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Vermicomposting of Fresh Water Weeds (Macrophytes) by *Eisenia fetida* (Savigny, 1826), *Aporrectodea caliginosa trapezoides* (Duges, 1828) and *Aporrectodea rosea rosea* (Savigny, 1826)

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ABSTRACT

A study was conducted to evaluate the efficiency of *Eisenia fetida*, *Aporrectodea caliginosa trapezoides* and *Aporrectodea rosea rosea* in recycling of macrophytes (fresh water weeds). *E. fetida* indicated 100%, *A. c. trapezoides* 53.66 ± 0.88% and *A. r. rosea* 33.66 ± 1% recycling potential at the end of a 60-day study period. A significant increase in number (285 ± 7.63%) and biomass (69.16 ± 2.06%) was exhibited by *E. fetida* compared to *A. c. trapezoides* (95 ± 7.63% and 11.95 ± 1.12%) and *A. r. rosea* (45 ± 3% and 8.82 ± 2.53%). Significant variation in cocoon production ($P < 0.05$) among these species was also observed. Vermicompost obtained by 60 days indicated an increase in potassium (19 ± 0.6 µg/g to 37.33 ± 0.90 µg/g), available phosphorous (324 ± 4.93 µg/g to 600 ± 7.93 µg/g) and organic nitrogen (5.53 ± 0.18 g/kg to 8.06 ± 0.17 g/kg), but a decline in organic carbon (576.66 ± 14.52 g/kg to 156.23 ± 8.51 g/kg) and mineralization (C:N ratio) (104.27 ± 5.58 to 19.38 ± 0.14) in the order: *E. fetida* > *A. c. trapezoides* > *A. r. rosea*. Significant variation ($P < 0.05$) in pH, organic carbon, organic nitrogen, C:N ratio were observed during the same time period. *E. fetida* has a relatively higher potential of recycling macrophytes among the three earthworm species.

Keywords: cocoon, earthworms, efficiency, macrophytes, recycling, species
Abbreviations: ACT, *Aporrectodea caliginosa trapezoides*; **ANOVA**, analysis of variance; **ARR**, *Aporrectodea rosea rosea*; **C:N ratio**, carbon to nitrogen ratio; **EF**, *Eisenia fetida*; **g/kg**, gram per kilogram; **K**, potassium; **µg/g**, microgram per gram; **mS/cm**, milli Simons per centimeter; **OC**, organic carbon; **ON**, organic nitrogen; **P**, phosphorous

INTRODUCTION

The impact of excessive nutrients on aquatic systems is recognized as a serious global problem, with nutrients, primarily nitrogen and phosphorus, reaching these systems from rapidly expanding urban areas, besides adverse disturbances in catchment areas such as agricultural and industrial activities (Hu *et al*. 2008). These nutrient inputs trigger cultural eutrophication, resulting in dominance of aquatic macrophytes which in turn lead to loss of key stone species, in addition to widespread degradation of aquatic ecosystems (Chase and Knight 2006). Over the last few years, the problem of efficient disposal and/or management of macrophytes has become more rigorous due to accelerated eutrophication resulting in the rapid growth of macrophytes. Production of large quantities of organic wastes (macrophytes) poses major environmental (offensive odors) and disposal problems (Khajuria *et al*. 2010), making their disposal a very important issue for maintaining a healthy environment (Erdogan *et al*. 2008). Although various physical, chemical and biological disposal methods of organic solid wastes are currently in use, these methods are either time consuming or involve high costs. In this regard, vermicomposting, being a viable, cost effective and ecofriendly technique for the efficient management of the organic solid wastes (Garg *et al*. 2006), is advocated.

Though approximately 4,400 diverse species of earthworms have been identified worldwide (Sinha 2009) and even though Julka *et al.* (2009) reported 590 species of earthworms from India, only 8% of these species were documented for their efficiency in recycling of organic substrates (Karmegam and Daniel 2009).

Earthworms, based on their ecology, differ greatly in their ability to digest organic wastes (Lattaud *et al*. 1998). Research studies have demonstrated earthworm species to consume a wide range of organic wastes such as crop residues, sewage sludge, oil palm waste, hospital waste (organic), pine apple waste, livestock excreta, human faeces and industrial refuse (Gupta and Garg 2008; Yadav and Garg 2009; Mainoo *et al*. 2009; Hayawin *et al*. 2010; Indrajeet *et al*. 2010; Pramanik and Chung 2010; Yadav *et al*. 2010). Several epigeic (*Eisenia fetida*, *Eisenia andrei*, *Eudrilus eugeniae*, *Perionyx excavatus* and *Perionyx sansibaricus*) and few anecic earthworms (*Lampito mauritii* and *Lumbricus terrestris*) have been identified as potential candidates to decompose organic waste materials (Garg and Kaushik 2005; Suthar 2007; Karmegam and Daniel 2009).

The premise for using locally available species of earthworms in vermicomposting is gaining importance because of their adaptability and suitability in converting organic materials into valuable vermicasts (Karmegam and Daniel 2009). Realizing the hazards of using alien species (Mackenzie 1991; Kaviraj and Sharma 2003), it is extremely unwarranted and undesirable to tamper with local biodiversity (Ismail 1995).

Keeping in view the above facts, three locally available earthworm species – *E. fetida*, which is an epigeic species and *A. c. trapezoides* and *A. r. rosea*, both endogeic species – were chosen to study their relative potential in the vermicomposting of macrophytes.

Received: 30 March, 2011. Accepted: 19 September, 2011.

Original Research Paper

MATERIALS AND METHODS

Macrophytes

Macrophytes collected from the three lakes of Kashmir Valley, i.e., Dal Lake, Khushalsar Lake and Anchar Lake, were brought to the laboratory washed thoroughly with tap water followed by ethylenediamine tetra acetic acid (EDTA) solution (0.01M) and finally rinsed with deionized water (Gupta 1999). After removing the adhered material, they were segregated, identified (Kak 1989) and allowed to drain excess water for 2 days under sunlight and further dried in an oven at 70°C for 24 h.

Earthworm cultures

The three earthworm species, *E. fetida*, *A. c. trapezoides* and *A. r. rosea* are the most widespread earthworm species of the Kashmir valley (Najar and Khan 2011). All three earthworm species were collected from several cultures maintained in the laboratory, where cow dung is used as feed. Earthworm biomass reported as live weight is measured after rinsing adhered material off and blotting earthworms dry.

Vermireactors

Circular plastic tubs (43 cm × 30 cm) were used as reactors into each of which 20 healthy and adult earthworms were introduced. 100 g of dried macrophytes (weed) and 20 g of cow dung (w/w dry weight) were added to each reactor. Reactors were run in triplicates for 15-, 30-, 45- and 60-day intervals. To assess the potential of composting the weed by these 3 earthworm species in relation to time, experiments were terminated at the end of 15, 30, 45 and 60 days and observations were noted in terms of amount of weed recycled, increase in number and biomass of earthworms and cocoon production. Earthworms were sorted from reactors by hand. The conversion rate was calculated after separating left-over weeds from vermicasts.

Vermicasts

Vermicast samples collected at the end of 60 days were air dried at room temperature and then kept in labeled air-tight containers for further use. They were analyzed for pH, electrical conductivity (EC) and organic nitrogen (ON) by the micro-Kjeldahl method (Jackson 1973), organic carbon (OC) (Walkley and Black 1934), potassium (K) by flame photometry (Simard 1993) and phosphorous (P) by spectrophotometry (Anderson and Ingram 1993).

Statistical analyses

The objective was to evaluate significant differences among pH, EC, K, P, OC, ON and C:N ratio of 3 different species of vermicasts over 4 different time periods. Hence, the experiment was replicated three times per species for each time duration and the arithmetic mean of the values was obtained. Thereafter, the analysis of variance (ANOVA) with statistical differences assessed at $P < 0.05$ (Zar 2009). All statistical analyses were performed using the SPSS statistical software (Version 16) and Sigma plot (Version 11) for Windows 7.

RESULTS

Results of all the analyzed parameters of vermicasts obtained after recycling of macrophytes by *E. fetida*, *A. c. trapezoides and A. r. rosea* during different time periods (15, 30, 45 and 60 days, each equivalent to one fortnight) are presented in **Fig. 1**.

pH ranged from 6.9 ± 0.06 to 7.7 ± 0.06, 6.9 ± 0.06 to 7.5 ± 0.05 and 6.7 ± 0.05 to 7.4 ± 0.06 in vermicasts of *E. fetida*, *A. c. trapezoides* and *A. r. rosea*, respectively during different fortnights (**Fig. 1A**).

EC indicated a value from 0.50 ± 0.02 to 0.71 ± 0.02 mS/cm, 0.45 ± 0.02 to 0.60 ± 0.02 mS/cm and 0.40 ± 0.02 to 0.55 ± 0.02 mS/cm in vermicasts of *E. fetida*, *A. c. trapezoides* and *A. r. rosea*, respectively during different fortnights (**Fig. 1B**).

Concentration of K ranged from 29.33 ± 0.9 to 37.33 ± 0.9 mg/g, 27.33 ± 1.45 to 35 ± 0.6 mg/g and 19 ± 0.6 to 29.66 ± 1.2 mg/g in vermicasts of *E. fetida*, *A. c. trapezoides* and *A. r. rosea*, respectively during different fortnights (**Fig. 1C**).

Available P had values ranging from 456.43 ± 10.32 to 600 ± 7.93 µg/g, 400 ± 10.50 to 523.66 ± 9.40 µg/g and 324 ± 4.93 to 401.33 ± 10.17 µg/g in vermicasts of *E. fetida*, *A. c. trapezoides* and *A. r. rosea*, respectively during different fortnights (**Fig. 1D**).

OC decreased from 441.13 ± 14.10 to 156.23 ± 8.51 g/kg, 480 ± 11.54 to 246.66 ± 14.52 g/kg and 576.66 ± 14.52 to 280 ± 17.32 in vermicasts of *E. fetida*, *A. c. trapezoides* and *A. r. rosea*, respectively during different fortnights (**Fig. 1E**).

There was an increase in ON from 4.97 ± 0.11 to 8.06 ± 0.32 g/kg, 5.34 ± 0.17 to 7.28 ± 0.24 g/kg and 5.53 ± 0.18 to 7 ± 0.17 g/kg in vermicasts of *E. fetida*, *A. c. trapezoides* and *A. r. rosea*, respectively during different fortnights (**Fig. 1F**).

Stability of C:N ratio was observed which ranged from 88.75 ± 2.44 to 19.38 ± 0.14, 89.88 ± 3.14 to 33.88 ± 2.63 and 104.27 ± 5.58 to 40 ± 1.37 in vermicasts of *E. fetida*, *A. c. trapezoides* and *A. r. rosea*, respectively during different fortnights (**Fig. 1G**).

ANOVA indicated significant variation ($P < 0.05$) in pH, EC, K, P, OC and C:N ratio among the vermicasts of the species and during different time period ($P < 0.05$). However, in the case of ON significant variation ($P < 0.05$) was observed only during the time period of 60 days.

Mean body weight was 0.64 ± 0.02 g in *E. fetida*, 0.53 ± 0.02 g in *A. c. trapezoides* and 0.15 ± 0.01 g in *A. r. rosea* (**Fig. 2A**). Mean growth rate was 3.11 ± 0.28 mg/worm/day) in *E. fetida*, 0.38 ± 0.06 mg/worm/day in *A. c. trapezoides* and 0.15 ± 0.03 mg/day *A. r. rosea* (**Fig. 2B**). The percentage of relative growth rate was 14.74 ± 1.39% in *E. fetida*; 1.93 ± 0.29% in *A. c. trapezoides* and 1.19 ± 0.30% in *A. r. rosea* (**Fig. 2C**).

Relative increase in earthworm number was 285 ± 7.63% in *E. fetida*, 95 ± 7.63% in *A. c. trapezoides* and 45 ± 3% in *A. r. rosea* (**Fig. 3A**) which was significant ($F = 6.58$, $P < 0.05$) among the species, though there was no significant variation in number during different fortnights. Increase in biomass was observed in *E. fetida* (69.16 ± 2.06%) and in *A. c. trapezoides* (11.95 ± 1.12%), only a decrease in *A. r. rosea* (8.82 ± 2.53%) (**Fig. 3B**). Variation in biomass was significant ($F = 21.03$, $P < 0.05$) among the species, with no significant variation ($F = 2.97$, $P < 0.05$) during the time period (60 days).

Cocoon production started after 15 days in both *E. fetida* and *A. c. trapezoides*, but after 45 days in the case of *A. r. rosea*, varying from 93 ± 6.06 to 174.7 ± 7.9 in *E. fetida*, 11.33 ± 1.76 to 54 ± 2.08 in *A. c. trapezoides* and 1.67 ± 3.3 to 15 ± 1.73 in *A. r. rosea* (**Fig. 3C**). The appearance of juveniles started after 30 days in *E. fetida*, after 45 days in *A. c. trapezoides* and after 60 days in *A. r. rosea* (**Fig. 3D**). Among these three species after 60 days recycling of macrophytes was 100% in the epigeic *E. fetida*, and it was 53.66 ± 0.88% and 33.66 ± 1% in the endogeic *A. c. trapezoides* and *A. r. rosea* (**Fig. 4**), respectively.

DISCUSSION

The marginal increase in pH with time interval and the overall increase in pH could be due the decomposition of ammonia, which forms a larger proportion of nitrogenous matter excreted by earthworms (Muthukumaravel *et al*. 2008).

EC indicated increasing trend from first fortnight to fourth fortnight but maximum increase was in the *E. fetida*-mediated treatment and minimum in the *A. r. rosea* treatment. The results corroborate the study of Kaviraj and Sharma (2003) where an increase in EC of vermicast during time interval was reported. Increase in EC with time inter-

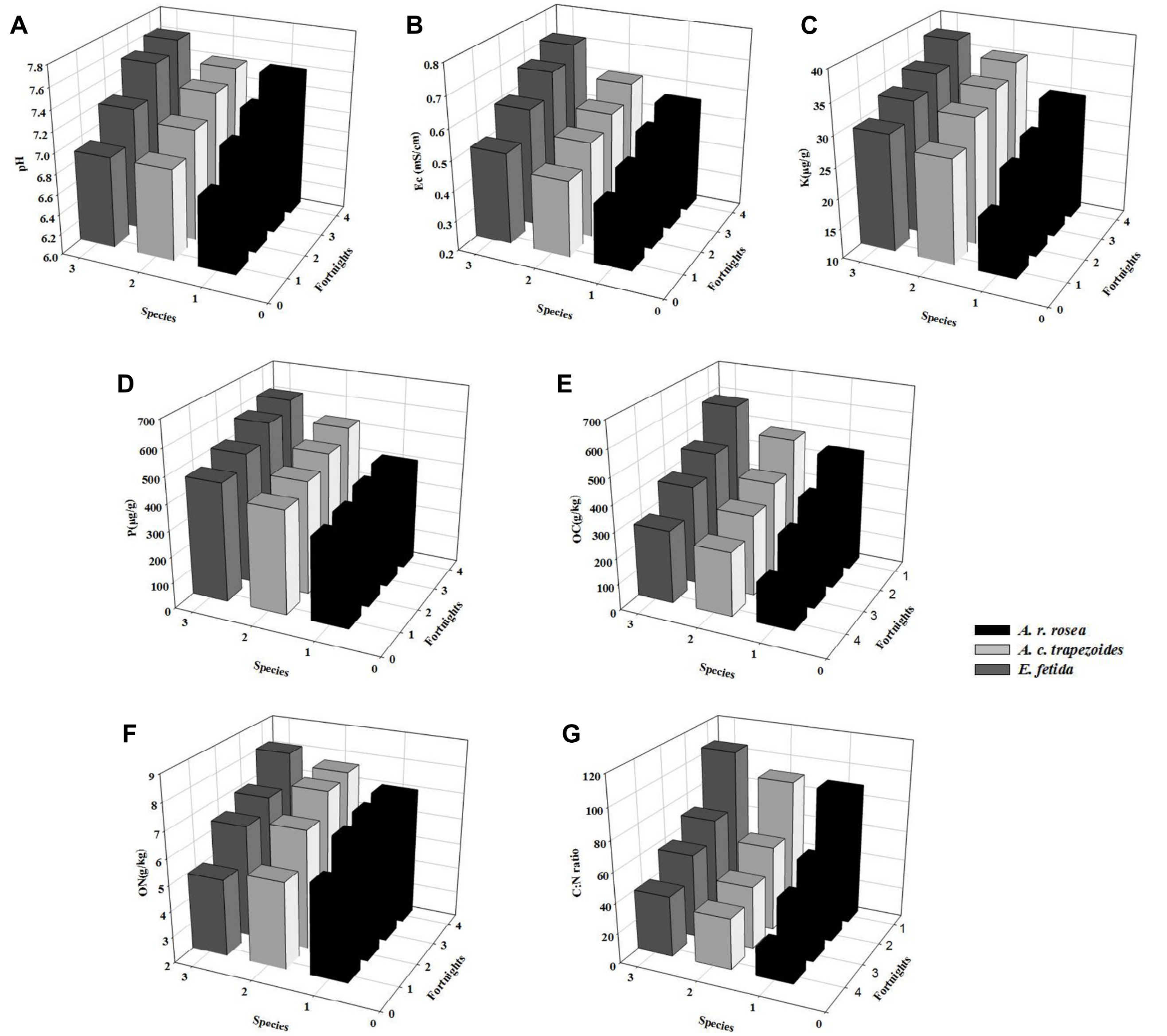

Fig. 1 3D graphs showing characteristics of vermicompost of recycled macrophytes during different fortnights by *E. fetida*, *A. c. trapezoides* and *A. r. rosea.*

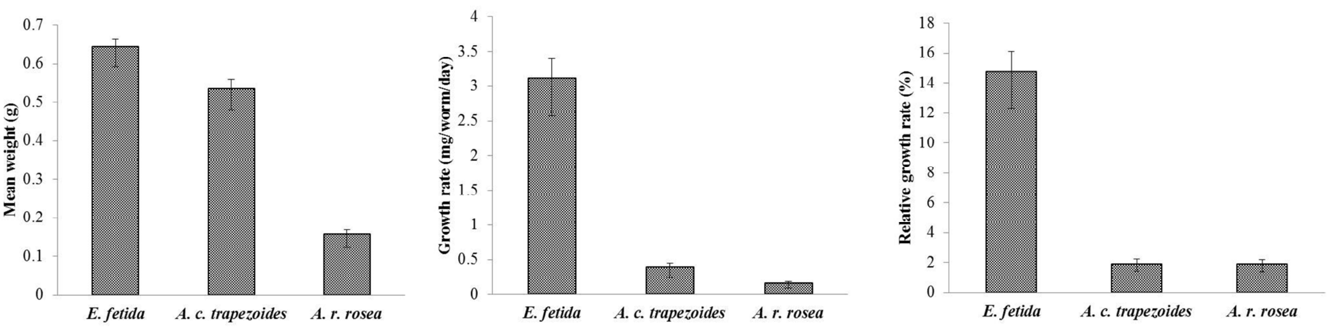

Fig. 2 Mean weight, growth rate and relative growth rate of earthworm species.

val is attributed to the loss of organic matter and release of different mineral salts in available forms such as phosphate, ammonia and potassium (Najar and Khan 2010).

Decrease in OC observed in all the three treatments is consistent with the studies of Garg and Kaushik (2005) and Suthar (2007). Goyal *et al*. (2005) reported that during vermicomposting a large fraction of organic matter in substrates is lost as carbon-dioxide.

Though increase in ON was observed over the time interval, the observed differences among the 3 species could be attributed directly to the feeding preferences of the epigeic and endogeic earthworm species and indirectly to mutualistic relationship between ingested microorganisms and intestinal mucus which might be species-specific (Suthar and Singh 2008).

The concentration of K in the vermicast of *E. fetida* is higher than in *A. c. trapezoides* and *A. r. rosea*, attributed to the production of carbonic, nitric and sulphuric acids by microorganisms present in the gut of earthworms (Kaviraj and Sharma 2003).

P content was higher after 60 days in all three treatments, being highest in *E. fetida* treatment followed by *A. c. trapezoides* and least in *A. r. rosea*. Garg *et al*. (2006) reported increase in concentration of phosphorous during vermi-

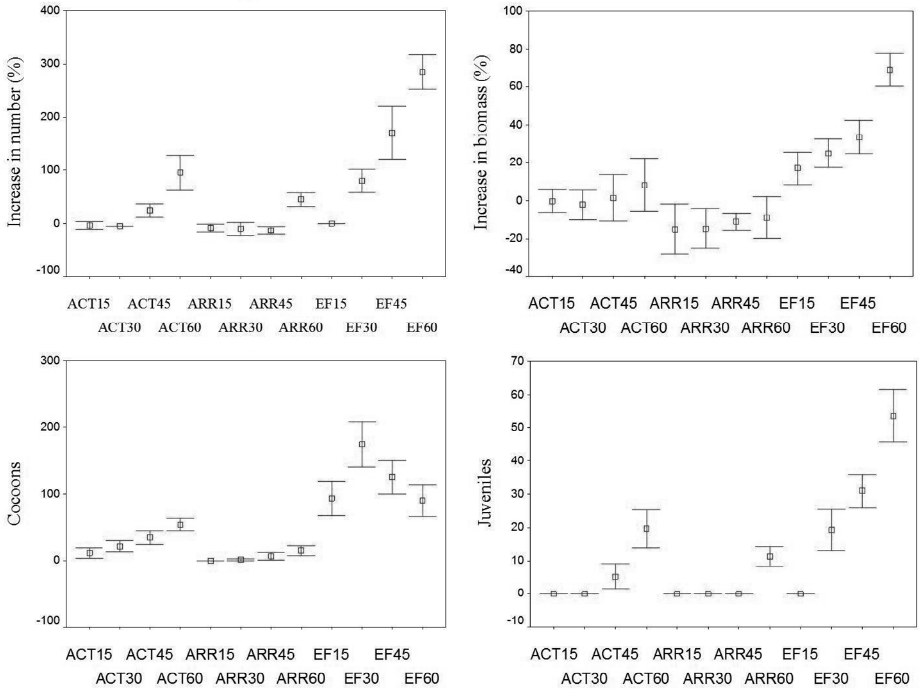

Fig. 3 Reproduction performances of *E. fetida* (EF), *A. c. trapezoides* (ACT) and *A. r. rosea* (ARR) on macrophytes during different fortnights.

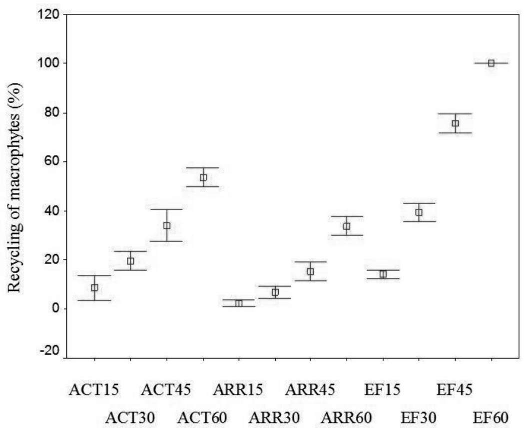

Fig. 4 Recycling of macrophytes during different fortnights by *E. fetida* (EF), *A. c. trapezoides* (ACT) and *A. r. rosea* (ARR).

composting. The enhanced phosphorous level in vermicompost is probably through mineralization and mobilization of phosphorus by bacterial and faecal phosphatase activity of earthworms (Bhattacharya and Chattopadhyay 2004; Jeyanthi *et al*. 2010).

Stability of C:N ratio during vermicomposting is attributed to loss of carbon as carbon dioxide in the process of respiration and production of mucus and nitrogenous excrements that enhance the level of nitrogen (Hayawin *et al*. 2010). Castillo *et al*. (2010) reported that a decline in C:N ratio to less than 20 indicates an advanced degree of organic matter stabilization and reflects a satisfactory degree of maturity of organic wastes. The low C:N ratio from the epigeic *E. fetida* processed treatment indicates that this species enhances the organic matter mineralization more efficiently than the two endogeics: *A. c. trapezoides* and *A. r. rosea*.

Vermicomposting experiment was also considered in terms of earthworm biomass besides number of cocoons produced. Vermicomposting results in the conversion of a part of the organic waste into worm biomass and respiratory products and excrete part of the ingested as partially stabilized product i.e., vermicast (Benitez *et al*. 1999).

At the end of the experiment increase in earthworm number was higher in epigeic *E. fetida* followed by *A. c. trapezoides* and least in *A. r. rosea*. Higher consumption of weed with time provides nutrients that enhance earthworm reproductive capability leading to increase in number (including juveniles) by the end of 60 days. However, it is evident that the variation in growth rates among the species observed is related to species-specific feeding habitat. Saini *et al*. (2010) and Monroy *et al*. (2006) reported growth and reproduction in *E. fetida* as rapid when compared to other species. Higher production of cocoon was obtained in *E. fetida* as compared to *A. c. trapezoides* and *A. r. rosea* during all fortnights. Chauhan *et al*. (2010) reported a varied number of cocoon production during the vermicomposting by using *E. fetida*, *E. eugeniae* and *P. excavatus*.

Efficient recycling of macrophytes over the period of time is shown by epigeic *E. fetida*. The observed difference in recycling of macrophytes between *E. fetida*, *A. c. trapezoides* and *A. r. rosea* could be related to the feed preferences by ecology of individual earthworm species (Suthar and Singh 2008; Indrajeet *et al.* 2010).

CONCLUSION

From the apparent discussion it could be concluded that the epigeic earthworm species *E. fetida* has a better potential in recycling of macrophytes than endogeic species- *A. c. trapezoides* and *A. r. rosea.* Further the data manifests vermicast of *E. fetida* as rich in plant nutrient relative to other two species. Moreover, the growth was higher and reproduce favorable on this substrate. Further the composting potential besides being species-specific character is also related to the feeding preferences of epigeic and endogeic composting earthworm. Species which are capable of dwelling in high percentage of organic material along with high adaptability to environmental changes, high fecundity and high rate of consumption, digestion, assimilation and growth possess a better potential for vermicomposting process. Thus the study revealed that the resourceful efficiency of *E. fetida* should be used to combat noxious macrophytic invasion of the lakes into value-added materials, i.e., vermicompost besides earthworm biomass.

ACKNOWLEDGEMENTS

The authors express thanks to Dr. Abdul Hai, Head, Hydrobiology Research Laboratory, Kashmir for providing laboratory facilities. The authors thank Dr. Jaime A. Teixeira da Silva for improving the grammar.

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