Research Article
Open Access

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 54ESP) *i.e.*, T_1(Control: 100%soil), T_2(25% VC and soil),T_3(50% VC and soil),T_4 (75% VC and soil)and T_5 (100% VC) in complete randomized design (CRD). Results indicated that plant height was significantly increased with increase in the doses of VC up to T_4, while in T_5 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 (T_2,T_3,T_4 and T_5 *i.e.,* vermicompost treatments) while control (T_1) alone constituted the second group, to perform cluster analysis. The dendrogram 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

Volume 3 Issue 5 - 2019

Pramod Kumar Singh,[1] Pokhraj Sahu,[1] Shalini G Pratap,[1] Pramod Kumar Tandon[2]

[1]Environment Science Division, School of Basic Science, Babu Banarasi Das University, India

[2]Department of Botany, University of Lucknow, India

Correspondence: Pramod Kumar Singh, Environment Science Division, School of Basic Science, Babu Banarasi Das University, India, Tel +919919193668, Email singh_p_kumar@rediffmail.com

Received: February 10, 2019 | **Published:** October 24, 2019

Abbreviations: ESP, exchange sodium percentage; VC, vermicompost; MSW, municipal solid waste; HCA, hierarchical cluster analysis; TCA, trichloroacetic acid; CAT, catalase; POX, peroxidise; 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 of 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 (*Perionyxexcavatus* 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 *ie.,* 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.[4–6] 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.[7–10] 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 upto 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.[12,13] Vermitechnology was employed to produce VC from MSW, VC was applied to sodic soil at graded level with mango ginger as test plant. The morpho-physiological changes of plant were studied to assess the impact of VC on sodic soil and data analyzed using statistical tool like correlation and hierarchical cluster analysis (HCA). HCA is an useful statistical approaches to bring together of objects, samples and parameters into cluster based on their similarities, step wise representing higher to lower similarities between clusters and presenting findings in dendrogram.

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 anepigic species of earthworms (*Perionyx excavatus* and *Lampitomauritii*) were spread in 3-4 layers in 3m x1m 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 wasteand 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.*, T_1(Control: 0%VC and 100 % sodic soil), T_2(25% VC and 75% sodic soil) T_3(50% VC and 50% sodic soil) T_4 (75% VC and 25% sodic soil)and T_5 (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 duringsoil analysis.[14]

Estimation of photosynthetic pigments

Photosynthetic pigments i.e. chlorophylls and carotenoids contents weredetermined in 80% acetone extract of the young fullyexpanded fourth leaf.[15] The homogenate was centrifuged at 4000x g for 10 min to remove the residue.The color intensity of clear supernatants was measured at 663.2 nm; 646.8 nm and 470nm for chlorophyll a, chlorophyll band carotenoids respectively. Results have been expressedas 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 20000x g for 10 min in refrigerated centrifuge at 2°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 Bisht[16] and the activity of CAT was expressed as µ mole H_2O_2 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.[18] SOD has been quantified on the basis of % inhibition. GR was assayed in accordance with the method given by Jablonski & Anderson.[19]

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

Proline content was determined using method of Bates et al.[20] 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 removed 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 Folin Ciocalteau reagent using the method of Lowry et al.[21] 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.[22] 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

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

sugars before and after hydrolysis by invertase. Starch was estimated by the method of Montgomery.[23] H_2O_2 was estimated by method of Brennan & Frenkel.[24] The results have been expressed as μmol H_2O_2 g^{-1} fresh weight. Total Phenol content was determined using Folin Ciocalteau reagent using the method Kumaran & Karunakaran.[25] The absorbance of resulting solution was measured at 765 nm in UV-spectrophotometer.

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 difference 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 levelto 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.[26] HCA was performing 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_5 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.[27–29] Improved growth, development and height of medicinal plants and other crops have previously been reported in the presence of optimal amounts of VC.[28–30] Singh et al.[11] 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

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

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

Plant Parameters	T1	T2	T3	T4	T5	LSDα=0.05
Plant height(cm)	23.21±1.33	32.77±1.18	35.77±1.32	37.44±0.90	35±0.95	3.654
No. of Tillers per plant	1±0.173	1±0.144	2±0.289	2.3±0.133	3±0.196	0.615
Dry weight of leaf(g/plant)	56±2.771	125±3.66	185.36±5.17	198.5±2.63	165.8±2.107	10.847
Dry weight of rhizome(g/plant)	50±3.060	196.66±4.994	283.83±7.217	280±3.776	253.33±5.906	16.405
Tuber yield (g/plant)	103.33±4.734	163.33±7.794	150±2.610	216.66±4.53	210±3.262	15.514
Dry weight of root (g/plant)	22.45±1.328	39.88±3.021	135.89±3.126	178.55±3.23	148.25±2.80	8.863
Biomass (g/plant)	231.78±8.458	524.87±7.101	755.08±10.90	873.71±8.45	777.38±10.27	28.818

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.[31–34]

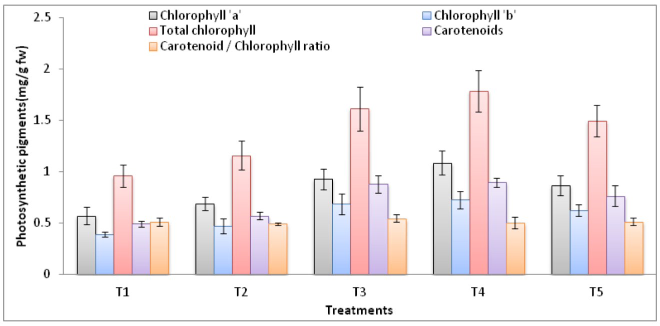

Figure 1 Effect of different levels of vermicompost on photosynthetic pigments of mango ginger (*Curcuma amada* Roxb.) grown in high sodic soil (After 120 days of growth).

Soil sodicityhave 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 thepresent 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 (T_1) 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).

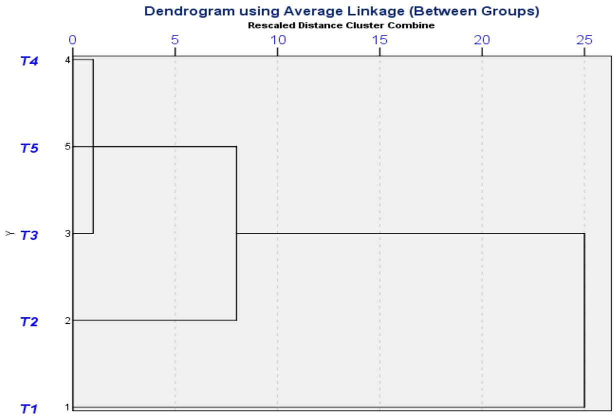

Figure 2 Dendrogram analysis in between different parameters e.g., vegetative growth, photosynthetic pigments and enzyme activities of mango ginger (*Curcuma amada* Rox b.) and different ratio of vermicompost with high sodic soil.

Sodic stress condition had been shown to affect the content of metabolites like proline, H_2O_2 and total phenol.[11] Results in present study indicate that the content of these three metabolites e.g., proline, H_2O_2 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 Flag[31] 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.[33] It has been observed that photosynthesis is enhanced in response to supplementation of sodic soil with VC.[35] 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 phosphorus[39–42] 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.

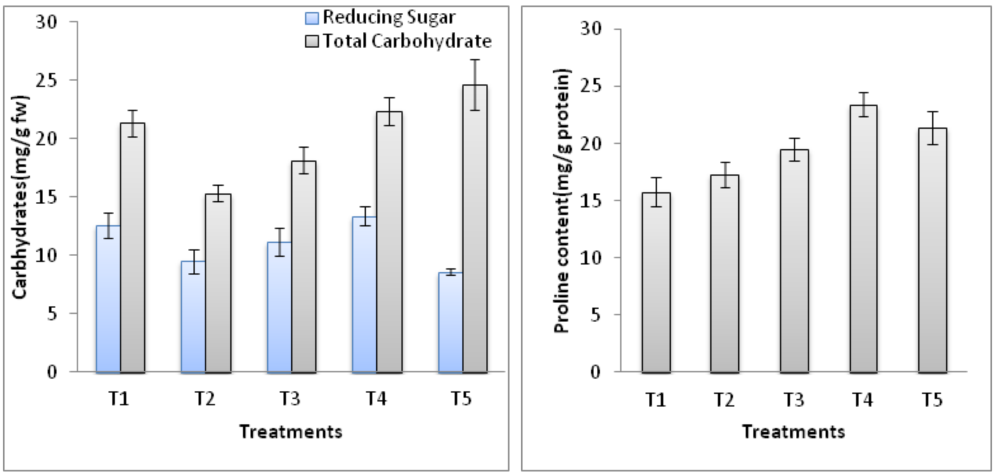

Figure 3 Effect of different levels of vermicompost on content of(a) reducing sugar and carbohydrate and (b) proline in plants of mango ginger (*Curcuma amada* Roxb.) grown in high sodic soil(After 120 days of growth).

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

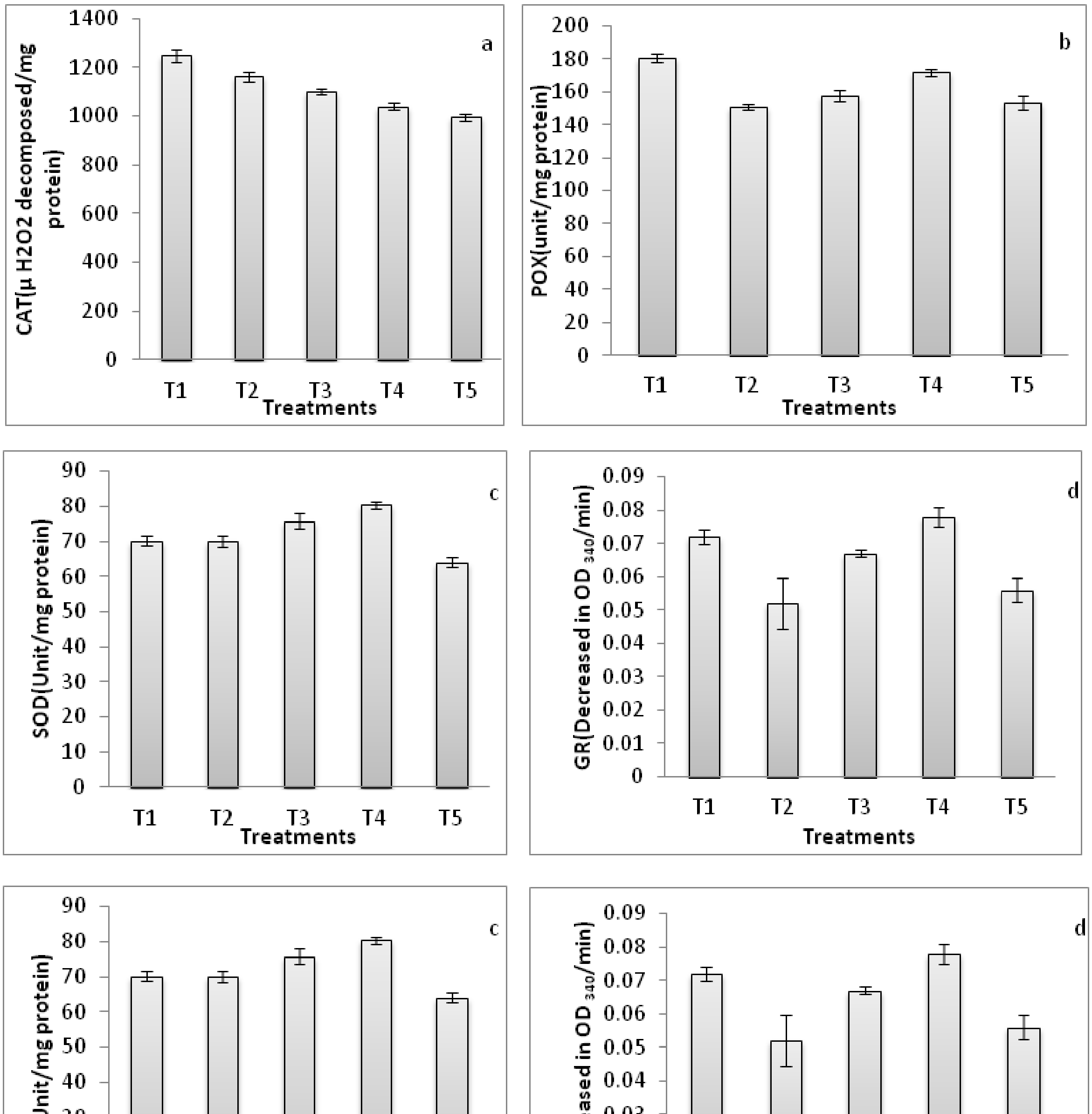

Figure 4 Effect of different levels of vermicompost on antioxidative enzymeseg., (a)CAT, (b) POX, (c)SOD, (d) GR and metabolites contents *eg.*, (e) H_2O_2 content and (f) total phenol content of mango ginger (*Curcuma amada*) grown in high sodic soil(After 120 days of growth).

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_2O_2 and proline while POX showed negative correlation with H_2O_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

	Plant height	No. of Tillers	Dry wt leaf	Dry wt rhizome	Tuber yield	Dry wt root	Biomass	Total chl.	Carotenoids	ReReducing Sugar	Total Carbohy
Plant height (cm)	1										
No. of Tillers per plant	0.679	1									
Dry weight of leaf (g/plant)	0.977**	0.737	1								
Dry weight of rhizome (g/plant)0	0.989**	0.711	0.987**	1							
Tuber yield (g/plant)	0.843	0.785	0.803	0.789	1						
Dry weight of root (g/plant)	0.844	0.887*	0.922*	0.864	0.811	1					
Biomass (g/ plant)	0.971**	0.813	0.988**	0.972**	0.875	0.947*	1				
Total chlorophyll (mg/gFW)	0.902*	0.764	0.969**	0.916*	0.772	0.972**	0.962**	1			
Carotenoids (mg/gFW)	0.872	0.754	0.956*	0.909*	0.681	0.956*	0.936*	0.987**	1		
Reducing Sugar (mg/g FW)	-0.69	-0.956*	-0.763	-0.756	-0.646	-0.862	-0.804	-0.768	-0.801	1	
Total Carbohydrate (mg/g FW)	-0.668	0.018	-0.547	-0.643	-0.325	-0.181	-0.472	-0.351	-0.345	0.088	1

**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

Enzyme / non-enzymatic activities	Glutathione reductase	Peroxidase	Catalase	SOD	H2O2 content	Total Phenol Phenol content	Proline content
Glutathione reductase (Decreased in OD340 / Min)	1						
Peroxidase (Unit mg -1protein)	0.848	1					
Catalase (µ H2O2 decomposed mg-1 protein)	0.094	0.462	1				
SOD (Unit mg-1 protein)	0.747	0.387	-0.027	1			
H2O2 Content (µM/100mg FW)	0.554	0.041	-0.554	0.842	1		
Total Phenol (µg/g DW)	0.042	-0.476	-0.688	0.566	0.855	1	
Proline (mg/g protein)	0.277	-0.143	-0.912*	0.384	0.787	0.74a2	1

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

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 associatedeffect 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_2O_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_2,T_3,T_4 and T_5) and second group (T_1) (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_3,T_4,T_5) and subgroup 2 (T_2). 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_1 *i,e.* 100% sodic soil. In sub-group 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 byoptimizing 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, andwith total chlorophyll contentit was at 0.05 level. Increasing chlorophyll contentprobably improved 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.

Acknowledgements

The author is thankful to Department of Science and Technology (DST), New Delhi for financial assistance through SERC Fast Track Scheme (SR/FT/L-172/2004).

Conflicts of interest

Authors declare that there is no conflict of interest.

References

1. Kale RD, Bano K, Krishnamurthy RV. Potential of *Periony xexcavaties* for utilizing organic wastes. *Pedobiologia*, 1982;23:419–425.
2. Yadav JSP. Salt affected soils and their management with special reference to Uttar Pradesh. *J Ind Soc Soil Sci.* 1993;41:623–629.
3. Duda lR, Purnell MF. Land resources: salt affected soils. *Rec Revegn Res.* 1986;5:1–9.
4. Ray Chaudhari SP. Classification and management of saline and alkaline soils of India. *Proc Symp Sodic Soils, Budapest Talajes. Agrok,* 1965;14:83–90.
5. Abrol IP, Bhumbla DR. Saline and alkaline soils in India, Their occurrence and management. *FAO World Resource Report*. 1971;41:42–51.
6. Bhargava GP. Salt affected soils of India- A source Book. *Oxford and IBH Publishing Co Pvt Ltd*. New Delhi; 1989.
7. Singh PK, Kumar P, Tandon PK. Soil sodicity alters antioxidative enzymes, photosynthetic pigments, water content and essential oil quality of fennel (*Foeniculum vulgare* Mill.). *Res J Soil Biol*. 2014;6(1):1–16.
8. Singh PK, Verma NS, Pandey N *et al.* Soil sodicity induced changes in aromatic plants: Effects on growth, water relation, photosynthetic pigments, antioxidative enzymes, cations concentration and quality of *Ocimum sanctum*. *Res J Med Plant.* 2015;9(8):375–394.
9. Garg VK, Singh PK, Pushpangadan P. Exchangeable sodium induced changes in yield, water relation and cation composition of fennel (*Foeniculumvulgare* Mill). *J Environ Biol.* 2005;26(2):335–340.
10. Singh D, Singh B. Influence of residual sodium carbonate in sodic water on the yield, oil content and oil production of lemongrass (*Cymbopogon cytratus*). *J Indian Soc Soil Sci.* 1997;45(2):354–357.
11. Singh PK, Pratap SG, Tandon PK. Tolerance of mango ginger (*Curcuma amada* Roxb.) against sodic stress soil: Effects on growth, rhizome yield, water relation, photosynthetic pigments, antioxidative enzymes, cations and heavy metals concentration. *Horticult Int J.* 2018;2(6):287–297.
12. Huxley A. The new RHS dictionary of gardening. *MacMillan Press*; 1992.
13. Chevallier A. The encyclopedia of medicinal plants. London: *Dorling Kindersley*; 1996.
14. Piper CS. Soil plant analysis, *Asia Publishing House*. 1967.
15. Lichtenthaler HK. Chlorophylls and carotenoids: pigments of photosynthetic membranes. In: Packer L & R Douce, editors. Methods in enzymology, *Academic Press*, New York; 1987:350–382.
16. Bisht SS. Effect of heavy metals on plant metabolism. Ph.D. Thesis, Lucknow University, Lucknow; 1972.
17. Luck H. Peroxidase in methods of enzymatic analysis. In: HU Bergmeyer. editor. *Academic Press*, New York; 1963:895–897.
18. Beauchamp CO, Fridovich I. Superoxide dismutase: improved assay and an assay applicable to acrylamide gels. *Anal Biochem*. 1971;44:276–287.
19. Jablonski PP, Anderson JW. Light-dependent reduction of oxidized glutathione by ruptured chloroplasts. *Plant Physiol.* 1978, 61:221–225.
20. Bates LS, Waldren RP, Teare ID. Rapid determination of free proline for water stress studies. *Plant Soil*. 1973;39:205–207.
21. Lowry OH, Rosebrough NJ, Farr AL, et al. Protein measurement with folin phenol reagent. *J Biol Chem.* 1951;193:265–275.

22. Nelson N. A photometric adaptation of Somogyi method for determination of glucose. *J Biol Chem*. 1944;153:375.
23. Montgomery R. Determination of glycogen. *Archs Biochem Biophys.* 1957;67:378–386.
24. Brennan T, Frenkel C. Involvement of hydrogen peroxide in the regulation of senescence in pear. *Plant Physiol.* 1977;59:411–416.
25. Kumaran A, Karunakaran RJ. *In vitro* antioxidant activities of methanol extracts of five *Phyllanthus* species from India. *LWT-Food Sci Technol*. 2007;40:344–352.
26. Mehrabi B, Mehrabani S, Rafiei et al. Assessment of metal contamination in groundwater and soils in the Ahangaran mining district, west of Iran. *Environ Monitoring &Assessment*. 2015;187:727.
27. Cavender ND, Atiyeh RM, Knee M. Vermicompost stimulates mycorrhizal colonization of roots of *Sorghum bicolor* at the expense of plant growth. *Pedobiologia.* 2003;47:85–89.
28. Arancon NQ, Edwards CA, Lee S, *et al*. Effects of humic acids from vermicomposts on plant growth. *Eur J Soil Biol.* 2006;42: 65–69.
29. Kumawat PD, Jat NL, Yadavi SS. Effect of organic manure and nitrogen fertilization on growth, yield and economics of barley(*Hordeumvulgare*). *Indian J Agric Sci.* 2006;76(4):226–229.
30. Arguello JA, Ledesma A, Nunez SB, *et al*. Vermicompost effects on bulbing dynamics, nonstructural carbohydrate content, yield, and quality of 'Rosado Paraguayo' garlic bulbs." *Hort Sci.* 2006;41(3):589–592.
31. Darzi MT, Ghalavand A, Rejali F, *et al*. Effects of Biofertilizers application on yield and yield components in fennel (*Foeniculumvulgare* Mill.). *Iran J Med Arom Plants.* 2007;22(4):276–292.
32. Haj Seyed Hadi SMR, Darzi MT, Ghandehari Z, *et al*. Effects of vermicompost and amino acids on the flower yield andessential oil production from *Matricaria chamomile* L. *J Med.Plants Res.* 2011;5(23):5611–5617.
33. Singh PK, Pandey N, Gupta M, *et.al*. Sustainable municipal solid waste management through vermitechnology: Impact of vermicompost on Sweet flag (*Acoruscalamus*) plants and sodic degraded land. *Int Ad Res J Sc Eng Tech.* 2015;2(1):139–146.
34. Darzi MT, Haj S, Hadi MR, *et.al*. Effects of the application of vermicompost and phosphate solubilizing bacterium on the morphological traits and seed yield of anise (*Pimpinella anisum* L.). *J Med Plants Res.* 2012;6(2):215–219.
35. Roy DK, Singh BP. Effect of level and time of nitrogen application with and without vermicompost on yield, yield attributes and quality of malt barley (*Hordeum vulgare*). *Indian J Agron.* 2006;51:40–42.
36. Migahed HA, Ahmed AE, Abdel G B F. Effect of different bacterial strains as biofertilizer agents on growth, production and oil of *Apium graveolens* under calcareous soil. *Arab Univ J Agric Sci.* 2004;12(2):511–525.
37. Jat RS, Ahlawat I P S. Effect of vermicompost, biofertilizer and phosphorus on growth, yield and nutrient uptake by gram (*Cicer arietinum*) and their residual effect on fodder maize (*Zea mays*). *Indian J Agric Sci.* 2004;74(7):359–361.
38. Zaller JG. Vermicompost as a substitute for peat in potting media: Effects on germination, biomass allocation, yields and fruit quality of three tomato varieties. *Sc Hortic.* 2007;112:191–199.
39. Pandey R. Management of *Meloidogyne incognita* in *Artemisia pallens* with bio-organics. *Phytoparasitica.* 2005;33(3):304–308.
40. Moradi R, Rezvani MP, Nasiri MM, *et.al*. The effect of application of organic and biological fertilizers on yield, yield components and essential oil of *Foeniculum vulgare* (Fennel). *Iran J Agron Res.* 2010;7(2):625–635.
41. Saeid NAH, Rezvani MP. Evaluation of compost, vermicompost and cattle manure application on yield, yield components and essential oil percent in cumin (*Cuminum cyminum*). *J Hortic Sci.* 2011;24(2):142–148.
42. Anwar M, Patra D D, Chand S, et al. Effect of organic manures and inorganic fertilizer on growth, herb and oil yield, nutrient accumulation and oil quality of French basil. *Com Soil Sci Plant Anal.* 2005;36(13-14):1737-1746.

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