

ASSESSMENT OF NITROGEN RETENTION FROM MAIZE CROP AND WETLAND DITCH PLANTS RESIDUES BY VERMICOMPOSTING

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ABSTRACT

An option for ecological engineers is to increase the yield of the agroecosystem with the reuse of nitrogen through the application of vermicomposting with *Eisenia fetida* prepared by using crop residues and wetlands plants jointly. The experiment was designed considering recycling and reuse of the agricultural crop (*Zea mays*) residues and wetland plants (*Canna indica*, *Cyperus alternifolius*, *Acorus calamus*, and *Hydrocotyle vulgaris*) and pig manure found in the Sichuan Basin, China. A total of fourteen treatments (V1-V14) were prepared, and the experiment for V1 to V4 treatments was set-up in cemented plots, and separate experiments were set-up for V5-V8 and V9-V14 in containers for three months (September to December 2017). The amount of total nitrogen (TN) improved in all the treatments (V1-V14) throughout the experimental period of 90 days. In case of group 1, considering major parameters like TOC, C:N ratio and TN, combination of *Zea mays* and *Canna indica* (V3) can be regarded as most suitable combination for vermicomposting. In the second group, V6 treatment [(*Cyperus alternifolius* (60%): Pig manure (40%)] was found to be suitable based on TN recovery. The mixture of combined *Zea mays* (50%), *Cyperus alternifolius* (5%), *Acorus calamus* (5%) and pig manure (V13) increased 76% TN and can be regarded as best in group 3 based on percent change. Results indicated that ditch plants and crop residues could be used as substrates in vermicomposting for nutrient recovery.

Keywords: Crop residues, Wetland plants, Vermicompost, Nitrogen, Sichuan Basin.

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INTRODUCTION

Nutrient recycling from organic and agricultural wastes in a sustainable manner is a current issue due to rapid increase of human population worldwide. To fulfil the needs of growing population, China has made substantial improvements to increase production of food in less than 0.1 hectares per capita arable area (Lu *et al.*, 2015). As the arable area is shrinking due to urbanization and industrialization, China is relying on nitrogen fertilizers to increase food production (Lv *et al.*, 2019) and it is reported for 28% of world's nitrogen fertilizer consumption (FAO 2019). Increased use of nitrogen fertilizers and less recycling of organic matter has caused soil and water pollution in China (Lv *et al.*, 2019). As per the year plan 2016 to 2020, China is focusing on recycling and treatment of organic waste material ending in compost to promote the circular economy (ISWA, 2020). In China, an estimated 700 million tones crop residues were produced per year in 2014 (Liu, 2015), but the utilization of crop residues increased 80% till 2015 by using it in animal feed, fertilizers or fuel (NDRC, 2016) but still a large amount of these residues is burnt (Lv *et al.*, 2019)

resulting in air pollution that needs to be used sustainably (Ren *et al.*, 2019). The main commodity grain is maize (Yin, 2016) that has caused a threat in crop production and for that matter, maize producers are being encouraged to use crop residues in agriculture soil for improvement in soil organic matter. It will not only improve the quality of the soil (Turmel *et al.*, 2015) but also refrain people from the ill effects of maize residues burning.

As mentioned earlier, China is facing both soil and water pollution, ecological ditches and wetland plants are very important for pollution reduction in water and sustaining the agriculture environment (Xiong *et al.*, 2015). The plants found in the ditches not only reduce the pollutants and heavy metals for water bodies from slopping cropland but, also provide a rich medium of agricultural nutrients especially nitrogen that can be reused for the nutrient recovery by different techniques. In the nitrogen cycle, materials are transformed from unusable forms to usable form of nitrogen for plants during several processes like composting and vermicomposting (Cáceres *et al.*, 2018). To recover nutrients by vermicomposting, different substrates were used, including crops found abundantly as agriculture wastes in upland areas of China

(Raza *et al.*, 2019). Various waste materials like agro-industrial wastes (Pigatin *et al.*, 2016), vegetable waste (Huang *et al.*, 2013), distillery slurry (Singh *et al.*, 2014), bakery industry (Yadav *et al.*, 2015), and milk industry slurry (Singh *et al.*, 2017) have been used for vermicomposting.

Vermicomposting is an effective and most valuable method for the utilization of bio-waste materials (Yang *et al.*, 2017). Agriculture wastes can be recycled and reused through different techniques, but still, there is a need to regain the nutrients from agroecological wetland plants found in ditches. Vermicomposting can be done with different species of earthworms, but *Eisenia fetida* has been considered most suitable as it studied well with several substrates such as waste produced by vegetables and food (Sharma and Garg, 2017), green wastes (Gong *et al.*, 2018), coffee husk along with market wastes (Ordoñez-Arévalo *et al.*, 2018), household wastes along with biological and chemical sludge (Amouei *et al.*, 2017) and human excrement (Yadav *et al.*, 2010).

The use of ditch plants and crop residues can be helpful in three ways (i) use of ditch plants can reduce water pollution and might be used as a source of nitrogen to the soil (ii) crop residues can be recycled as nutrient-rich material for soil (iii) less burning of crop residues

means less pollution. To conclude anything, the first two above-mentioned points need to be tested experimentally to suggest the use of ditch plants and crop residues as a nitrogen-rich source, and economical organic fertilizer as only a few researches have been done on vermicomposting using ditch plants. The major objectives of the current study were (a) to study different combinations of crop residues and ditch plants for maximum nutrient recovery, (b) to analyze the physicochemical properties, carbon, and nitrogen reactive forms during vermicomposting.

MATERIALS AND METHODS

Collection of Raw Materials: Crop residues (*Zea mays*) and ditch plants were harvested from constructed wetlands around Agroecological Research Station of CAS (31°16'N, 105°28'E), Yanting, Sichuan Basin, China. Pig manure was arranged from the pig breeding farm, located nearby the site, while clitellate earthworms (*Eisenia fetida*) were arranged from the market for decomposition of materials as this species native to the study site area. The detailed physicochemical properties of raw materials have been shown in Table 1.

Table 1. Physicochemical properties of raw materials before the experiment set-up of organic wastes (mean \pm SD, n=3).

Raw dry materials	N (g/kg)	C (g/kg)	OM (g/kg)	C:N ratio	pH	EC (μ s/cm)	TDS (mg/L)
Crop residues (Maize)	12.1 \pm 1.0	376.6 \pm 8.1	649.2 \pm 14.0	31.3 \pm 2.3	6.5 \pm 0.0	3.6 \pm 0.4	2.4 \pm 0.3
Pig manure	28.7 \pm 0.2	368.3 \pm 13.7	634.9 \pm 23.7	12.9 \pm 0.6	6.5 \pm 0.0	4.8 \pm 0.0	3.3 \pm 0.1
<i>Canna indica</i>	14.6 \pm 1.1	378.8 \pm 7.8	653.1 \pm 13.5	26.1 \pm 0.6	7.2 \pm 0.1	11.0 \pm 1.8	7.4 \pm 1.2
<i>Cyperus alternifolius</i>	11.0 \pm 0.8	381.7 \pm 15.1	658.1 \pm 26	34.7 \pm 3.7	6.8 \pm 0.1	9.7 \pm 0.5	6.5 \pm 0.4
<i>Acorus calamus</i>	15.2 \pm 0.2	377.5 \pm 13.5	650.8 \pm 23.4	24.9 \pm 1.4	6.6 \pm 0.0	9.1 \pm 0.2	6.1 \pm 0.1
<i>Hydrocotyle vulgaris</i>	33.9 \pm 4.5	319.0 \pm 0.7	683.2 \pm 13.8	9.4 \pm 0.1	6.2 \pm 0.1	5.3 \pm 0.1	3.5 \pm 0.0

Experimental designs among different treatments:

Vermicomposting system was established for three months (September to December 2017) in covered cemented plots (1m length and 1.50m width having 0.6m depth) using plants wastes in three replicates in the presence of 15cm purplish soil as a base layer having a light texture and alkaline in nature (Zhou *et al.*, 2014). Different treatments were prepared with varying ratios, crop residues of maize, and ecological wetland plants. The combination of four treatments, V1 to V4, was as follows. V1. Crop residues (Maize + *Canna indica*):12 kg 4:6 Pig manure 18kg
V2. Crop residues (Maize + *Canna indica*):15 kg 5:5 Pig manure 15kg
V3. Crop residues (Maize + *Canna indica*):18 kg 6:4 Pig manure 12kg
V4. Crop residues (*Canna indica*): 18 kg 6:4 Pig manure 12kg

While experimental design for the vermicomposting process with treatments (V5-V8) was

prepared in circular containers. The V5 to V8 treatments were designed independently as 60% species of ecological ditch plants with 40% of pig manure. Four species of wetland plants with pig manure were also decomposed with earthworms independently

V5. *Canna indica* (60%): Pig manure (40%)

V6. *Cyperus alternifolius* (60%): Pig manure (40%)

V7. *Acorus calamus* (60%): Pig manure (40%)

V8. *Hydrocotyle vulgaris* (60%): Pig manure (40%)

Besides, the agricultural and ecological waste mixtures (treatments V9 to V14) were prepared, and the concentration of pig manure (40%) was constant for the following treatments given as follows.

V9. Maize (50%) + *Canna indica* (5%) + *Cyperus alternifolius* (5%)

V10. Maize (50%) + *Canna indica* (5%) + *Hydrocotyle vulgaris* (5%)

V11. Maize (50%) + *Canna indica* (5%) + *Acorus calamus* (5%)

V12. Maize (50%) + *Cyperus alternifolius* (5%)

+*Hydrocotyle vulgaris* (5%)

V13. Maize (50%) +*Cyperus alternifolius* (5%) +*Acorus calamus* (5%)

V14. Maize (50%) +*Acorus calamus* (5%) +*Hydrocotyle vulgaris* (5%)

The treatments from V9 to V14 were mixed as maize residues combined with a mixture of ecological ditch plant species with pig manure into 6:4 ratios. All the materials were taken on a dry-weight basis. Maize residues and ditch plants mentioned in the above treatments were chopped into smaller pieces of less than 5cm and then filled into circular plastic containers (0.6m diameter and 0.5m height), furthermore, kept under the shady area to prevent direct sunlight and rain and to provide a favorable environment for vermicomposting. All the material was filled and mixed thoroughly. After two weeks, 100 clitellate earthworms were added into compost piles and covered with plastic mesh to avoid escape, prevention from predators such as birds, and direct environmental effects. Water was sprinkled two times a week to maintain the moisture around 60-70 % during the complete experiment. Mixture piles were well mixed twice a month for better aeration.

Physicochemical analysis: Samples were taken from each treatment for analysis. The frequency of collected compost samples was firstly one month, and then after every twenty days. The physicochemical properties of the vermicompost, including pH, total dissolved solids, and electrical conductivity, were measured in deionized water suspension (1/10). The values were determined by pH meter and conductivity meter (Mahaly *et al.*, 2018).

To determine total carbon and total nitrogen, dried samples were analyzed with an elemental analyzer (Germany). Organic matter concentration was calculated by losses during ignition. The fresh compost samples were also taken and packed into plastic bags and analyzed for dissolved organic carbon (DOC), reactive nitrogen forms such as ammonium nitrogen ($\text{NH}_4^+\text{-N}$), and nitrate-nitrogen ($\text{NO}_3^-\text{-N}$) contents using 25 mL of K_2SO_4 solution (0.5M) by Auto-analyzer Germany.

Statistical Analysis: The treatments for various nutrients were statistically analyzed by using SPSS through one-way ANOVA with post hoc Tukey's test. The statistical analysis was performed groupwise, such as Group 1 (V1 to V4), Group 2 (V5 to V8), Group 3 (V9 to V14). Intergroup comparison was not done due to differences in experimental conditions. The significance of differences among different treatments was evaluated on the basis of the least significant difference LSD ($P < 0.05$) values. The graphical representation is shown by using Origin 2018 software.

RESULTS AND DISCUSSION

Physicochemical Changes: In this study, the pH

decreased in all treatments substantially from their initial values (Table 2). In group 1, that pH at the initial stage ranged from a minimum of 6.63 ± 0.2 (V1) to a maximum of 6.66 ± 0.0 (V4), while minimum and maximum pH after the completion of the experiment was 6.32 ± 0.1 (V3) and 6.42 ± 0.0 (V1), respectively. In the second group (V5 to V8), a maximum decline in pH was observed in V5, while V8 showed the minimum decrease in pH from its initial concentration. In the third group (V9 to V14), pH decreased from 6.83 ± 0.0 to 6.59 ± 0.0 in V11 treatment showing the maximum decline in the group from its initial concentration. The findings of the current research are similar to the results concluded by Hau *et al.* (2005), where the optimum pH of most plant species ranged from 6.5-8.6. The present study showed that the pH increased during the initial period while decreased during the rest of the process.

Similarly, the differences in increase and decrease of electrical conductivity (EC) might be due to different ratios of the substrates. Values were optimum at an initial stage while showed a decrease at the final stage in V1 to V4. Less EC is suitable for plant growth, as low EC slowly releases the mineral salts, which are adequate for plant growth (Ansari and Kumar, 2010). The maximum EC was found in V4 (5.68 ± 1.1), and it showed a substantial decline at the final stage with EC (2.53 ± 0.4). Whereas, increase in EC was observed at the final stage in V5 to V8 and V9 to V14. The results were in accordance with the study of Garg *et al.* (2006), which could be regarded as an activity of earthworms to release the bond element during earthworm digestion, which release minerals as cations through the process of decomposition in the vermicompost (Hanc and Chadimova, 2014). Ansari and Rajpersaud (2012), also showed an initial decrease and rapid increase in EC at the final stage.

Total dissolved salts (TDS) increased at final stages in V1 and V5 to V8 and V9 to V14, whereas the in rest of the treatments, TDS decreased in the final stage. Like EC, in the case of TDS, a maximum decline in values was observed in V4 in first group while increase in TDS was noted in second and third groups as shown in Table 2.

Changes in nutrients and its reactive forms during vermicomposting: In our study, TOC decreased in all treatments but no significant difference was observed within groups. The maximum decrease was observed in V4 (53.06%) followed by V1 (44.87%) (Table 3). A higher reduction in TOC in V1 treatment can also be due to earthworms and microbial respiration and carbon assimilation as earthworms and microbial biomass (Pattnaik and Reddy, 2010). The reduction of TOC was well explained by Nikaeen *et al.* (2015), as degraded organic wastes by microbial respiration during the vermicomposting process. The decline in TOC concentration over the period of time can be regarded as due to microbial oxidation from carbon to carbon dioxide (Das *et al.*, 2014).

Table 2. Initial and final physicochemical properties during the experiment (mean \pm SD, n=3).

Treatments	pH		EC (μ s/cm)		TDS (mg/L)	
	Initial	Final	Initial	Final	Initial	Final
V1	6.63 \pm 0.2	6.42 \pm 0.0	4.46 \pm 0.1	3.08 \pm 1.2	2.99 \pm 0.1	3.17 \pm 0.1
V2	6.64 \pm 0.1	6.35 \pm 0.1	3.95 \pm 0.3	3.50 \pm 0.3	2.64 \pm 0.2	2.35 \pm 0.2
V3	6.64 \pm 0.0	6.32 \pm 0.1	4.15 \pm 0.4	4.04 \pm 0.4	2.78 \pm 0.2	2.65 \pm 0.3
V4	6.66 \pm 0.0	6.40 \pm 0.0	5.68 \pm 1.1	2.53 \pm 0.4	3.81 \pm 0.7	2.12 \pm 0.1
V5	6.74 \pm 0.1	6.60 \pm 0.2	5.29 \pm 0.5	6.11 \pm 0.8	3.55 \pm 0.3	4.10 \pm 0.5
V6	6.72 \pm 0.1	6.66 \pm 0.1	5.59 \pm 0.1	5.85 \pm 0.5	3.74 \pm 0.1	3.92 \pm 0.3
V7	6.72 \pm 0.1	6.70 \pm 0.1	5.69 \pm 0.5	5.70 \pm 0.2	3.81 \pm 0.3	3.82 \pm 0.1
V8	6.78 \pm 0.0	6.77 \pm 0.1	4.44 \pm 0.4	5.08 \pm 0.4	2.97 \pm 0.3	3.41 \pm 0.3
V9	6.86 \pm 0.1	6.64 \pm 0.1	3.66 \pm 0.4	4.37 \pm 0.5	2.45 \pm 0.3	3.02 \pm 0.4
V10	6.83 \pm 0.1	6.67 \pm 0.0	3.59 \pm 0.2	4.24 \pm 0.2	2.40 \pm 0.1	2.84 \pm 0.1
V11	6.83 \pm 0.0	6.59 \pm 0.0	3.42 \pm 0.3	4.67 \pm 0.2	2.29 \pm 0.2	3.13 \pm 0.1
V12	6.71 \pm 0.1	6.54 \pm 0.0	2.66 \pm 0.7	4.16 \pm 0.5	2.40 \pm 0.0	2.78 \pm 0.4
V13	6.65 \pm 0.1	6.57 \pm 0.0	3.41 \pm 0.2	3.87 \pm 0.2	2.28 \pm 0.1	2.60 \pm 0.1
V14	6.64 \pm 0.0	6.52 \pm 0.1	3.20 \pm 0.4	4.40 \pm 0.2	2.28 \pm 0.1	2.95 \pm 0.3

The OM content reduced in all treatments, whether species were degraded individually and in mixtures of different ratios. The maximum OM loss was significantly ($P<0.05$) reduced as 53.08 \pm 5.2 % in V4 in which *Canna indica* was vermicompost with pig manure

in soil medium while without soil in V5, the reduction carried out were 15.27 \pm 4.3%. The initial and final values from V1-V4 are shown in Fig. 1a. While from V5 to V9 are represented in Fig. 1b.

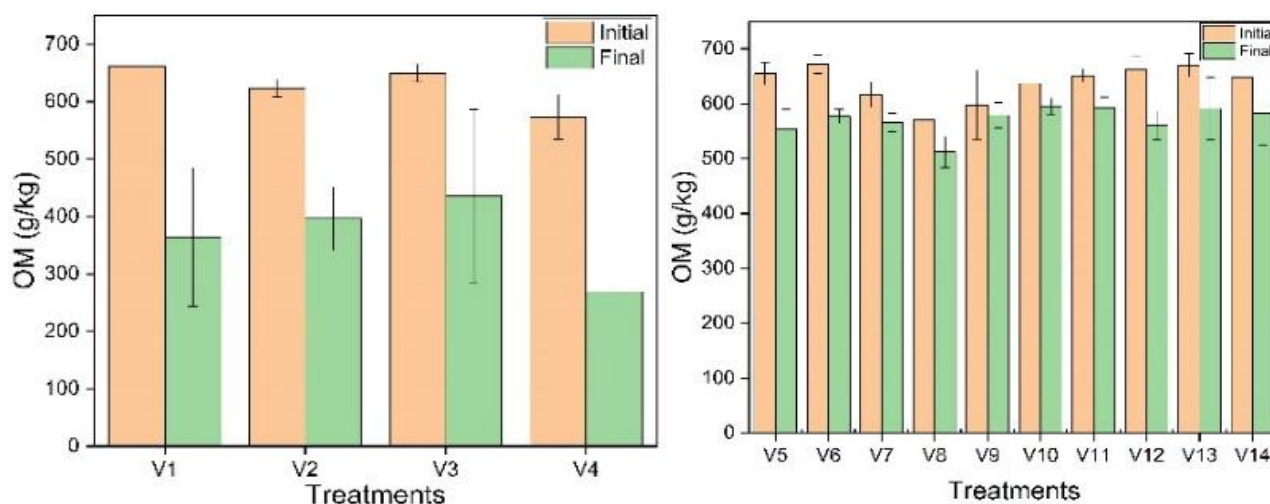


Fig. 1. (a) Organic matter (OM) from treatments V1-V4 (b) treatments V5-V14 during a vermicomposting period and bars represents standard deviations.

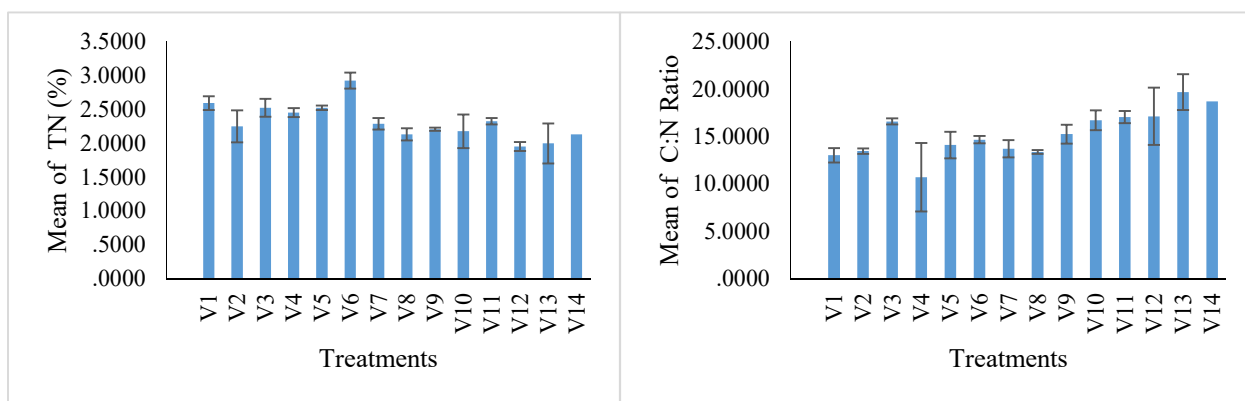
The decreased OM showed the degradation process of organic waste materials. The microbial activities and aeration enhanced OM loss (Dias *et al.*, 2010). In our study, the presence of earthworms accelerated the degradation process in all treatments,

which showed consistency with other studies (Hait and Tare, 2012).

Total nitrogen (TN) content increased in all treatments, but no significant difference was observed in intragroup statistical analysis (Table 3, Fig. 2a).

Table 3 Percentage increase of total nitrogen and decrease of total organic carbon and C:N ratios during vermicomposting (mean \pm SD, n=3).

Treatments	TOC (%)			TN (%)			C:N ratio (%)		
	Initial Value	Final value	% Decrease	Initial value	Final value	% Increase	Initial value	Final value	% Decrease
V1	38.35 \pm 1.1	21.14 \pm 8.5	44.87	1.56 \pm 0.1	2.59 \pm 0.2	66.02	24.57 \pm 2.5	13.01 \pm 1.1	46.68
V2	36.15 \pm 1.0	22.98 \pm 3.8	36.43	1.51 \pm 0.1	2.24 \pm 0.1	48.34	23.88 \pm 1.0	13.45 \pm 1.3	43.67
V3	37.70 \pm 1.1	25.29 \pm 7.1	32.91	1.30 \pm 0.2	2.25 \pm 0.4	73.07	29.85 \pm 6.5	16.58 \pm 0.4	44.45
V4	33.24 \pm 2.7	15.60 \pm 3.0	53.06	2.06 \pm 0.2	2.45 \pm 0.2	18.92	16.44 \pm 3.8	10.70 \pm 0.5	34.91
V5	37.96 \pm 1.4	32.16 \pm 2.5	15.27	2.18 \pm 0.5	2.52 \pm 0.1	15.59	18.19 \pm 5.0	14.09 \pm 6.2	22.53
V6	38.98 \pm 1.2	33.47 \pm 0.8	14.13	2.21 \pm 0.4	2.92 \pm 0.0	32.12	17.92 \pm 2.7	14.64 \pm 2.4	18.30
V7	35.76 \pm 1.6	32.79 \pm 1.2	8.30	2.23 \pm 0.2	2.28 \pm 0.2	2.24	14.13 \pm 1.3	13.69 \pm 0.6	3.11
V8	33.08 \pm 3.8	29.70 \pm 2.0	10.21	2.06 \pm 0.0	2.13 \pm 0.1	3.39	13.47 \pm 1.8	13.37 \pm 1.5	0.74
V9	34.67 \pm 4.4	33.59 \pm 1.6	3.11	1.64 \pm 0.4	2.20 \pm 0.1	34.14	22.59 \pm 7.0	15.24 \pm 0.3	32.53
V10	36.95 \pm 0.8	34.52 \pm 1.1	6.57	1.60 \pm 0.1	2.17 \pm 0.0	35.62	23.20 \pm 2.4	16.71 \pm 1.7	27.97
V11	37.76 \pm 0.8	34.32 \pm 1.3	9.11	1.58 \pm 0.1	2.32 \pm 0.4	46.83	24.00 \pm 2.9	17.04 \pm 1.8	29
V12	38.42 \pm 1.6	32.48 \pm 1.8	16.41	1.36 \pm 0.2	1.95 \pm 0.0	43.38	28.71 \pm 5.4	17.12 \pm 1.1	40.36
V13	38.86 \pm 1.5	34.28 \pm 4.0	11.78	1.13 \pm 0.0	1.99 \pm 0.1	76.10	34.28 \pm 3.4	19.65 \pm 5.2	42.67
V14	37.52 \pm 1.6	33.76 \pm 4.1	10.02	1.49 \pm 0.1	2.13 \pm 0.5	42.95	25.29 \pm 3.0	18.69 \pm 3.2	26.09

**Fig. 2.** (a) TN content in different treatments (b) C: N ratio of all treatments

Percentage change was also calculated over the initial, and V3 showed a maximum increase (73.07%) while V4 showed the minimum (18.92%). In the second and third groups, the maximum increase was observed in V6 (32.12%) and V13 (76.10%), respectively. An increase of 48% TN from initial cattle dung was reported by Jjagwe *et al.* (2019), while Bhat *et al.* (2015) observed about 49% increase in TN which is less than the increment of TN in V13 treatment of the current study. An increase in TN during whole vermicomposting duration can be attributed to several processes, i.e., decrease in produced dry mass, mechanisms of composting organic waste products having mutualistic approach between microorganisms and earthworms. The decomposition (Atiyeh *et al.*, 2000), ammonification is a process that releases inorganic nitrogen back into the ecosystem as ammonia during decomposition (Zhang and Sun, 2014). In the current study, the nitrogen increase in all treatments was supported in another study (Boruah *et al.*, 2019) that explained nitrogen increase with green wastes.

The carbon to nitrogen ratio for the three groups was also determined along with percentage change over the initials. Like TN, no significant difference was observed in intragroup statistical analysis. Percent change showed that the C/N ratio decreased around 46.68% in V1 that was found to maximum reduction as compared to other treatments. The maximum reduction in C:N ratio in the second and third groups was observed in V5 and V13, respectively. C/N reduction during a whole vermicomposting period of sewage sludge encouraged decreased loadings of total greenhouse gases to lessen the environmental loadings (Lv *et al.*, 2018). The C/N ratio is considered as a scale to determine the quality and maturation of vermicompost (Hait and Tare, 2011), and ideal C:N ratio is less than 20 (Hau *et al.*, 2005), and the results of the current study are in compliance with it.

Trends in reactive forms, dissolved organic carbon (DOC) and (NH_4^+ -N and NO_3^- -N) during vermicomposting: The dissolved organic carbon (DOC) in all treatments from

initial values to final vermicompost showed a reducing trend (Fig. 3a to 3c). It is an important parameter in vermicomposting processes, and the decrease in concentration is a reflection of enhanced decomposition (Ansari and Rajpersaud, 2012) and degradation of OM.

There was a gradual increase during the early stages in V8 (Fig. 3b), while after 45 days, little increase in DOC occurred probably because of CO₂ production during biological activities in composted piles (Christ and David, 1996).

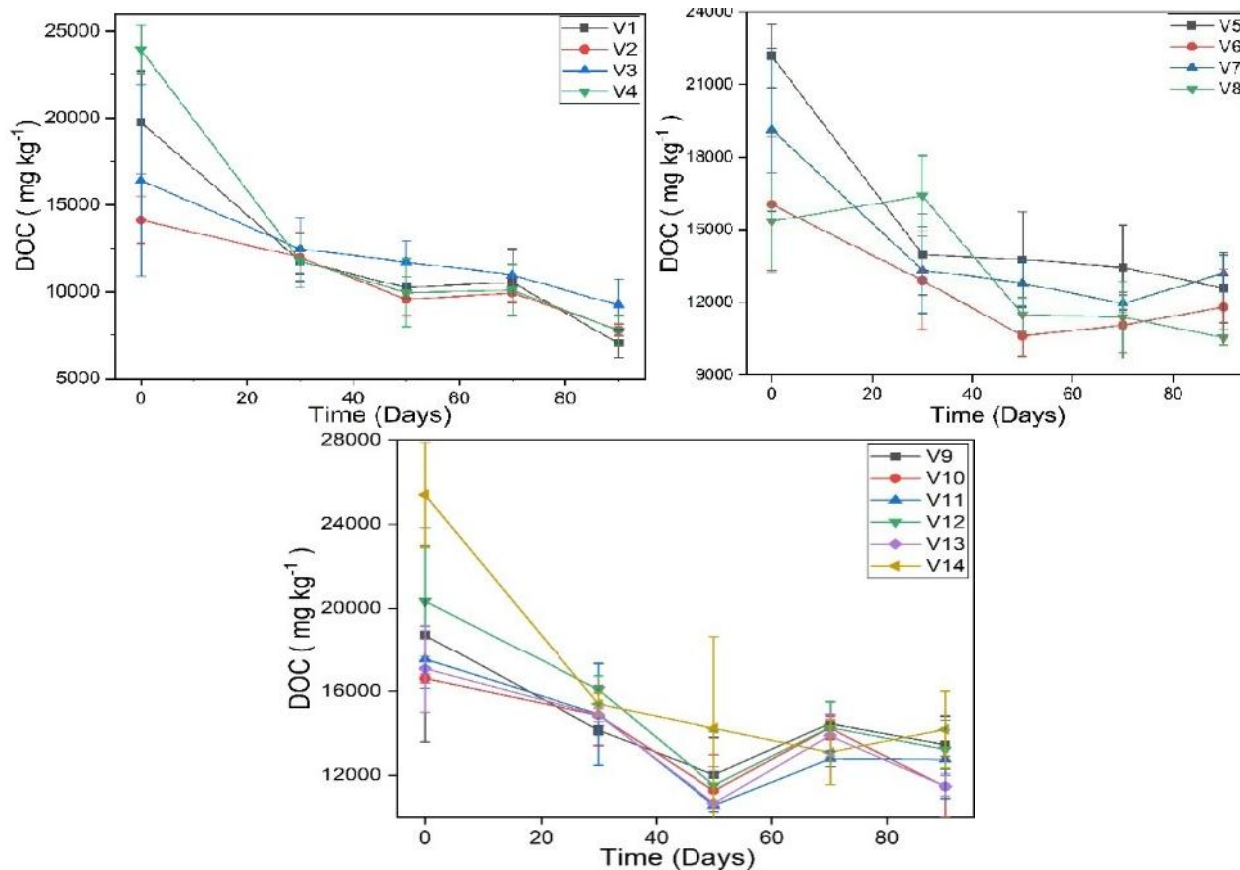


Fig. 3. (a) DOC from treatments V1-V4 (b) treatments V5-V8 (c) treatments V9-V14 during a vermicomposting period and bars represent standard deviations.

In the current research, DOC decreased very sharply except in V8 treatment. Then a gradual increase was observed, but the overall reduction was noted, and our results were in accordance with other scientists who worked on vermicomposting (Chen *et al.*, 2019; Wang *et al.*, 2016). Our results are similar to previous studies during vermicomposting in which DOC decreased significantly due to chemical and biological reactions in degrading organic waste materials (Aira *et al.*, 2007; Caricasole *et al.*, 2010; Lv *et al.*, 2013).

The trends of NH₄⁺-N in all treatments are shown in Fig. 4a to 4c during the degradation processes of wastes. The decreased contents of NH₄⁺-N were due to the transformation of ammonia to nitrate by nitrobacteria (Jiang *et al.*, 2016). The decreasing trend of NH₄⁺-N was

also supported during vermicomposting of sewage sludge (Lv *et al.*, 2018).

The dynamics of NO₃⁻-N content for all treatments increased in all treatments from its initial to a final value (Fig. 5a to 5c). It might be attributed due to nitrification processes within compost piles by earthworms' activities. Hence, our results are also accordingly (Lv *et al.*, 2018). The gradual increase in NH₄⁺-N was also observed after 65 days that may be attributed due to ammonia excretory products found in earthworms and can affect decreased hydrogen ions concentrations. The overall decrease in NH₄⁺-N and increase in NO₃⁻-N was also reported in earlier studies (Hanc and Chadimova, 2014).

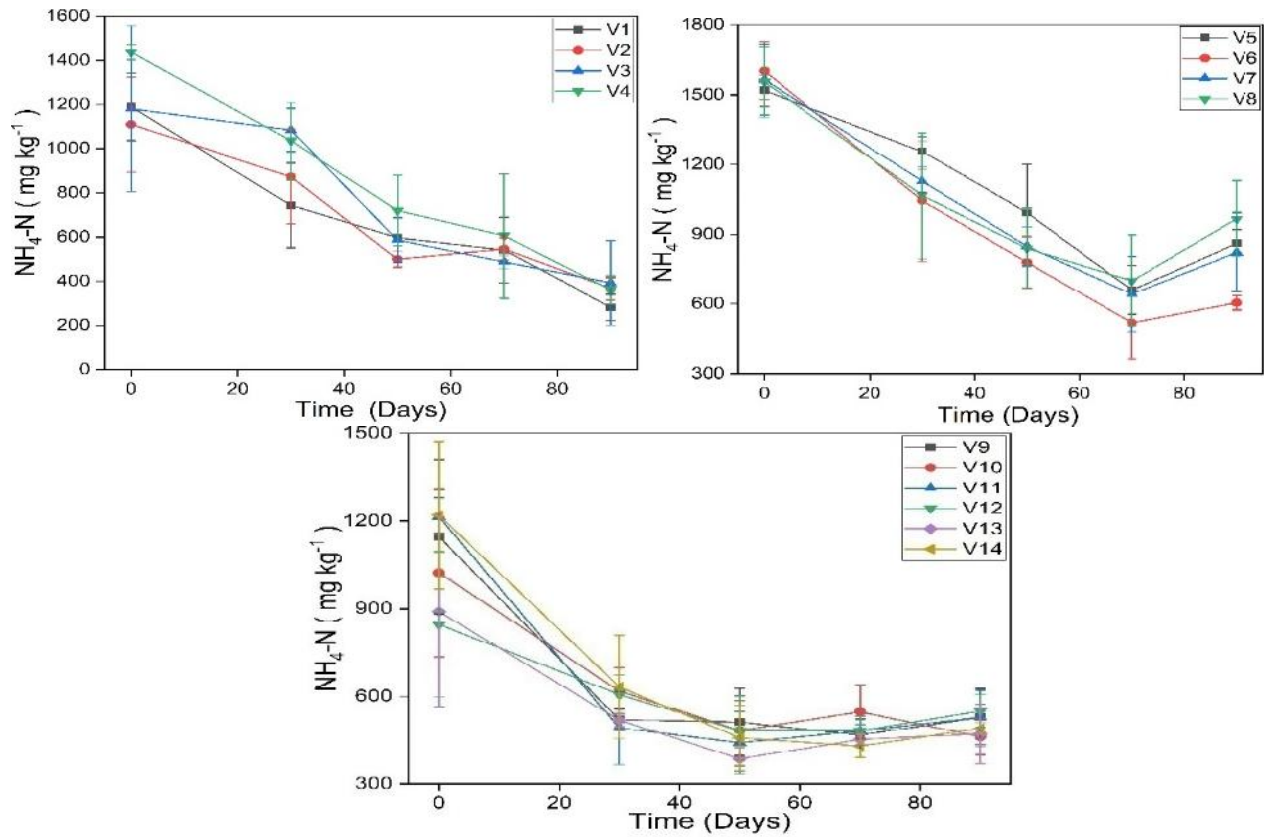


Fig. 4. (a) $\text{NH}_4\text{-N}$ from treatments V1-V4 (b) treatments V5-V8 (c) treatments V9-V14 during a vermicomposting period, and bars represent standard deviations.

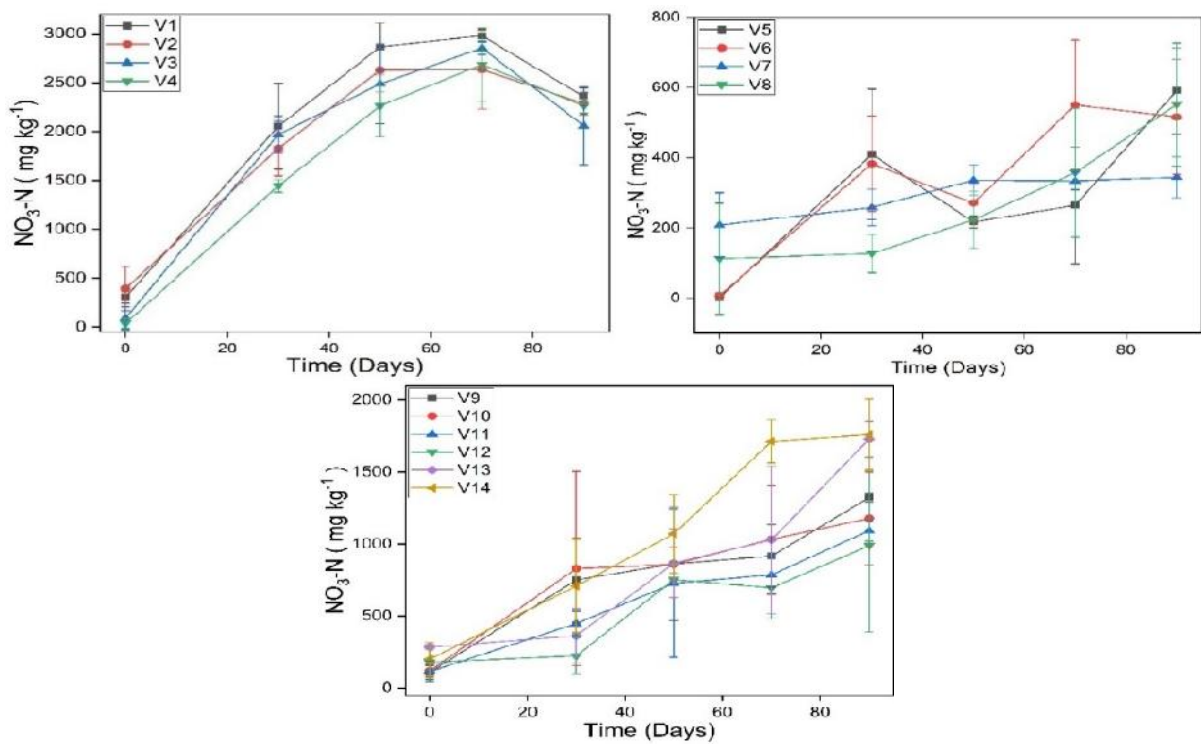


FIG. 5. (a) $\text{NO}_3\text{-N}$ from treatments V1-V4 (b) treatments V5-V8 (c) treatments V9-V14 during a vermicomposting period, and bars represent standard deviations.

Conclusion: The agricultural wastes and particularly wetland plants are known as non-point source pollution-rich in nutrients can be utilized for agroecosystems. Ecological ditch plants mixed with other crop residues in appropriate ratios can be utilized as better fertilizer by implications in soil fertility and plant growth. According to the combination of the results of *Zea mays* and *Canna indica* can be regarded as a suitable treatment for vermicomposting as it not only increased the nitrogen concentration but also decreased the carbon and C:N ratio significantly.

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