| $T_6$ : Compost 4 | 0.155 b | 17.9 bc | 11.4 c | 10.9 ab |
| $T_7$ : 50% CF + $T_3$ | 0.155 b | 17.6 c | 14.1 b | 7.1 de |
| $T_8$ : 50% CF + $T_4$ | 0.185 a | 19.5 b | 13.7 b | 10.4 b |
| $T_9$ : 50% CF + $T_5$ | 0.133 c | 17.6 c | 13.7 b | 9.0 c |
| $T_{10}$ : 50% CF + $T_6$ | 0.190 a | 21.8 a | 15.5 a | 11.6 a |
| Level of significance | ** | ** | ** | ** |
| CV (%) | 4.64 | 6.16 | 4.93 | 4.56 |
| SE (±) | 0.01 | 0.23 | 1.09 | 1.38 |
| **Initial status** | **0.12** | **6.08** | **3.47** | **7.10** |

$T_1$= Control, $T_2$= Fertilizers ( NPKS), $T_3$ = Compost 1 (100% MSW at 10 t ha$^{-1}$**)**, $T_4$ = Compost 2 (50% MSW + 20% MOC + 30% PM), $T_5$ = Compost 3 (50% MSW + 20% MOC + 30% CD**)**, $T_6$ = Compost (50% MSW + 20% MOC + 30% SPM), $T_7$ = $T_3$ + 50% CF, $T_8$ = $T_4$ + 50% CF ,$T_9$ = $T_5$ + 50% CF and $T_{10}$ = $T_6$ + 50% CF; *Trichoderma* used for MSW compost treatments, $T_3$ – $T_{10}$

SE (±) = Standard error of means, CV= Coefficient of variation
*, P <0.05; **, P < 0.01
In a column means followed by same letters are not significantly different at 5% level by DMRT

## 4. Conclusions

The market available MSW compost which has a very low nutrient status is a big constraint to higher crop productivity. Use of 20% mustard oil cake and 30% sugarcane press mud or poultry manure or cow dung with 50% MSW compost greatly added the nutrient value of MSW compost. The integrated use of 50% chemical fertilizers and 50% compost mixture (50% MSW compost + 20% MOC + 20% SPM at a rate of total 10 t ha$^{-1}$) inoculated with *Trichoderma* produced higher cabbage yield with increased nutrient (N, P, K & S) content and improved soil fertility. Hence, organic amendment by mustard oil cake and some manure as sugarcane press mud, poultry manure or cow dung is a good and sustainable way to enhance the nutrient status of marketed MSW compost and to harness its potential benefit to crop and soil.

UNDER PEER REVIEW

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