Eco. Env. & Cons. 29 (2) : 2023; pp. (896-903)
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ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2023.v29i02.059

Effect of seasonal variations on compost quality of *Eichhornia crassipes* and *Ipomoea carnea* with fish pond sediment

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(Received 16 November, 2022; Accepted 11 January, 2023)

ABSTRACT

Co-composting of invasive aquatic/wetland plants with sediment is an environment-friendly and cost-effective technique that can help in managing the socio-economic and ecological problems arising due to weed invasion and accelerated sedimentation. We hypothesize that the quality of composts prepared during different seasons may differ because of variations in environmental conditions. To test this hypothesis, we conducted a study that assessed the efficacy of compost prepared from two dominant aquatic/wetland invasive plant species (viz., *Eichhornia crassipes* and *Ipomoea carnea*) in India along with fish pond sediments as the bulking agent across two different seasons viz., summer and winter. Our study revealed a significant change in the compost quality with respect to seasons. We found that the compost quality was better during winter compared to summer season. The study therefore highlights some facts related to variations in the compost quality with respect to seasons and application of such information in fertility management of soil.

***Key words**: Eichhornia crassipes, Ipomoea carnea, Fish pond sediment, Compost quality, Seasonal variations*

Introduction

Invasion by alien species is the second major threat to global biodiversity following habitat loss (Park, 2004). In this context we would like to mention two dominant aquatic/wetland plants viz., *Eichhornia crassipes* and *Ipomoea carnea* which have turned out to be invasive in India (www.bsienvis.nic.in). These species degrade the habitat of native species, endanger biodiversity, affect aquaculture and agriculture, and hinder various ecosystems services (Center *et al*., 1999; Patel, 2012). It is also to be noted that sedimentation has become a potential source of pollution in aquatic systems including the fish farms particularly in tropical countries like India (Haque *et al*., 2016). When the sedimentation in aquatic systems is very high it leads to reduction in water depth (Dhal *et al*., 2011) leading to depletion of dissolved oxygen (Bhateria and Jain, 2016) and release of toxic elements (Smolders *et al*., 2010). All these have profound implications on the health of the aquatic communities (Misra and Chaturvedi, 2016) including the production of fishery resources and the ecosystem service potential of such aquatic ecosystem (Haines and Potschin, 2010). However, it may be mentioned that as fish pond sediment is enriched with organic matter, nitrogen, phosphorus, and various macro and micronutrients it can be a potential fertilizer supplement and soil conditioner (Prein, 2002; Shyam *et al.,* 2022).

Co-composting the selected invasive species with fish pond sediment may be one of the promising ways to manage these harmful plant species and potential harmful sediments in fish ponds. Composting uses naturally occurring microorganisms to convert biodegradable organic matter into a humus-like product and in the process destroys pathogens, and improves the nature of the waste materials (Tweib *et al.,* 2011). The significant role of pond sediment as bulking agent in compost preparation has earlier been mentioned by Karak *et al*. (2013) and Shyam *et al.*(2022).

In the present study we hypothesize that the quality of composts prepared during contrasting seasons of the year may differ because of the variations in environmental conditions. To test this hypothesis, we conducted a study that assessed the efficacy of compost prepared from the two dominant invasive species of India (viz., *Eichhornia crassipes* and *Ipomoea carnea*) and using fish pond sediment (FPS) as the bulking agent for the compost preparation.

For the present study we used three treatments for the compost preparation. These are:

(i) Treatment 1 (T1): 2.5 kg *Eichhornia crassipes* + 0.5 kg of FPS (5:1).

(ii) Treatment 2 (T2): 2.5 kg *Ipomoea carnea* + 0.5 kg of FPS (5:1).

(iii) Treatment 3 (T3): 1.25 kg *Eichhornia crassipes* + 1.25 kg *Ipomoea carnea* + 0.5 kg of FPS (2.5:2.5:1).

The basis of maintaining the typical proportions of the compost feed is based on earlier studies (Shyam *et al.,* 2022) which showed that the compost quality of both *E. crassipes*, and *I.carnea* was better when they were co-composted with FPS maintaining the ratio of 5:1. In addition, we added another treatment (T3) maintaining the ratio of 2.5:2.5:1 (*E. crassipes*: *I. carnea*: FPS; air dried w/w) to find out if there was farther improvement in the quality of the composite compost when FPS are added to both the plant species together in the compost feed under a single treatment. The objectives of the present study were to (i) find out the best combination of composite compost amongst the three treatments and to (ii) find out if there were any significant variations amongst the compost properties and their respective quality across two different seasons, namely summer and winter.

Materials and Methods

Raw materials

The raw materials used for compost preparation were *Eichhornia crassipes*, *Ipomoea carnea* and FPS. While *Eichhornia crassipes* (free-floating species) was collected from surface water of aquatic bodies, *Ipomoea carnea* (emergent species) was collected from the riparian region of the aquatic bodies. FPS (from a depth of 0-15cm) was collected from a fish pond. All the raw materials were collected from aquatic bodies located near Assam University campus in Silchar, Southern Assam, Northeast India across two seasons; summer (June-July) and winter (November-December) of the year 2017. During both the seasons immediately after their collection, *Eichhornia crassipes* and *Ipomoea carnea* were rinsed with distilled water and air dried under sun for one day and were cut into small pieces (3-5 cm) while FPS was air-dried for 24 hours. After that a portion of the raw materials were collected in sterilized polythene bags for their nutrient analyses and the remaining portion was used in the experimental set-up.

Experimental design

We followed a randomized block design comprising of three composting mixtures under three treatments with three replicates during each seasonal study. A total of nine earthen pots of the dimension of 52 cm x 22 cm (diameter x height) were used for compost preparation. The total amount of compost feed in each earthen pot was 3 kg. Aerobic composting method was used for compost preparation. All the compost feed under different treatments were put in different pots following the randomized block design. For uniform breakdown and faster decomposition, the compost feed was turned upside down on every 4th day. Sprinkling of water was done at 2 days interval to maintain the optimum moisture level in the compost feed. All the treatments were kept under shed to avoid the effect of sun and rain. The temperature of the compost feed was monitored daily throughout the compost preparation period until the compost attained maturity.

Determination of maturation of the compost

In order to avoid risk related to application of immature compost like inhibition of seed germination, solubility of heavy metals, spread of pathogen, immobilization of nutrients in the rhizosphere zone of soil (Jimenez and Garcia, 1992; Karak *et al.,* 2013; Shyam *et al.,* 2022), the compost feeds under different treatments were allowed to mature completely. Monitoring the maturation phase of the prepared compost was done by noting down the temperature and physical appearance of the compost on daily basis. The temperature of the compost feed under different treatments was noted down daily at 10 AM using mercury bulb thermometer. The maturation of the compost was first determined visually when the compost feed under each treatment turned into black 'soil type' materials without any smell with a stable thermal condition. Further, confirmation of maturation of the prepared compost was done immediately by germination study using chickpea seeds (*Cicer arietinum*). The compost feed is confirmed to be mature when the germination index of the test plant species is higher than 80% using water extract of compost under different treatments compared to the control (using distilled water) (Zucconi *et al*., 1985).

Determination of physico-chemical properties of the raw materials and matured compost under different treatments

The raw materials which were used as compost feed (FPS, *E. crassipes* and *I. carnea*) were analyzed for their nutrient contents like NPK, organic carbon, nitrate-nitrogen (NO_3-N) and phosphate-phosphorous (PO_4-P). On the other hand, the mature composts under different treatments were analyzed for their physical parameters like temperature, bulk density, and moisture content and chemical parameters like pH, conductivity, organic carbon, NO_3-N and PO_4-P. The temperature of the mature compost was noted down using a mercury bulb thermometer. Standard methods were followed for determination of bulk density (Mohee and Mudhoo, 2005), moisture content (Allen *et al.,* 1974), organic carbon (Walkley and Black, 1934), NO_3-N (Sparks, 1996), and PO_4-P (Anderson and Ingram, 1993). Determination of pH and conductivity were done using pH meter (make: Systronics; model: pH System 362) and conductivity meter (make: Systronics; model: Conductivity meter 308), respectively. For the raw materials, total nitrogen was determined using the Kjeldahl method (Kjeldahl, 1883), total phosphorous was determined using the colorimetric method (Sherman, 1942), and total potassium was determined using the flame photometer method (Barnes *et al.,* 1945).

Evaluation of quality of the matured compost under different treatments

The quality of the matured compost under different treatments was evaluated through seed germination experiment (Zucconi *et al*., 1985). A water extract from each of the composts under different treatments was prepared by mixing the matured compost samples with distilled water at 1:10 (w/v) ratio and shaking it for 1 hour in a shaker and then finally filtering the compost extract using filter paper. Ten millilitre (10 ml) of compost extract was applied to each Petri plate (9.5 cm diameter) containing 20 overnight pre-soaked chickpea seeds in distilled water. All replicates were run in triplicate with one triplicate set with distilled water which was treated as the control. Therefore, during every germination study, a total of 240 chickpea seeds (*Cicer arietinum*) were used with 20 chickpea seeds in each petri plate which were soaked overnight in distilled water. All the petri plates were kept at room temperature for 72 hours after which the germination index was calculated based on the values of seed germination and root elongation (Zucconi *et al*., 1985).

Statistical analysis

One-way ANOVA followed by post-hoc test was performed to find out if there were any significant variations in the properties of the raw materials and the different parameters of matured compost under different treatments during the respective seasons (summer and winter). Independent sample t-test was performed to find out if there were any significant variations in nutrient contents of the raw materials and the different parameters of the prepared compost across different seasons viz., summer and winter. Principal component analysis (PCA) was performed to identify the significant properties of the prepared compost which were responsible for characterizing the compost quality across the two seasons. All the statistical analyses were done using SPSS version 20.

Results and Discussion

Variations in physico-chemical properties of the raw materials used for preparation of the composts across different seasons

There was variation in the nutrient content of the selected raw materials during each season and also across different seasons for each of the selected raw materials. Interestingly, it was observed that during both the seasons, amongst all the raw materials, *I. carnea* had significantly greater values of total nitrogen, total phosphorus, total potassium, and phosphate-P while fish pond sediments had significantly greater values of organic carbon and nitrate-N (Table 1). Though there was an overall increase in nutrient contents of all the selected raw materials during winter however, significantly greater values were observed for total nitrogen and PO_4-P in FPS and *E. crassipes* and, organic carbon only in *E. crassipes* (Table 1). This indicates during winter the concentration of nutrients increases in aquatic systems and wetlands (Adeyemo *et al.*, 2008; Dalu *et al.*, 2019) leading to their greater absorption by the existing aquatic and wetland vegetation in such systems.

Variations in maturation time of composts under different treatments and across different seasons

During both the seasons the compost feeds under different treatments showed a similar pattern of peak and dip in temperature before they attained the thermal stability indicating their maturity, which was further confirmed immediately by the germination index study. We could observe seasonal variations in maturity of the compost feed under different treatments with speedy maturation during summer (20 weeks) in contrast to that of winter (22 weeks) (Figure 1) thereby revealing the fact that maturation rate of compost is related to seasonal fluctuations.

Variations in physico-chemical properties and quality of composts under different treatments and across different seasons

Amongst all the treatments significantly less values of bulk density, moisture content, conductivity and greater values of organic carbon and germination index was observed in the compost under Treatment 2 (T2) during both seasons viz., summer and winter (Table 2). The study showed that the properties and the quality of the compost varied from one treatment to the other. However, when compared for their quality it was observed that amongst all the treatments, the compost having *I. carnea* and FPS in the ratio 5:1 (T2) was the best combination. This is revealed by the significantly greater value of germination index of the test plant species, *Cicer arietinum*, when treated with the extract of the respective compost (T2) during both the seasons. This might be attributed to significantly greater concentration of nutrients in the selected raw materials viz., *I. carnea* (where the concentration of NPK, and PO_4-P were significantly greater) and FPS (where the concentration of organic carbon and NO_3-N were significantly greater) (Table 1). However, it might be mentioned here that when the compost properties under T2 during both seasons were compared with the relevant standard (Fertilizer Control Order, 2013, Ministry of Agriculture, Government of India; source: www.indiacode.nic.in) it was observed that the moisture content was quite high while pH was quite low. Nevertheless, the problem of high moisture content and low pH in such compost can be potentially resolved by air drying the composts for 24 hours under natural environment (Shyam *et al.*, 2022).

When season-wise variations in the properties and quality of the compost was considered, it was

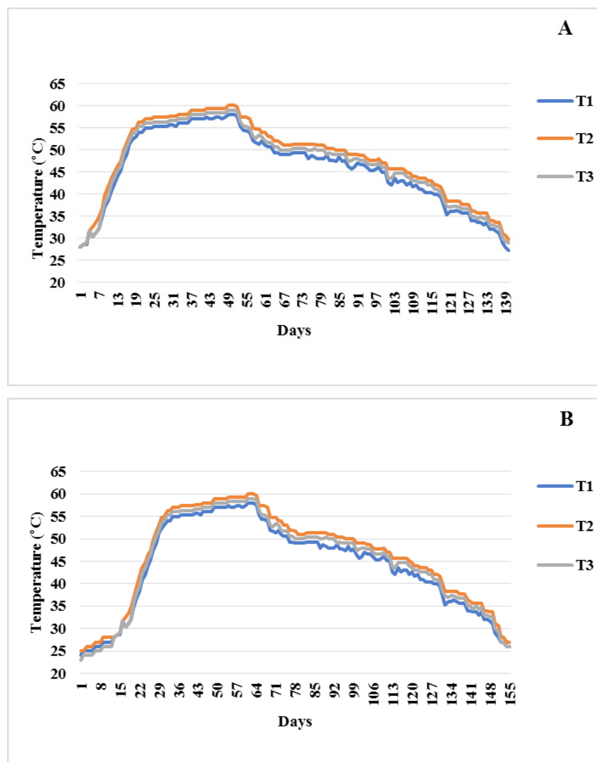

Fig. 1. Daily variations in temperature of the compost feed under different treatments till its maturation during (A) summer and (B) winter seasons respectively; T1 indicates treatment including *E. crassipes* and fish pond sediment in the ratio of 5:1; T2 indicates treatment including *I. carnea* and fish pond sediment in the ratio of 5:1; T3 indicates treatment including *E. crassipes*, *I. carnea* and fish pond sediment in the ratio of 2.5:2.5:1

Table 1. Seasonal variations in nutrient contents of different types of raw materials used for preparation of compost. And, one-way ANOVA showing significant variations in nutrient contents of the raw materials with their types as the main effect variable during summer and winter seasons while t-value indicating the extent of seasonal variations in nutrient contents of the raw materials

Parameters	Types of raw materials	Nutrient content		t-value
		Values during summer	Values during winter	
Total nitrogen(%)	Fish pond sediment (FPS)	0.79±0.008 [a] (0.78-0.81)	0.93±0.02 [a] (0.89-0.99)	-4.421*
	Eichhornia crassipes (*E. crassipes*)	1.23±0.01 [b] (1.21-1.25)	1.41±0.01 [b] (1.39-1.44)	-9.878**
	Ipomoea carnea (*I. carnea*)	2.8±0.07 [c] (2.69-2.94)	3±0.11 [c] (2.8-3.2)	-1.185
Total phosphorous (%)	Fish pond sediment (FPS)	0.02±0.005 [a] (0.01-0.03)	0.04±0.006 [a] (0.03-0.05)	-2.449
	Eichhornia crassipes (*E. crassipes*)	0.1±0.006 [a] (0.09-0.11)	0.12±0.01 [b] (0.1-0.14)	-1.250
	Ipomoea carnea (*I. carnea*)	0.33±0.03 [b, c] (0.27-0.38)	0.4±0.009 [c] (0.39-0.42)	-2.059
Total potassium(%)	Fish pond sediment (FPS)	0.02±0.003 [a] (0.01-0.02)	0.03±0.006 [a] (0.02-0.04)	-2.000
	Eichhornia crassipes (*E. crassipes*)	2.67±0.07 [b] (2.55-2.8)	2.96±0.08 [b] (2.8-3.1)	-2.554
	Ipomoea carnea (*I. carnea*)	3.25±0.17 [c] (2.98-3.56)	3.42±0.17 [b] (3.1-3.67)	-0.713
Organic carbon (%)	Fish pond sediment (FPS)	5.8±0.11 [a] (5.6-6)	6.3±0.17 [a] (5.98-6.6)	-2.359
	Eichhornia crassipes (*E. crassipes*)	2.59±0.02 [b] (2.56-2.63)	2.9±0.08 [b] (2.7-3)	-3.021*
	Ipomoea carnea (*I. carnea*)	3.29±0.04 [c] (3.21-3.37)	3.41±0.06 [c] (3.3-3.5)	-1.525
Nitrate-nitrogen (%)	Fish pond sediment (FPS)	2.03±0.14 [a] (1.8-2.3)	2.28±0.09 [a] (2.1-2.4)	-1.436
	Eichhornia crassipes (*E. crassipes*)	1.05±0.10 [b] (0.84-1.2)	1.27±0.25 [b, c] (0.8-1.65)	-0.833
	Ipomoea carnea (*I. carnea*)	1.21±0.17 [b, c] (0.9-1.5)	1.33±0.22 [c] (0.89-1.6)	-0.416
Phosphate-phosphorus(%)	Fish pond sediment (FPS)	0.21±0.003 [a] (0.2-0.21)	0.26±0.003 [a] (0.25-0.26)	-10.607**
	Eichhornia crassipes (*E. crassipes*)	0.31±0.14 [b] (0.29-0.34)	0.4±0.11 [b, c] (0.38-0.42)	-4.670**
	Ipomoea carnea (*I. carnea*)	0.39±0.2 [c] (0.36-0.43)	0.42±0.14 [c] (0.41-0.47)	-1.170

Mean±SE; n=3; for f-ratio degree of freedom (n-1) =2; mean values of the respective parameters under different treatments with similar alphabet(s) are not significantly different from each other whereas mean values of the respective parameters under different treatments with dissimilar alphabet(s) are significantly different from each other ($p<0.05$; as per Tukey's post hoc analysis); for t-test, degree of freedom=4; **$p<0.01$; *$p<0.05$

observed that in all the treatments, viz., T1, T2 and T3, significantly less values in compost temperature, bulk density and organic carbon with significantly higher value in germination index was observed during winter. On the other hand, in T1 significantly higher value in NO_3-N was observed during winter. And, in T2 and T3 significantly less values were observed for pH and conductivity respectively during winter (Table 2). The results revealed that the properties as well as the quality of the mature compost under different treatments varied across seasons. Further analyses using PCA revealed that during

Table 2. Seasonal variations in physico-chemical properties of the prepared compost and their respective germination index values under different treatments. And, one-way ANOVA showing significant variations in compost parameters with treatments as the main effect variable during summer and winter seasons while t-value indicating the extent of seasonal variations in physico-chemical properties of the prepared compost and their respective germination index values

Physico-chemical properties	Treatments	Values during summer	Values during winter	t-value
Temperature (CT; °C)	T1	27±0 [a] (27-27)	25±0.58 [a] (24-26)	3.464*
	T2	28±0[a] (28-28)	25.33±0.33 [a] (25-26)	8.000**
	T3	28±0[a] (28-28)	25.33±0.33 [a] (25-26)	8.000**
Bulk density (BD; g cm^{-3})	T1	1.39±0.01[a] (1.37-1.41)	1.3±0.01 [a] (1.28-1.31)	6.424**
	T2	1.3±0.01[a, b] (1.27-1.32)	1.24±0.01 [b] (1.23-1.26)	3.138*
	T3	1.35±0.02[a] (1.31-1.39)	1.27±0.01 [a, b] (1.25-1.28)	3.371*
Moisture content (MC; %)	T1	46.9±0.38[a] (46.2-47.5)	45.34±0.61 [a] (44.13-46)	2.175
	T2	39.7±1.75[a, b] (37-43)	38.99±0.64 [b] (37.8-40)	0.376
	T3	45.49±1.53[a] (42.8-48.1)	42.61±0.55 [c] (41.9-43.7)	1.775
pH	T1	5.52±0.09[a] (5.34-5.66)	5.23±0.07 [a] (5.12-5.38)	2.353
	T2	5.6±0.01[a] (5.58-5.62)	4.89±0.2 [a] (4.48-5.14)	3.431*
	T3	5.3±0.15[a] (5-5.53)	5.16±0.06 [a] (5.09-5.28)	0.880
Conductivity (Cond.; μS cm^{-1})	T1	480.32±10.01[a] (468.99-500.3)	467.26±20.48 [a] (431-501.88)	0.573
	T2	301.47±18.76[b] (269.8-334.76)	271.93±14.22 [b] (250.8-299)	1.254
	T3	432.68±2.45[a, c] (428.4-436.9)	375.88±10.73 [c] (355-390.67)	5.157**
Organic carbon (OC; %)	T1	1.58±0.03[a] (1.52-1.65)	1.31±0.02 [a] (1.28-1.34)	6.608**
	T2	3.27±0.03[b] (3.2-3.32)	2.5±0.17 [a] (2.2-2.8)	4.337*
	T3	2.85±0.17 [b, c] (2.5-3.04)	1.87±0.02 [a] (1.82-1.9)	5.564**
Nitrate-nitrogen (Nitrate-N; %)	T1	2.67±0.38[a] (1.92-3.2)	4.42±0.13 [a] (4.29-4.68)	-4.301*
	T2	4.60±0.70[a] (3.39-5.83)	5.04±0.16 [a] (4.79-5.33)	-0.610
	T3	4.22±0.38[a] (3.56-4.9)	4.74±0.37 [a] (4.18-5.35)	-1.011
Phosphate-phosphorus (Phosphate-P; %)	T1	0.60±0.19[a] (0.27-0.93)	1.06±0.16 [a] (0.82-1.35)	-1.859
	T2	1.43±0.32[a] (0.79-1.82)	1.58±0.31 [a] (1.05-2.11)	-0.353
	T3	0.98±0.23[a] (0.57-1.38)	1.26±0.21 [a] (0.99-1.68)	-0.885

Table 2. *Continued ...*

Physico-chemical properties	Treatments	Values during summer	Values during winter	t-value
Germination index	T1	84.3±0.60 [a] (83.11-85.01)	88.47±0.80 [a] (87.3-90)	-4.179*
	T2	92.79±0.21[b] (92.38-93.1)	97.09±1.11 [b] (95-98.8)	-3.788*
	T3	83.43±0.83 [a] (81.89-84.73)	89.96±1.18 [a] (87.9-92)	-4.525*

Mean±SE; n=3; for f-ratio degree of freedom (n-1) =2; mean values of the respective parameters under different treatments with similar alphabet (s) are not significantly different from each other whereas mean values of the respective parameters under different treatments with dissimilar alphabet(s) are significantly different from each other (p<0.05; as per Tukey's post hoc analysis); for t-test, degree of freedom =4; **p<0.01; *p<0.05; T1 indicates treatment including *E. crassipes* and fish pond sediment in the ratio of 5:1; T2 indicates treatment including *I. carnea* and fish pond sediment in the ratio of 5:1; T3 indicates treatment including *E. crassipes*, *I. carnea* and fish pond sediment in the ratio of 2.5:2.5:1

Table 3. Loading of variables on principal components rotated according to the Varimax method for compost properties prepared under different treatments during summer and winter seasons respectively

	Compost properties	Summer		Winter	
		VF1	VF2	VF1	VF2
Loading scores	Temperature	-.834	.244	.259	.894
	Bulk density	.963	.215	.981	-.036
	Moisture content	.913	.157	.967	-.227
	pH	.051	.701	.870	.247
	Conductivity	.941	-.156	.956	-.271
	Organic carbon	-.847	.437	.941	.242
	Nitrate-nitrogen	.051	.955	-.203	.942
	Phosphate-phosphorus	-.415	.883	-.057	.954
Eigen value		4.236	2.528	4.563	2.843
% of Variance		52.953	31.605	57.043	35.537
% of Cumulative variance		52.953	84.557	57.043	92.580

VF, Variance factor

summer, temperature was the dominant factor in characterising the compost quality, while during winter it was the pH which characterised the compost quality (Table 3). The growth performance of the test plant species, *Cicer arietinum* varied significantly across the two seasons with significantly greater value during winter (Table 2) thereby indicating that the quality of the composite compost prepared out of *Eichhornia crassipes* and *Ipomoea carnea* with fish pond sediments is always better during winter.

Conclusion

Our study showed that maturation of compost prepared from aquatic/wetland plant(s) and aquatic sediment takes place at a faster rate during summer as compared to winter. The study also showed that amongst the three treatments of the prepared compost [Treatment 1- *E. crassipes* and FPS in the ratio 5:1 (w/w); Treatment 2- *I. carnea* and FPS in the ratio 5:1 (w/w); and, Treatment 3- *I. carnea*, *E. crassipes* and FPS in the ratio 2.5:2.5:1 (w/w)], the quality of compost under T2 was the best in both seasons. However, when the quality of compost under T2 was compared across seasons we could observe its better quality during winter. The present study therefore highlights some facts related to variations in compost quality prepared from aquatic/wetland plant(s) and aquatic sediment with respect to seasons and application of such information in fertility management of soil.

Acknowledgements

The authors are thankful to the Head, Department of Ecology and Environmental Science, Assam University, Silchar for providing infrastructure facilities for undertaking this research.

Conflict of interest statement

The authors declare no conflict of interest.

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