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Sustainable Municipal Solid Waste Management through Vermitechnology: Impact of Vermicompost on Sweet flag (*Acorus calamus*) plants and Sodic Degraded Land.

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Abstract: A pot experiment was conducted on sweet flag (*Acorus calamus)* grown in different levels of vermicompost (VC) and sodic soils (Soil pH 10.12 and Exchangeable sodium percentage 54) *i.e.*, T_1=100% sodic soil (control), T_2=75% sodic soil + 25% VC, T_3=50% sodic soil+50% VC, T_4=25% sodic soil+75% VC, T_5=100% VC in complete randomized design (CRD). Results indicate that vegetative growth (*i.e.*, plant growth, number of leaves and number of tillers per plant) were significantly increased on increasing the doses of vermicompost up to T_4. While in T_5 it decreases than T_3 and T_4. The maximum rhizomes and biomass yield were observed at T_4 level. The photosynthetic pigments (chlorophyll 'a', chlorophyll 'b' total chlorophyll and carotenoid contents) were also significantly increases on increasing the vermicompost dose in sodic soil while carotenoid chlorophyll ratio was decreased up to T_4. The anti-oxidative enzymes like catalase, peroxidase and glutathione reductase and superoxide dismutase were also significantly increases on increasing the dose of vermicompost. Quality of rhizome and leaves were also improved through increasing reducing sugars, total carbohydrates and protein levels. Soil properties were also improved by reducing soil pH and ESP and increasing organic carbon and nutrient status in soils. Thus, through vermitechnology MSW and sodic degraded land were managed sustainably.

Keywords: Earthworm, vermicompost, sodic soil, sustainable management, metabolism

I. Introduction

Cultivation of several aromatic crops in India has a great scope due to its commercial value in national and international market for development of new and exotic flavor and fragrance. But due to ever rising pressure to produce more food, fiber, fodder and other agricultural commodities, it is difficult to spare fertile land for cultivation of aromatic crops. A viable alternative could be the utilization of cultivable wastelands including the salt affected i.e. alkali or sodic and saline wastelands to raise these crops through development of agro technology by using vermicompost in sodic degraded land. In arid and semi arid parts of the world the problem of soil salinity and sodicity is prevalent to considerable extent [1]. According to [2]salt affected soils occupy nearly 7% of the worlds land area or 932 M Ha of which an estimated 316 M Ha are in developing countries [3]. In India, the salt affected area were estimated time to time ranged from 6.1 to 23.3 million ha [4,5,6]. The detrimental effects of alkalinity and salinity on growth, dry matter production and grain yield of different crops have been reported by several workers [7,8,9,10].

Solid Waste Management in Indian cities has emerged as a major concern over the past few years. The rise in urban population and economic growth in the absence of an effective management mechanism has manifested in the current state of solid waste management in Indian cities which is far from perfect. About 40 million tones of municipal waste is generated in India every year. The main problem in the MSW management are lack of financial as well human resources trained in SWM practices in the sphere of collection, transportation, processing and final disposal. Technology referred to as Vermitechnology has been developed to process the waste to produce an efficient bio-product vermicompost [11]. The method of vermicomposting involving a combination of local epigeic and anecic species of earthworms (*Perionyx excavatus* and *Lampito mauritii*) is called Vermitech. Vermitechnology involves stabilization of organic waste through the joint action of earthworms and aerobic microorganisms. It is an eco-biotechnological process that transforms energy-rich and complex organic substances into stabilized humus like product vermicompost. It was concluded that in vermi-composting process, inoculated earthworm maintains aerobic condition in the organic wastes, converts a portion of the organic material into worm biomass and respiration products and expels the remaining partially stabilized product, since the potential of some epigeic earthworm (*Lumbricus terrestris, Eisenia fetida, E. Andrei Eudrilus eugeniae* and *Perionyx excavates)* to recycle organic waste materials

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into value-added products is well documented [11]. Initially, microbial decomposition of biodegradable organic matter occurs through extra cellular enzymatic activity (primary decomposition). Earthworms feed on partially decomposed matter, consuming five times their body weight of organic matter per day. The ingested food is further decomposed in the gut of the worms, resulting in particle size reduction. The worm cast is a fine, odorless and granular product. This product can serve as a biofertilizer in agriculture.

In present study vermi-technology was used for sustainable management of MSW and vermicompost production which was applied for sodic soil development and growth of sweet flag (*Acorus calamus)*. The morpho-physiological changes of sweet flag were also study to assess the impact of vermicompost and sodic soil on the crops.

II. Materials and Methods

Vermicompost Production

MSW were collected from Lucknow University Campus by Muskan Jyoti a Non Government Organization (NGO). After collection of solid waste were segregated on the basis of degradable organic waste and non-degradable. Technology referred to as Vermi-technology has been developed to process the waste to produce an efficient bio-product vermicompost. The method of vermicomposting involving a combination of local epigeic and anepigic species of earthworms (*Perionyx excavatus* and *Lampito mauritii*) is called Vermitech. Vermitech involves stabilization of organic waste through the joint action of earthworms and aerobic microorganisms. It is an eco-biotechnological process that transforms energy-rich and complex organic substances into stabilized humus-like product vermicompost. It was taking to time for complete decomposition nearly 45 day. The ingested food is further decomposed in the gut of the worms, resulting in particle size reduction. The worm cast is a fine, odorless and granular product. This product can serve as a biofertilizer in agricultures (Fig. 1).

Plant materials and experimentation

Acorus calamus (Sweet flag) is a tall perennial wetland monocot of the Acoraceae family. It is also known as buksh, a medicinal plant used in different Siddha and Ayurvedic medicines while widely used in modern herbal medicine. A pot experiment was conducted on *Acorus calamus* grown in different levels of vermi-compost and sodic soils (Soil pH 10.12 and ESP 54) *i.e.*, T_1=100% soil (control), T_2=75% soil+25% vermi-compost (VC), T_3=50% soil+50% VC, T_4=25% soil+75% VC, T_5=100% VC in complete randomized design with four replicate. The chemical properties of used sodic soils in experiment were as follow: soil pH (10.12), electrical conductivity (0.69 dSm^{-1}), organic carbon (0.09%), ESP (54.5%), exchangeable Na (7.82 cmol kg^{-1}), exchangeable K (0.5 cmol kg^{-1}), exchangeable (Ca +Mg), available K (394.5 kg ha^{-1}), available P (19.12 kg ha^{-1}) and micronutrients i.e. Fe, Zn, Cu and Mn were 9.75 ppm, 0.27 ppm, 0.63 ppm and 6.4 ppm respectively

Growth and Yields

Data were recorded as plant height and dry matter yield (oven dried at $70^{O}C$ for 24h) and rhizome yield. Plant height was measured from soil level to top of leaf flag. Yield was recorded at harvest. Harvested plants were washed and thoroughly separated into root, rhizome and leaves and dried in an oven at $70^{o}C$ for 24 h.

Soil analysis

The soil sample was analyzed 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 samples were analyzed for different physico-chemical-chemical characteristics of soil viz, pH, EC, organic carbon, exchangeable cations, cations exchange capacity (CEC) and ESP. for evaluating fertility, total nitrogen, available phosphorus and available K were determined. The standard methods were adopted during soil analysis[12].

Estimation of photosynthetic pigments

Concentration of chlorophylls and carotenoids were determined in 80% acetone extract of the young fully expanded fourth leaf [13]. 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; 646.8 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) containing 1.0% insoluble Polyvinyl Pyrrolidone (PVP) using chilled pestle and mortar kept in ice bath. The homogenate was filtered with two-fold muslin cloth and centrifuged at 20000x g for 10 min in refrigerated centrifuge at $2^{o}C$. the supernatant was stored at $2^{o}C$ and used for enzyme assays within 4h [14]. Enzyme activity is expressed as μ mole H_2O_2 reduced unit fresh matter or protein weight. Peroxidase was assayed by modification of the method [15]. Superoxide dismutase activity was determined [16].

Estimation of proline, starch and sugar

The concentration of free proline was determined in fresh leaf tissue with acid ninhydrin complex in toluene [17]. The protein concentration in the homogenate was determined in Tri Chloro Acetic Acid (TCA) precipitate [18] using Bovine Serum Albumin (BSA) as standard. Sugars were determined calorimetrically [19].

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III. Results:

Effects on plant growth and rhizome yields

Results indicated that plant height of sweet flag was significantly affected due to use of vermicompost in the sodic soils. It was significantly increases on increasing the vermicompost levels and maximum growth was at T_4 level while at T_5 comparatively decreases than T_4 (Table 1). Similar trends were also observed in number of leaves per plant, number of tillers per plant. The yields were indicated in the form of dry weight of leaves, rhizome, roots and total biomass. The dry weight of leaves, rhizome and root were significantly increases on increasing the vermicompost levels. It was significantly increases on increasing the vermicompost levels and maximum dry weight was observed in roots at T_4 level while at T_5 comparatively decreases than T_4. Similar trend was observed in biomass yields.

Effect on photosynthetic pigments

The photosynthetic pigments *i.e.*, chlorophyll a, chlorophyll b, total chlorophyll and carotenoids contents were significantly increases on increasing the doses of vermicompost. The maximum photosynthetic pigments were observed in T_4 level while in T_5 all pigments were decreases in comparison to T_4 (Fig. 2).

IV. Effects on antioxidative enzymes

Catalase (CAT) activity: Result indicated that catalses activity was significantly increases up to T_4 but in T5, it was significantly decreases than the other treatment. Catalase activity was ranged from 864 to 1280 µM H_2O_2 decomposed/100 mg FW while maximum content was observed in T_4 (fig. 3a).

Peroxidase (POX) activity: Result indicated that POX activity was significantly increased on increasing the VC percentage in the soils POX activity was ranged from 143.3 to 185.35 µM/100mg FW. Minimum POX activity was observed in T_1 (control) and maximum in T_4 (fig. 3b).

Superoxide dismutase (SOD) activities: Result indicated that SOD activity was significantly increased on increasing the VC percentage in the soils. SOD activity was ranged from 44.15 to 92.84 unit/mg protein. Minimum SOD activity was observed in T_1 (control) and maximum in T_4(fig. 3c).

Glutathione Reductase (GR) activities: Result indicated that GR activity was significantly increased on increasing the VC percentage in the soils. It was increased up to T_4 while in T_5 decreases than T_4(fig. 3d).

Proline content: Result indicated that proline content was significantly increased up to T_4 but in T_5 it was decreased. Proline content range from 15.1 to 27.05 mg g^{-1} (fig. 4).

Reducing sugars and total carbohydrate

Results indicated that reducing sugars was significantly increases on increasing the vermicompost doses. Maximum reducing sugars was observed in T_5. Total carbohydrate content was also increases on increasing the dose of vermicompost but it was maximum in T_4(fig. 4).

Changes in soil properties

Soils were analyzed after harvesting of crops. Results indicated that soil properties were improved by application VC and growth of crops. Before experiment soil pH was 10.12 which were decreases up to 9.2 in T_1 (control i.e. without VC) and it was decreases on increasing dose of VC. Organic carbon was 0.09% before experiment which was increases 0.65% in T_1 (control)and it was increases on increasing the dose of vermicompost. Other soil properties were also improved by use of vermicompost and growth of sweet flag which is indicated in (table 2).

Discussions

According to this study, use of vermicompost in sodic degraded land increases organic matter, nutrients (macro and micro nutrients) and high water-holding capacity [20, 21 and 22] have a positive effect on biomass production and subsequently enhanced plant height. Improved growth, development and height of medicinal plants and other crops have previously been reported in the presence of optimal amounts of vermicompost [23, 24, 25]. According to the present analysis, use of vermicompost enhance photosynthesis[26]. On the other hand, vermicompost application through the improvement of biological activities of soil and mineral element absorption reported by different workers in aromatic and medicinal crops [27, 28, 29, 30, 31, and 32]. According to the present analysis, vermicompost have increased rhizome yields by enhancing the rate of photosynthesis and the biomass production which is similar finding by other [32,33] that clearly demonstrate the effectiveness of vermicompost in increasing the biomass yield. Vermicompost increases the growth rate because of the water and mineral uptake such as; nitrogen and phosphorus [21, 28, 30, 31, 32 and 34] which leads to the biomass yield improvement.

Conclusions

Thus, use of vermicompost in sodic degraded land improve organic matter, nutrient content and water holding capacity and decreases the soil pH and ESP (soil sodicity). The growth of sweet flag also improves soil properties by absorbing exchangeable sodium and reducing the content sodium in soil and adding organic matter as dead residues of roots and leaf. Thus municipal solid waste can be sustainably managed by use of vermi-technology and sodic soil can be reclaimed by adding vermicompost and growing sweet flag (*Acorus calamus*).

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Caption for Tables

Table: 1 Effect of different level of vermicompost on vegetative growth of sweet flag (*Acorus calamus*) grown in sodic degraded land.

Vegetative Growth	T1	T2	T3	T4	T5	CD $_{\alpha\ 0.05}$
Plant Height(cm)	26.33	35.66	35.7	35.33	34	0.85
Number of leaves/plant	9.5	12.5	13.16	14.16	12.16	0.64
Number of tillers/plant	1	3.16	2.5	4	3.5	0.25
Dry weight of leaves (g/plant)	12.243	35.255	36.38	73.43	38.906	3.6
Dry weight of Rhizome(g/plant)	18.13	36.878	39.459	83.343	55.793	2.8
Dry weight of Root(g/plant)	30.377	72.133	72.839	156.773	93.855	6.45
Biomass (g/plant)	60.75	144.266	148.678	313.546	188.554	2.3

Table 2: Changes in chemical properties of soil after harvesting of sweet flag (*Acorus calamus*) grown in different vermicompost level and sodic soil.

Soil Properties	T1	T2	T3	T4	T5
Soil pH (1:2soil water)	9.3±0.141	8.15±0.071	7.97±0.099	7.88±0.028	7.6±0.141
Soil EC (dSm-1)	0.3635±0.005	0.314±0.001	0.3675±0.046	0.361±0.049	0.4785±0.004
Organic carbon(%)	0.675±0.042	0.8175±0.032	0.9825±0.032	1.8±0.382	2.39±0.544
Exchangeable Na(cmolkg-1)	73.3±8.91	50.75±6.152	54.4±7.354	98.25±17.324	129.9±11.4
Available K (kg/ha)	416.64±9.504	513.52±30.886	497.84±18.215	769.26±32.951	1107.94±39.5
Availabl. P (kg/ha)	36.45±7	29.25±4.455	22.95±0.636	26.6±4.384	22.95±0.636
Iron (ppm)	8.92±2.121	10.445±1.846	15.065±6.654	27.995±1.280	37.085±5.339
Manganese(ppm)	9.905±0.403	10.48±0.792	13.705±0.799	15.495±0.955	15.595±0.346
Copper(ppm)	1.49±0.014	1.985±0.460	2.49±0.042	4.045±0.431	4.77±0.071
Zinc (ppm)	1.17±0.042	2.56±0.057	2.715±0.163	5.335±0.332	7.325±0.078

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Caption for figures

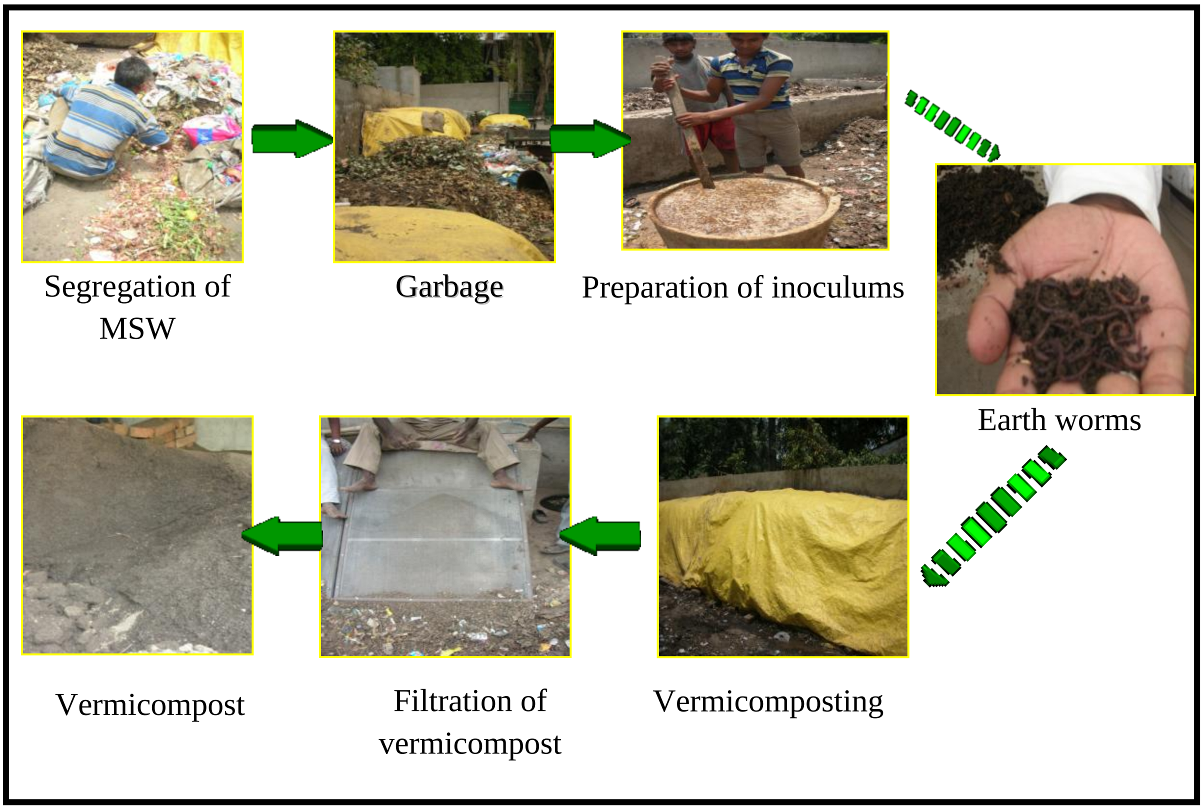
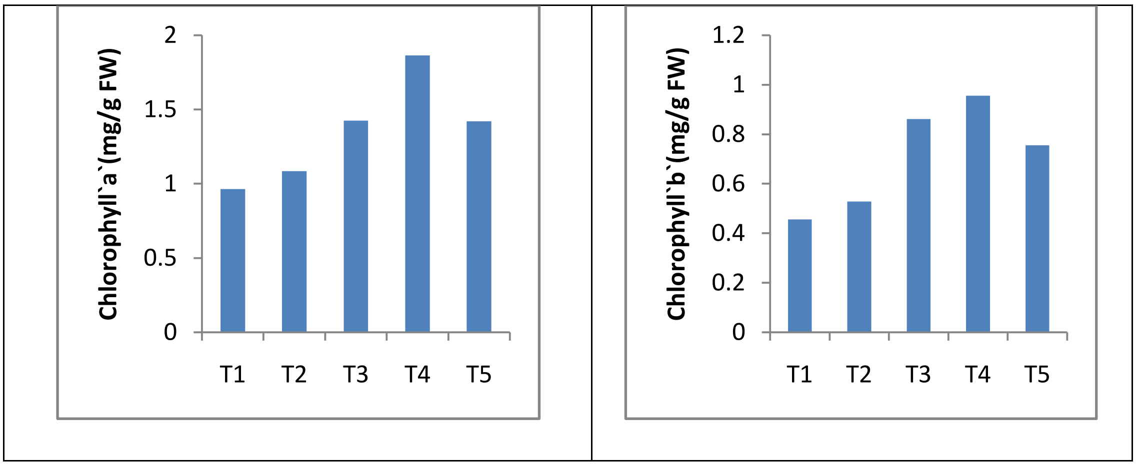


Fig.1: Different steps involved in vermitechnology *i.e.*, collection, transportation, storage, segregation, aerobic decomposition by bacteria and decomposition by local epigeic and anepigeic species of earthworms (*Perionyx excavatus* and *Lampito mauritii*).



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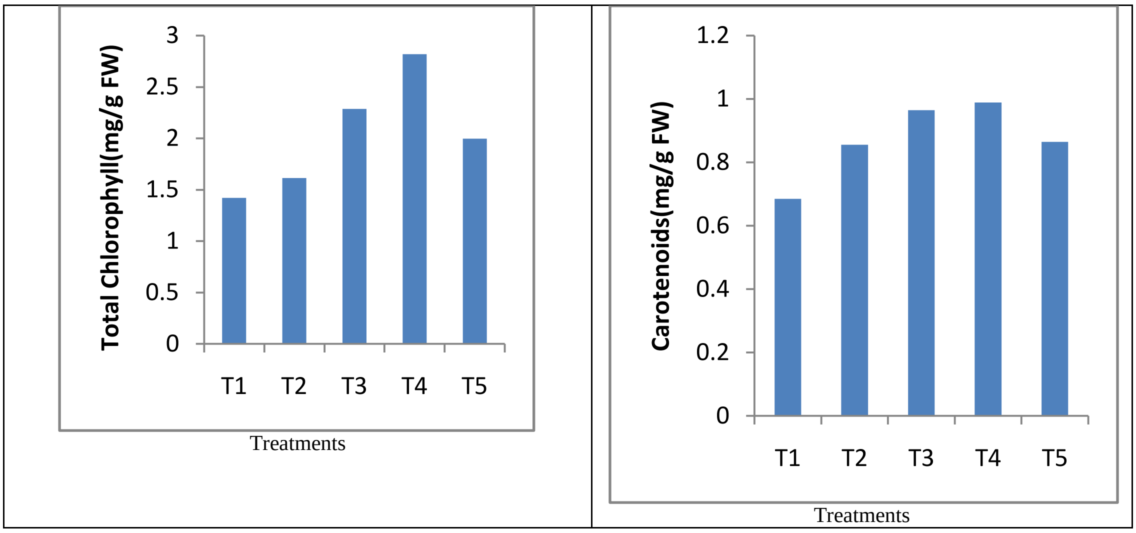

Fig. 2: Effect of different doses of vermicompost on the photosynthetic pigments *i.e.*, chlorophyll a, chlorophyll b, total chlorophyll and carotenoids contents in the leaves of sweet flag (*Acorus calamus*) grown in sodic soil.

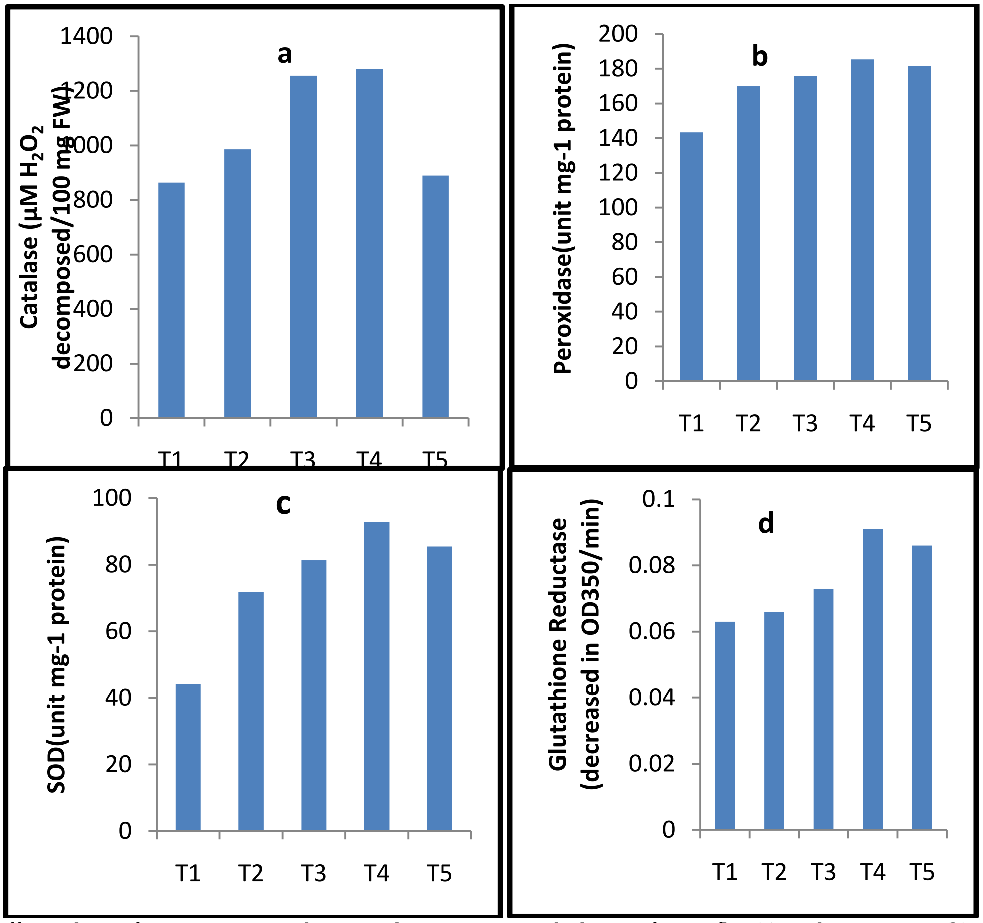

Fig.3: Effect of different doses of vermicompost on the antioxidative enzymes in the leaves of sweet flag.(a) catalase activities, (b) peroxidase activities, (c) Superoxide Dismutase activities, and (d) Glutathione reductase activities.

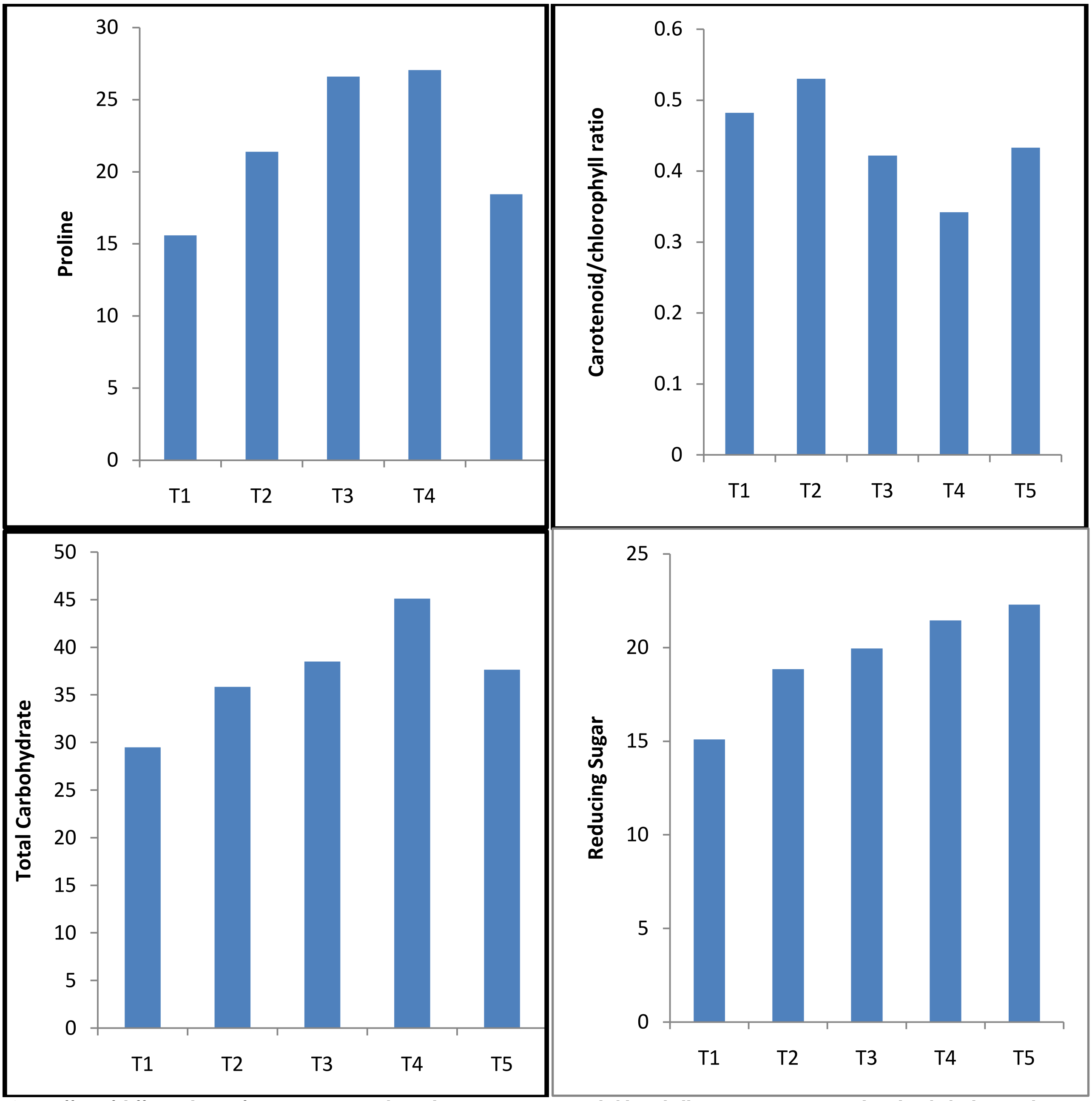

Fig.4: Effect of different doses of vermicompost on the proline content, carotenoid/chlorophyll ratio, sugar content and total carbohydrate in the leaves of sweet flag.