Effect of vermicompost developed from municipal solid waste on rhizome yield, photosynthetic pigments and metabolism of mango ginger (*Curcuma amada* Roxb.) grown in highly degraded sodic soil

**Abstract**

A pot experiment was conducted using mango ginger (*Curcuma amada* Roxb.) to assess the effect of different levels of vermicompost (VC) obtained from municipal solid waste (MSW) on highly sodic soil (pH 10.12 and 54 ESP) i.e., T₁ (Control: 100% soil), T₂ (25% VC and soil), T₃ (50% VC and soil), T₄ (75% VC and soil) and T₅ (100% VC) in complete randomized design (CRD). Results indicated that plant height was significantly increased with increase in the doses of VC up to T₃, while in T₅ decrease was seen. Dry weight of leaf, rhizome, root, tuber and biomass were significantly increased with the increase in VC level in sodic soil. Photosynthetic pigments i.e. content of total chlorophyll and carotenoids, also increased significantly with increase in the VC in sodic soil. A significant correlation coefficient was found between plant height with dry weight of leaf, biomass and dry weight of rhizome at 0.01 levels and at 0.05 levels for total chlorophyll content. Increase in chlorophyll level led to better growth of plant and increased biomass. While total carbohydrate content was significantly increased with increasing supply of VC, reducing sugar content decreased. The antioxidative enzyme, CAT was significantly decreased with increase in level of VC. Though activity of the other antioxidative enzymes viz. POX, SOD, and GR were decreased however, no conclusive trend was observed. All groups were clustered into two broad groups based on their dissimilarities, first group comprised of (T₁, T₂, T₃ and T₄, i.e., vermicompost treatments) while control (T₅) alone constituted the second group, to perform cluster analysis. The dendogram of cluster analysis reflected maximum dissimilarity of second group from first group. Thus, it was concluded that sodic degraded land can be managed sustainably using VC obtained through MSW; the later can also be dealt with success.

**Keywords:** pigments, metabolism, vermicompost, solid waste, sodic soil, correlation

**Abbreviations:** ESP, exchange sodium percentage; VC, vermicompost; MSW, municipal solid waste; HCA, hierarchical cluster analysis; TCA, trichloroacetic acid; CAT, catalase; POX, peroxidase; SOD, superoxide dismutase; GR, glutathione reductase

**Introduction**

Solid waste generation and its management have emerged as a major concern over the past few years particularly, in developing country like India. In India, about 40 million tonnes of municipal solid waste (MSW) is generated every year due to increasing urban population and economic growth. Indian cities lack an effective mechanism to manage possibly due to lack of resources both revenue as well human resources trained in management practices involving in the sphere of collection, transportation, processing and final disposal of MSW. Vermi-technology is regarded as most effective tool to manage MSW which, relates to the development of a process that produces an efficient bio-product i.e., vermicompost, from the MSW.¹ Vermitechnology is an eco-biotechnological process that transforms energy-rich and complex organic substances into stabilized humus-like product. Vermicompost (VC) is stabilized organic waste obtained by the joint action of earthworms and aerobic microorganisms. Local epigeic and anecic species of earthworms (*Perionyxexsecavatus* and *Lampitomauritii*) are used in vermi composting.

Occurrence of soil sodicity and salinity is worldwide and is one among the major problems which are responsible for land degradation. In arid and semi arid parts of the world, the problem of soil salinity and sodicity is prevalent to considerable extent.² Salt affected soils occupy nearly 7% of the world’s land area equivalent to nearly 932 M Ha, and approximately one-third of this is, nearly 316 M Ha are in developing countries.³ In India, the salt affected area was estimated time to time ranged from 6.1 to 23.3 million Ha.³ The detrimental effects of alkalinity and salinity on growth, dry matter production and grain yield of different crops have been reported earlier by several workers.³–⁶ Singh et al.¹¹ have assessed the tolerance status and mechanism of plant’s tolerance against sodic stress using mango ginger plant at different level of soil sodicity and observed that plant displayed tolerance against sodic stress up to medium levels of ESP without decreasing rhizome yield and quality. Plant defended stress by maintaining electrolytic balance, increasing water potential, activities of antioxidant enzymes and content of metabolites.

In present study, holistic effort has been made to sustainably manage MSW as well as sodic degraded land using mango ginger
as test plant. Mango ginger (Curcuma amada Roxb.) is rhizomatous perennial plant of Zingiberaceae family with leafy tuft. Fresh rhizome contain smell of green mango and hence known as mango ginger. The plant is cultivated in tropical areas, especially in India, for its root, which is used medicinally and as a mild ginger spice.1,2 Vermicompost was developed from municipal solid waste (MSW) used as soil amendments. In the present study, the MSW was filtered by sieve to remove non-decomposed waste and the remaining material was used as test plant. Mango ginger (Curcuma amada Roxb.) is rhizomatous perennial plant of Zingiberaceae family with leafy tuft. Fresh rhizome contain smell of green mango and hence known as mango ginger. The plant is cultivated in tropical areas, especially in India, for its root, which is used medicinally and as a mild ginger spice.1,2

Materials and methods

Vermicompost (VC) production

MSW was collected from University Campus. After collection of solid waste were segregated on the basis of degradable organic waste and non-degradable waste. Layer of degradable organic waste materials and local epigeic and anepigeic species of earthworms (Perionyx excavatus and Lumitomiaauritii) were spread in 3-4 layers in 3m x 1m cemented pits. Moisture was maintained adequately. It took nearly 45 days for complete decomposition. The decomposed MSW was filtered by sieve to remove non-decomposed waste and the worm cast obtained was a fine, odourless and granular product was referred as VC. Properties of VC are presented in Table 1.

Plant materials and experimentation

A pot experiment was conducted on mango ginger grown in five different levels of VC mixed with sodic soils (Soil pH 10.12 and ESP 54) i.e., T1(Control: 0% VC and 100 % sodic soil), T2(25% VC and 75% sodic soil), T3(50% VC and 50% sodic soil), T4(75% VC and 25% sodic soil) and T5 (100% VC and 0% sodic soil) in complete randomized design (CRD) with four replicate each. The chemical properties of sodic soil used in experiment are presented in Table 1.

Growth and yields

Data were recorded as plant height (in cm), dry matter yield (in g/plant) of plant and different plant parts. Plant height was measured from level of soil to the top of leaf flag. Yield was recorded at time of harvesting. Harvested plants were washed and thoroughly separated into root, leaves, rhizome and tuber. The separated plant parts were oven dried at 70°C for 48h.

Soil analysis

The soil was collected from naturally occurring sodic soil of Banthara village of district Lucknow situated at Lucknow-Kanpur highway. It was analyzed for soil characteristics before plantation and after harvesting. Soil samples were brought to the laboratory and allowed to dry in shade. Loose stubbles attached grasses and bigger clods were first removed and then spread uniformly on polythene sheet for complete drying. The dried soil samples were powdered in agate mortar/grinder and then they were sieved through a 1 mm sieve and kept in polythene packets in dark place until analyzed. Processed soil samples were analyzed for different physico-chemical characteristics viz. pH, EC, organic carbon, exchangeable cations, cations exchange capacity (CEC) and ESP. For evaluating fertility, available P and available K were determined. The standard methods were adopted during soil analysis.4

Estimation of photosynthetic pigments

Photosynthetic pigments i.e. chlorophylls and carotenoids contents were determined in 80% acetone extract of the young fully expanded fourth leaf.13 The homogenate was centrifuged at 4000xg for 10 min to remove the residue. The color intensity of clear supernatant was measured at 663.2 nm; 646.8 nm and 470nm for chlorophyll a, chlorophyll b and carotenoids respectively. Results have been expressed as mg chlorophyll or carotenoids g⁻¹ fresh weight.

Enzyme extraction and estimation

Fresh leaf tissue (2.5g) was homogenized in 10.0ml of chilled 50mM potassium phosphate buffer (pH 7.0) using 1.0% insoluble polyvinyl pyrrolidone (PVP) using chilled pestle and mortar. The homogenate was filtered with two-fold muslin cloth and centrifuged at 20000xg for 10 min in refrigerated centrifuge at 4°C. The supernatant was stored at 2°C and used for enzyme assays within 4h. Enzyme activity of CAT was assayed according to the method of Bisht4 and the activity of CAT was expressed as μ mole H₂O₂ decomposed per unit protein. Peroxidase was assayed by modification of the method of Luck.17 The enzyme activity has been expressed as units 100 mg⁻¹ fresh weight protein, an enzyme unit being defined as the difference of 0.01 in the optical density between blank and sample per minute of reaction time. SOD activity was determined according to the method of Beauchamp & Fridovich.13 SOD has been quantified on the basis of % inhibition. GR was assayed in accordance with the method given by Jablonski & Anderson.18

Estimation of proline, protein, reducing sugar and carbohydrate, H₂O₂ and phenol contents

Proline content was determined using method of Bates et al.10 in fresh leaf tissue (1.0 g) with acid ninhydrin complex in toluene. Determination of protein in tissue extracts was made to determine the specific activity of enzyme. Protein was precipitated in tissue extracts with an equal volume of 20% chilled TCA and tissue-TCA mixture was allowed to stand for 4 h at 4°C. The content was centrifuge and the residue washed with 5% TCA. Glass distilled water was finally used to remove TCA. This residue was then freed of the pigment by extracting thrice with acetone. The residue was then dried in vacuum. The dried residue so obtained was solubilized in 0.1 M NaOH at 80°C for 10 min on water bath and protein was estimated by using Folin Ciocalteau reagent using the method of Lowry et al. Estimation of protein was measured in UV-spectrophotometerat 660 nm. The color intensity was measured in UV-spectrophotometerat 660 nm. The readings were referred to calibration curve prepared from crystalline bovine serum albumin (BSA) from Sigma chemical Co., St Louis, USA. The results have been expressed on percent fresh weight basis.

For the estimation of carbohydrates (sugar and starch), plant material was fixed in boiling 80% ethanol in the proportion of 1:10. The fixed material was crushed in a pestle and mortar. Alcohol soluble and insoluble fractions were separated by repeated centrifugation at 8,000 g. In the alcohol soluble fractions, sugar was estimated while alcohol insoluble fraction was used for the determination of starch. Sugar was determined calorimetrically by using the method of Nelson.25 Total (reducing plus non-reducing) sugars were estimated as reducing sugars after carrying out the enzymatic hydrolysis of the non-reducing sugars (using invertase) for 24 h. The non-reducing sugars were calculated as the difference in the concentration of

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Statistical analysis

Significant difference within the treatments was determined by one way ANOVA using Sigma Stat 3.2. Data are means plus/minus SE and are significantly different at P<0.05.

Spearman correlation coefficient

Spearman correlation coefficient is nonparametric version of Pearson product-moment correlation and it measures the strength and monotonic relationship between two variables. In this investigation, Spearman correlation analysis was analyzed by SPSS at 0.05 and 0.01 level to correlation between different levels of vermicompost and physicochemical parameter.

Hierarchical cluster analysis (HCA)

Hierarchical cluster analysis is multivariate statistical analysis technique for analytical data mining. HCA analyzed the data and grouped the data according to their similarity or dissimilarity in the form of hierarchy plot. HCA was performed by SPSS software to clustering the data of different morphophysiological changes in mango ginger plants due to different dose vermicompost used in high sodic soil.

Results and discussion

Vegetative growth and rhizome yield

Results indicate that plant height of mango ginger was increased significantly on increasing the VC levels. However, a decrease was observed when plants were raised entirely on VC i.e., T level (Table-2). Similar trend was also observed for number of leaves per plant, number of tillers per plant, dry weight of leaves, rhizome, tuber and root. Total yield was recorded in the form of total biomass of dry weight of leaves, rhizome, roots and tuber. As indicated in Table 1, VC contained high content organic matter, macro and micronutrients that probably enhanced the growth and yield of mango ginger. Supplementing VC in sodic degraded land has been shown to effect positively on biomass production and subsequent enhanced plant height through increase in organic matter, nutrients (macro and micro nutrients) and better water-holding capacity. Improved growth, development and height of medicinal plants and other crops have previously been reported in the presence of optimal amounts of VC. Singh et al. observed that medium and high ESP level significantly decreased mango ginger plant growth, rhizome yield and biomass. However, in the present study, supplementing VC ameliorated effects of high ESP and resulted in better plant growth, improved rhizome yield and biomass.

Table 1 Chemical properties of sodic soil and vermicompost (VC) before experiment

<table>
<thead>
<tr>
<th>Properties</th>
<th>Soil</th>
<th>Vermi compost</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH (1:2 soil water ratio)</td>
<td>10.13±0.036</td>
<td>6.36±0.84</td>
</tr>
<tr>
<td>EC (1:2 soil water ratio)</td>
<td>0.69±0.03</td>
<td>0.25±0.053</td>
</tr>
<tr>
<td>Organic Carbon (%)</td>
<td>0.23±0.01</td>
<td>1.47±0.15</td>
</tr>
<tr>
<td>Exchangeable Na (cmolkg-1)</td>
<td>7.82±0.04</td>
<td>-</td>
</tr>
<tr>
<td>Exchangeable K (cmolkg-1)</td>
<td>0.50±0.01</td>
<td>-</td>
</tr>
<tr>
<td>Exchangeable Ca+ Mg (cmolkg-1)</td>
<td>8.9±0.09</td>
<td>-</td>
</tr>
<tr>
<td>ESP (%)</td>
<td>54.5±3.49</td>
<td>-</td>
</tr>
<tr>
<td>Available K (kg ha-1)</td>
<td>394.50±16.67</td>
<td>459±13.5</td>
</tr>
<tr>
<td>Available P (kg ha-1)</td>
<td>19.12±1.07</td>
<td>81.26±2.34</td>
</tr>
<tr>
<td>Fe (ppm)</td>
<td>9.75±0.63</td>
<td>33.31±1.23</td>
</tr>
<tr>
<td>Zn (ppm)</td>
<td>0.27±0.14</td>
<td>7.38±0.86</td>
</tr>
<tr>
<td>Mn (ppm)</td>
<td>0.63±0.06</td>
<td>15.84±0.74</td>
</tr>
<tr>
<td>Cu (ppm)</td>
<td>0.48±0.034</td>
<td>4.72±0.065</td>
</tr>
</tbody>
</table>

Table 2 Effect of different levels of VC on vegetative growth of mango ginger (Curcuma amada Roxb.) grown in high sodic soil

<table>
<thead>
<tr>
<th>Plant Parameters</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
<th>LSD0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant height (cm)</td>
<td>23.21±1.33</td>
<td>32.77±1.18</td>
<td>35.77±1.32</td>
<td>37.44±0.90</td>
<td>35±0.95</td>
<td>3.654</td>
</tr>
<tr>
<td>No. of Tillers per plant</td>
<td>1±0.17</td>
<td>1±0.14</td>
<td>2±0.289</td>
<td>2.3±0.133</td>
<td>3±0.196</td>
<td>0.615</td>
</tr>
<tr>
<td>Dry weight of leaf (g/plant)</td>
<td>56±2.771</td>
<td>125.6±3.66</td>
<td>185.36±5.17</td>
<td>198.5±2.63</td>
<td>165.8±2.107</td>
<td>10.847</td>
</tr>
<tr>
<td>Dry weight of rhizome (g/plant)</td>
<td>50±3.060</td>
<td>196.66±4.994</td>
<td>283.83±7.217</td>
<td>280±3.776</td>
<td>253.33±5.906</td>
<td>16.405</td>
</tr>
<tr>
<td>Tuber yield (g/plant)</td>
<td>103.33±4.734</td>
<td>163.33±2.794</td>
<td>150±2.610</td>
<td>216.66±4.53</td>
<td>210±3.262</td>
<td>15.514</td>
</tr>
<tr>
<td>Dry weight of root (g/plant)</td>
<td>22.45±1.328</td>
<td>39.88±3.021</td>
<td>135.89±3.126</td>
<td>178.5±3.33</td>
<td>148.25±2.80</td>
<td>8.863</td>
</tr>
<tr>
<td>Biomass (g/plant)</td>
<td>231.78±8.458</td>
<td>524.87±7.101</td>
<td>755.08±10.90</td>
<td>873.71±8.45</td>
<td>777.38±10.27</td>
<td>28.818</td>
</tr>
</tbody>
</table>

Photosynthetic pigments and metabolism

The photosynthetic pigments *i.e.*, chlorophyll a, chlorophyll b, total chlorophyll and carotenoids contents were significantly increased with increase in the doses of VC. Raising plants exclusively on VC decreased content of all photosynthetic pigments (Figure 1). Increased rhizome yield and other growth indices observed in the present study probably resulted from enhanced rate of photosynthesis. This perhaps can be concluded on the basis of increased content of all photosynthetic pigments. This clearly demonstrates the effectiveness of VC in countering detrimental effect of high ESP on plant health. Similar findings were also reported earlier for sweet flag (*Acorus calamus*) and other plants by different workers.11–34

![Figure 1](image1.png) **Figure 1** Effect of different levels of vermicompost on photosynthetic pigments of mango ginger (*Curcuma amada* Roxb.) grown in high sodic soil (After 120 days of growth).

Soil sodicity have been found to affect antioxidative enzymes in mango ginger *i.e.*, activity of CAT, SOD and GR were found to increase on increasing level of the soil sodicity, while decrease in activity of POX was reported.11 In the present study, activity of CAT decreased on increasing the level of VC (Figure 2), the decrease being significant. The activity of POX and GR were lower than control (T1) but there was no fixed trend (Figure 2). However, in case of SOD, activity was found to increase with increasing the level of supplementation of VC to sodic soil (Figure 2).

![Figure 2](image2.png) **Figure 2** Dendrogram analysis in between different parameters *e.g.*, vegetative growth, photosynthetic pigments and enzyme activities of mango ginger (*Curcuma amada* Roxb.) and different ratio of vermicompost with high sodic soil.

Sodic stress condition had been shown to affect the content of metabolites like proline, H₂O₂ and total phenol.11 Results in present study indicate that the content of these three metabolites *e.g.*, proline, H₂O₂ and total phenol were increased significantly in plants and the increase was a function of percentage of VC added to sodic soil. However, plants grown exclusively on VC experienced a slight decrease (Figure 3&4). Similar finding was also observed in sweet Flag31 while reducing sugar was significantly decreased, total carbohydrate contents increased on increase in VC levels in sodic soils (Figure 3). Similar finding has also been observed by others.31 It has been observed that photosynthesis is enhanced in response to supplementation of sodic soil with VC.31 It has been observed in various aromatic and medicinal crops that supplementation of VC to sodic soil improves biological activities in soil leading to better absorption of mineral element and this finally results in increased productivity and biomass.36–39 According to the present study, application of VC has increased rhizome yield and the biomass production probably by enhancing the rate of photosynthesis; this finding is similar to earlier workers.40,41 VC increases the growth rate because of the better water and mineral uptake such as; nitrogen and phosphorus38–42 which leads to the biomass yield improvement.

Present study clearly demonstrates the effectiveness of VC in increasing the biomass yield and supports similar earlier findings.

![Figure 3](image3.png) **Figure 3** Effect of different levels of vermicompost on content of (a) reducing sugar and carbohydrate and (b) proline in plants of mango ginger (*Curcuma amada* Roxb.) grown in high sodic soil (After 120 days of growth).

Effect of vermicompost developed from municipal solid waste on rhizome yield, photosynthetic pigments and metabolism of mango ginger (Curcuma amada Roxb.) grown in highly degraded sodic soil

Spearman correlation coefficient

Pearson correlation coefficient was applied on data in SPSS software for identification of growth pattern of plant. The significant correlation coefficient found between plant height with dry weight of leaf, biomass and dry weight of rhizome at 0.01 level, but significant correlation at 0.05 level with total chlorophyll content (Table 3). Increasing chlorophyll level and rhizome that also support to growth of plant as well as biomass. The significant correlation was found between no. of tillers per plant and dry weight of root, because root provide mineral to growing for plant and increasing their tiller. While negative correlation found with reducing sugar. Carotenoid, total chlorophyll, biomass, dry weight of root, dry weight of rhizome, showed significant relation with plant leaf, where root and rhizome up-taking minerals and distributing to aerial part of plant such as leaf, fruit, stem and flower. The main reason of significant association was that both are supplement for each other. Rhizome significant correlated with height, leaf, biomass, total chlorophyll and carotenoid of mango ginger plant. Number of tillers, dry weights of leaf, biomass,
chlorophyll and carotenoids all plant part found significant with growth or weight of root. The biomass and total chlorophyll content of mango ginger plant significant correlated with all plant part, except tuber yield, number of tiller of plant, reducing sugar and carbohydrate contents. Carotenoids significantly association with leaf, rhizome, root, biomass and chlorophyll content of mango ginger plants. CAT activities showed negative correlation with SOD, phenol, H$_2$O$_2$ and proline while POX showed negative correlation with H$_2$O$_2$ and proline (Table 4). But other enzymatic and non enzymatic antioxidant showed positive correlation with each others.

**Table 3** Correlation between different morphological parameters, photosynthetic pigments and carbohydrates due to application of graded level of VC in sodic soil

<table>
<thead>
<tr>
<th>Plant height (cm)</th>
<th>No. of Tillers per plant</th>
<th>Dry weight of leaf (g/plant)</th>
<th>Dry weight of rhizome (g/plant)</th>
<th>Tuber yield (g/plant)</th>
<th>Biomass (g/plant)</th>
<th>Total chlorophyll (mg/gFW)</th>
<th>Carotenoids (mg/gFW)</th>
<th>Reducing Sugar (mg/g FW)</th>
<th>Total Carbohydrate (mg/g FW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant height (cm)</td>
<td>1</td>
<td>0.679</td>
<td>0.977**</td>
<td>0.843</td>
<td>0.971**</td>
<td>0.902*</td>
<td>0.872</td>
<td>-0.668</td>
<td>-0.018</td>
</tr>
<tr>
<td>No. of Tillers per plant</td>
<td>1</td>
<td>0.737</td>
<td>0.983**</td>
<td>0.798</td>
<td>0.988**</td>
<td>0.969**</td>
<td>0.956</td>
<td>-0.956</td>
<td>0.018</td>
</tr>
<tr>
<td>Dry weight of leaf (g/plant)</td>
<td>0.737</td>
<td>0.983**</td>
<td>0.916*</td>
<td>0.972**</td>
<td>0.962**</td>
<td>0.916*</td>
<td>0.956</td>
<td>-0.956</td>
<td>0.054</td>
</tr>
<tr>
<td>Dry weight of rhizome (g/plant)</td>
<td>0.798</td>
<td>0.988**</td>
<td>0.972**</td>
<td>0.947</td>
<td>0.462</td>
<td>0.848</td>
<td>0.462</td>
<td>-0.462</td>
<td>-0.547</td>
</tr>
<tr>
<td>Tuber yield (g/plant)</td>
<td>0.789</td>
<td>0.987**</td>
<td>0.972**</td>
<td>0.947</td>
<td>0.462</td>
<td>0.848</td>
<td>0.462</td>
<td>-0.462</td>
<td>-0.547</td>
</tr>
<tr>
<td>Biomass (g/plant)</td>
<td>0.947**</td>
<td>0.972**</td>
<td>0.962**</td>
<td>1</td>
<td>0.848</td>
<td>0.848</td>
<td>0.848</td>
<td>-0.848</td>
<td>-0.848</td>
</tr>
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</table>

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).**

**Table 4** Correlation between different antioxidative enzymes and metabolites due to application of graded level of VC in sodic soil

<table>
<thead>
<tr>
<th>Enzyme / non-enzymatic activities</th>
<th>Glutathione reductase</th>
<th>Peroxidase</th>
<th>Catalase</th>
<th>SOD</th>
<th>H$_2$O$_2$ content</th>
<th>Total Phenol Phenol content</th>
<th>Proline content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glutathione reductase (Decreased in OD340 / Min)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peroxidase (Unit mg -1protein)</td>
<td>0.848</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catalase (µ H2O2 decomposed mg-1 protein)</td>
<td>0.994</td>
<td>0.462</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOD (Unit mg-1 protein)</td>
<td>0.747</td>
<td>0.387</td>
<td>-0.027</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H$_2$O$_2$ Content (µM/100mg FW)</td>
<td>0.554</td>
<td>0.041</td>
<td>-0.554</td>
<td>0.842</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Phenol (µg/g DW)</td>
<td>0.042</td>
<td>-0.476</td>
<td>-0.688</td>
<td>0.566</td>
<td>0.855</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proline (mg/g protein)</td>
<td>0.277</td>
<td>-0.143</td>
<td>-0.912*</td>
<td>0.384</td>
<td>0.787</td>
<td>0.74a2</td>
<td></td>
</tr>
</tbody>
</table>

*.Correlation is significant at the 0.05 level (2-tailed)

**Citation:** Singh PK, Sahu P, Shalini GP, et al. Effect of vermicompost developed from municipal solid waste on rhizome yield, photosynthetic pigments and metabolism of mango ginger (Curcuma amada Roxb.) grown in highly degraded sodic soil. *Horticult Int J.* 2019;3(5):252–259. DOI: 10.15406/hij.2019.03.00139
Hierarchical cluster analysis (HCA)

HCA is an useful statistical approaches to bring together of objects, samples and parameters into cluster based on their similarities representing higher to lower similarities between clusters step by step presenting in dendrogram. In this investigation, the group linkage method with rescaled distance cluster was used for the significant variance approaches to appraise between clusters. The mango ginger (Curcuma amada) was grown in different ratio of VC with high sodic soil and their associated effect on vegetative growth, total and rhizome yield, content of photosynthetic pigments, assaying activities of antioxidative enzymes, content of carbohydrate viz, total and reducing sugars; proline, H$_2$O$_2$ and TBA reactive substances were estimated. The Cluster analysis was applied for clustering the different mixture of VC and high sodic soil. The dendrogram of cluster analysis clustering all the groups into two broad groups based on their dissimilarities, first group comprised of (T$_3$, T$_3$, T$_3$ and T$_3$) and second group (T$_3$) (Figure 4). T$_1$ represented plants grown in 100% sodic soil along with their growth indices, total and rhizome yield, photosynthetic pigments and the metabolic parameters of the mango ginger. The first group was further divided into two subgroups, subgroup 1(T$_1$, T$_1$, T$_1$) and subgroup 2 (T$_3$). The soil and VC ratio was 1/3, which is poor to support growth of mango ginger as compared to treatment groups of subgroup 1, while it was better than T$_3$, i.e. 100% sodic soil. In subgroup 2, the soil vermicompost ratio 1/1 and 100% vermicompost are lesser supported to rhizome yield, photosynthetic pigments and metabolism of Mango ginger (Curcuma amada) as compare to soil vermicompost ratio of 3/1. So it was clear from dendrogram of cluster analysis that the rhizome yield/vegetative growth, photosynthetic pigments and metabolism of mango ginger were estimated higher in soil vermicompost ratio of 3/1 and lowest in 100% sodic soil.

Conclusion

Solid waste generation and its management as well as sodic waste land management have emerged as a major challenge over the past few years. Reclaimed sodic soils revert back due to mismanaged agricultural practices. In the present study a holistic approach was practiced, MSW managed through vermin-technology; VC obtained was used for management of sodic degraded land keeping in mind the problem of reversal. It was found that supplementation of VC improved the plant growth, rhizome yield and metabolic activities of mango ginger plantprobably by alleviating effects of sodicity and byopimizing nutrientsupply. Different statistical tools were applied to justify the finding. The correlation coefficient found between plant height with dry weight of leaf, biomass and dry weight of rhizome was significantat 0.01 level, and with total chlorophyll contentis at 0.05 level. Increasing chlorophyll contentimproved photosynthetic output reflected in form of increased growth of plant and biomass of rhizome, a storage organ. All groups were clustered into two broad groups based on their dissimilaritiesto perform cluster analysis, first group comprised of VC treatmentswhile control alone constituted second group. The dendrogram of cluster analysis reflected maximum dissimilarity of second group from first group. The increase inrhizome yield, photosynthetic pigments and metabolism of mango ginger (Curcuma amada) was a function of ratio of VC was added to the sodic soil.

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Conflicts of interest

Authors declare that there is no conflict of interest.

References

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