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Technical Note

Efficacy of bioconversion of paper mill bamboo sludge and lime waste by composting and vermiconversion technologies

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HIGHLIGHTS

- Bioconversion of paper mill bamboo and lime waste is a novel effort.
- Solubility of heavy metals in paper mill wastes reduced due to vermiconversion.
- Vermicomposted paper mill wastes improve soil health.
- Vermicomposted paper mill wastes enhances crop yield.

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ABSTRACT

Paper Mill Bamboo Sludge (PMBS) and Paper Mill Lime Waste (PMLW) are extensively produced as solid wastes in paper mills. Untreated PMBS and PMLW contain substantial amount of heavy metals (Zn, Pb, Ni, Cd, Cr) in soluble forms. Efficiency of vermiconversion and aerobic composting with these wastes is reported here. Adopted bioconversion systems enhanced the availability of some essential nutrients (N, P, K and Zn) in various combinations of cow dung (CD) with PMBS and PMLW. Colonization of nitrogen fixing bacteria and phosphate solubilizing bacteria considerably intensified under the vermiconversion system. Moreover, significant metal detoxification occurred due to vermiconversion. Various combinations of bioconverted PMBS and PMLW were applied to tissue cultured bamboo (*Bambusa tulda*) and chilli (*Capsicum annum*). Accelerated nutrient uptake coupled with improved soil quality resulted in significant production of chilli. Furthermore, vermiconverted PMBS + CD (1:1) and PMLW + CD (1:3) confirmed as potential enriching substrate for tissue cultured bamboo.

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1. Introduction

Paper Mill Bamboo Sludge (PMBS) and Paper Mill Lime Waste (PMLW) are generated as by-products of paper production in mills. The disposal of these materials presents acute environmental complications. Paper mills generally consume around 30 000–35 000 t of bamboo annually (Yen et al., 1996). Hence, bamboo dusts and bamboo chips along with other synthetic additives are the principal constituents of PMBS. The composition of this waste mainly depends on the type of paper produced and the origin of cellulose fibers. However, high occurrence of toxic heavy metals is the major threat for ecological considerations. Lime sludge (i.e. PMLW) is the solid waste produced as subsidiary products of the process that turns wood chips into pulp for paper. The major component is calcium carbonate. Approximately, 0.47 m^3 of lime mud/sludge is generated to produce 1 t of pulp (Wirojanagud et al., 2004). Extreme alkalinity due to high occurrence of Ca and Na is the major constraint for utilizing the waste through bioconversion.

Aerobic composting and vermiconversion are two of the best known processes for stabilization of solid organic wastes. In recent years, we achieved significant success in useful vermiconversion of coal ashes of various large and medium scale industries such as thermal power plants, tea factories and paper mills (Bhattacharya et al., 2012; Goswami et al., 2013). Moreover, capability of *Eisenia fetida*, an epigeic earthworm in heavy metal detoxification was identified in our previous experiments.

The present investigation deals with the possibilities of utilizing untreated sludge materials viz. PMBS and PMLW employing vermiconversion and composting technologies. We assessed the efficiency of different combinations of these wastes and organic matter through vermicomposting and composting. Moreover, we

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Table 1
Basic properties of PMLW and PMBS ($n = 6$).

Parameters	PMLW	PMBS
pH	10.6–11.1	6.0–7.3
Water holding capacity (%)	71 ± 6.5	80 ± 6.5
OC (%)	0.14 ± 0.05	1.2 ± 0.3
TKN (%)	0.03 ± 0.006	5.6 ± 0.8
Av. P (mg kg^{-1})	0.08 ± 0.008	115.0 ± 8.9
Av. K (mg kg^{-1})	0.4 ± 0.04	105.9 ± 9.6
Av. Na (mg kg^{-1})	2.4 ± 0.3	–
Av. Ca (mg kg^{-1})	7.5 ± 0.7	–
Av. Mg (mg kg^{-1})	1.9 ± 0.2	–
Exch. Mn (mg kg^{-1})	1.4 ± 0.2	4.0 ± 0.6
Exch. Zn (mg kg^{-1})	0.62 ± 0.09	1.5 ± 0.2
Exch. Cu (mg kg^{-1})	0.25 ± 0.04	0.21 ± 0.04
Exch. Ni (mg kg^{-1})	ND	0.04 ± 0.003
Exch. Cd (mg kg^{-1})	ND	0.15 ± 0.06
Exch. Cr (mg kg^{-1})	0.005 ± 0.001	0.01 ± 0.001
Exch. Pb (mg kg^{-1})	0.15 ± 0.03	0.15 ± 0.002
$CaCO_3$ (%)	67 ± 7	–

succeeded to employ the organic mixtures of PMBS and PMLW as fertilizers for chilli and growth media for tissue cultured bamboo plants.

2. Materials and methods

2.1. PMBS, PMLW and earthworm species used for vermiconversion

Samples were collected from Hindustan Paper Mill (HPCL), Jagiroad (Assam) and Sonabill Tea Garden, Tezpur (Assam) respectively. Urine free cow dung (CD), collected from a nearby dairy farm, was used as the organic source to initiate as well as expedite the biological conversion process. Juvenile, non-clitellated specimens of epigeic earthworm *E. fetida*, weighing about 200–250 mg, were obtained from our experimental vermiculture unit and used for composting of organically mixed PMBS and PMLW.

2.2. Experimental design and bioconversion techniques

We have adopted two bioconversion techniques viz. aerobic composting and vermiconversion by following our previously standardized techniques (Goswami et al., 2013). Both PMBS and PMLW were mixed with cow dung in various ratios. The following mixtures were used for both aerobic composting and vermiconversion experimentations: PMBS only; PMBS + CD – 1:1; PMBS + CD – 2:1; PMLW + CD – 1:2; PMLW + CD – 1:3; PMLW + CD – 1:4.

The experiments were conducted for two months and the substrates were set aside in triplicate for each treatment combination. Elemental changes during the bioconversion processes were enumerated by drawing samples at 0, 30 and 60 d from each replicate. However, changes in the heavy metal content and growth of Nitrogen Fixing Bacteria (NFB) and Phosphate Solubilizing Bacteria (PSB) were estimated at 0 and 60 d after incubation.

2.3. Tissue cultured bamboo, crop and soil study

Selected bioconverted mixtures of PMBS were applied to tissue cultured bamboo (*Bambusa tulda*). The well grown plantlets of were transferred into a greenhouse and kept for 30 d in a mist

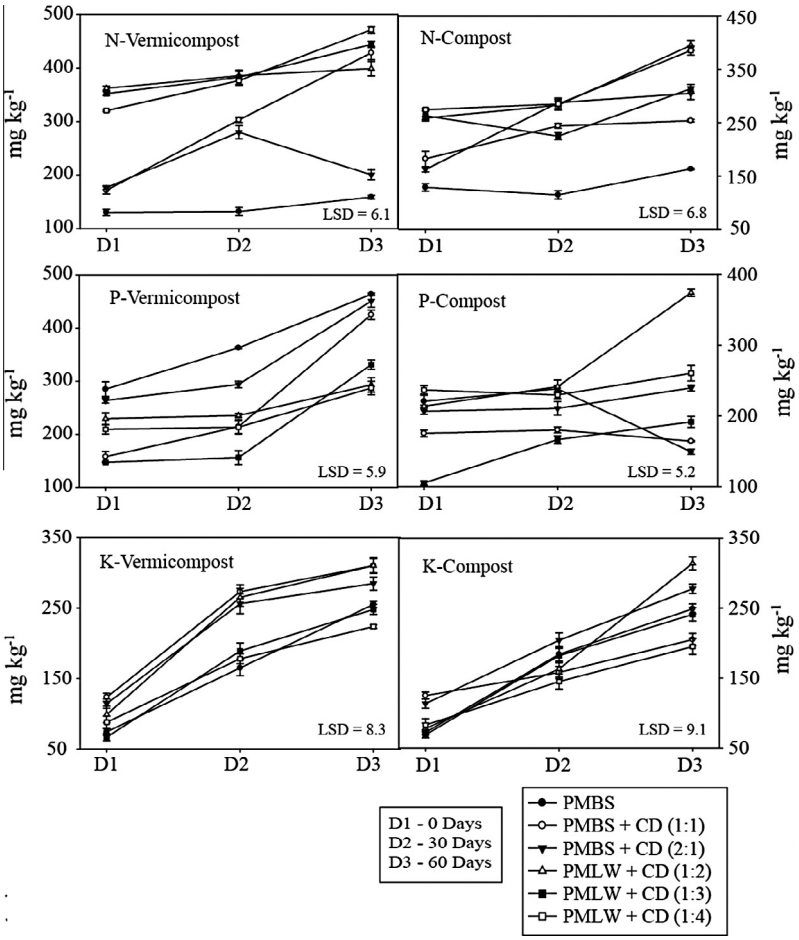

Fig. 1. Changes in nutrient availability under various treatments during bio-composting process.

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