Economic Affairs, Vol. 68, No. 02, pp. 1121-1128, June 2023
DOI: 10.46852/0424-2513.2.2023.18

AESSRA

Research Paper

Composting of Natural Fibre Wastes for Preparation of Organic Manures and Bio-enhancers

Nilimesh Mridha, Deb Prasad Ray*, Atul Singha, Avijit Das, Manik Bhowmick, Rakesh Kumar Ghosh, Manjunatha, B.S., Biplab Saha, Alok Nath Roy, Laxmikanta Nayak and Amit Das

ICAR-National Institute of Natural Fibre Engineering and Technology, Kolkata, India

*Corresponding author: drdebprasadray@gmail.com (**ORCID ID:** 0000-0002-6676-4498)

Received: 22-01-2023 **Revised:** 30-05-2023 **Accepted:** 06-06-2023

ABSTRACT

Various agricultural and industrial activities produce natural fibre waste that can harm the environment if not disposed properly. These wastes contain valuable plant nutrients that need to be recycled to sustain soil quality and health, and reduce environmental pollution. Composting is an efficient, sustainable, and inexpensive way to treat solid wastes. This study focused on the preparation of composts from jute leaf waste, pineapple leaf wastes, banana pseudo stem waste along with retting liquors as bio-enhancers and to evaluate their quality. The quality of compost determines its ability to perform its projected function. The feedstocks are the main factor that affects the compost qualities, but the composting process also counts. The compost and retting liquors were tested in the laboratory for different parameters such as electrical conductivity, pH, organic carbon, total nitrogen, total phosphorus and potassium, micronutrients, heavy metals and C/N ratio. The results showed that compost made from natural fibre and bio-enhancer i.e. retting liquor can be a good source of plant nutrition and microbial activity. Pineapple leaf waste had a higher C: N ratio than jute leaf waste which resulted faster decomposition of jute leaves. Retting liquor had more bacteria than fungi. No actinomycetes were seen in the liquor. Waste wool had the highest nitrogen content among other fibre residues, so it can be a sustainable alternative to nitrogen source for crop nutrition. The quality evaluation will give us an insight on influence of compost produced from natural fibre waste in crop production.

HIGHLIGHTS

- Evaluated the characteristics of compost prepared from natural fibre waste.
- Jute leaf compost showed minimum C:N ratio among others.
- Retting liquor can be utilized as bio-enhancer for crop growth.
- Pineapple leaf compost contains lowest amount of heavy metals like Zn, Pb and Cd than other composts.

Keywords: Composting, Natural Fibre waste, Bio-enhancer, quality evaluation

Natural fiber waste is generated from various agricultural and industrial activities, such as pineapple leaf, jute leaf, banana, sisal, and wool production. These wastes can cause environmental problems if not disposed properly, such as landfilling, burning, or dumping (Essien *et al.* 2005). However, these wastes also have potential value as a source of plant nutrients and organic matter that can be recycled through composting (Abdallah *et al.* 2019). Composting is a biological process that converts organic waste into a stable and humus-

How to cite this article: Mridha, N., Ray, D.P., Singha, A., Das, A., Bhowmick, M., Ghosh, R.K., Manjunatha, B.S., Saha, B., Roy, A.N., Nayak, L. and Das, A. (2023). Composting of Natural Fibre Wastes for Preparation of Organic Manures and Bio-enhancers. *Econ. Aff.*, **68**(02): 1121-1128.

Source of Support: None; **Conflict of Interest:** None

like material called compost, which can be used as a soil amendment or fertilizer for crop production. Natural fibre wastes like jute, wool, coir, banana, sisal, flax and pineapple (Kumar *et al.* 2019) are abundant, renewable and biodegradable, and can provide valuable nutrients and organic matter to the soil when composted. However, different natural fibre wastes may have different characteristics and composting behaviour depending on their origin, composition and processing (Kumar *et al.* 2019; Sivakumar *et al.* 2018). It is well known that organic manures are natural sources of plant nutrients that can improve the soil physical, chemical and biological properties, and enhance the crop productivity and quality (Adekiya *et al.* 2020). It can also reduce the environmental impact of conventional agriculture that relies heavily on inorganic fertilizers and pesticides (Gill and Garg 2014). However, different organic manures may have different effects on the soil and crop depending on their composition, quantity and application method. Composting is a cheap, efficient and sustainable treatment for solid wastes that is always included in any manure treatment scenario. Compost quality determines a product's ability and capacity to perform its intended function. Although the composting process is also influential, feedstocks are the important factor in determining the qualities of compost.

During fibre extraction from banana pseudostem, huge quantity of scutcher (about 30 to 35 t/ha) is generated. This scutcher is being converted to natural products like vermicompost by adding other essential components in order to value addition in proper way (Oliveira *et al.* 2007 and Phirke *et al.* 2001). Process has been standardized for vermicompost preparation using pseudostem scutcher along with dung in ratio of 70:30 (Patil and Kolambe, 2011). Pineapple leaf contains only 2.5-3.5% fibre, covered by a hydrophobic waxy layer, which remains beneath the waxy layer (Paul *et al.* 1998). In India, pineapple is cultivated approximately in 87.2 thousand hectare of land and ~600 thousand tons of pineapple leaf fibre can be extracted from this agro-waste leaves after harvest of the fruit (Doraiswami & Chellamani, 1993). During extraction of fibre, significant amount of succulent green biomass debris is left after scrapping out the waxy surface layer from pineapple leaf (Mridha *et al.* 2021). This residual sludge can be utilized successfully for vermicomposting to make the total integrated system economically viable. Pineapple waste is one type of organic material containing a high C/N ratio (50%–70%) (Ridwan *et al.* 2018). Prior research (Zheljazkov, 2005; Zheljazkov *et al.* 2008a) has demonstrated that uncomposted wool could be used as plant nutrient source. Composted wool has been used as a N source for crop plants such as chickpea and wheat (Tiwari *et al.* 1989).

Quality evaluation of compost prepared from natural fibre wastes involves assessing their physical, chemical and biological properties that affect their suitability and safety for soil application. Some of the important parameters to evaluate include moisture content, pH, electrical conductivity, carbon to nitrogen ratio, nutrient content, organic matter content, humic substances content, stability, maturity and heavy metal content (Cesaro *et al.* 2015; Jakubus 2020). These parameters can influence the availability and release of nutrients to the plants, the soil structure and fertility, the microbial activity and diversity, and the potential environmental risks of compost application. The quality evaluation can help to optimize the composting process and the compost utilization. For instance, cotton waste is a rich source of cellulose that can be composted with nitrogen-rich materials such as poultry manure or urea to produce high-quality compost (Sivakumar *et al.* 2018). Jute waste is a lignocellulosic material that can be composted with cow dung or microbial inoculants to enhance its decomposition and nutrient release (Kumar *et al.* 2019). Wool waste is a proteinaceous material that can be composted with straw or sawdust to reduce its odour and ammonia volatilization (Garg et al. 2006). The optimal type and ratio of natural fibre wastes and other materials for composting may vary depending on the desired compost quality and the intended crop use. This study focuses to evaluate organic manure prepared from natural fibre wastes highlighting few important quality parameters.

MATERIALS AND METHODS

Waste collection

Various natural fibre wastes like jute leaf waste, pineapple leaf Waste and banana pseudo-stem waste (Fig. 1) were collected. Cattle manure was

(a) (b) (c)

Fig. 1: Natural Fibre wastes **(a)** Jute leaf Wastes **(b)** Pineapple leaf wastes & **(c)** Banana Pseudostem waste

collected from a dairy farm, Kolkata, West Bengal. Pre-composting of each feedstock (waste mixture containing cattle manure and natural fibre wastes leaf litter as given in Table 1) was done for 2 weeks to remove volatile toxic substances. Pre-composting also helps in breaking feedstock fatty and oily substances. Compost were prepared by mixing with cow dung in 60 % (feedstocks) & 40 % (cow dung) proportions in weight basis. Evaluation of different retting liquors were also carried out. The experiment was conducted using CRD statistical design.

Composting Process

The composting process involves four main steps: pre-treatment, decomposition, curing and screening (Cesaro *et al.* 2015).

Pre-treatment: This step involves the preparation of the natural fibre wastes and other materials for composting which include shredding, mixing, moistening, adding bulking agents and inoculating with microorganisms to enhance the decomposition process. The pre-treatment may also involve adjusting the carbon to nitrogen ratio of the mixture to achieve an optimal range of 25:1 to 35:1 for aerobic composting (Cesaro *et al.* 2015).

Decomposition: This step involves the active phase of composting where the organic materials are degraded by microorganisms under aerobic or anaerobic conditions. Aerobic composting requires regular turning or forced aeration to maintain sufficient oxygen levels for the microorganisms. Anaerobic composting does not require turning or aeration but produces methane and odours as by-products. The decomposition phase is characterized by high temperatures (50-70°C), high microbial activity and rapid reduction of organic matter. The duration of this phase depends on the type and quantity of natural fibre wastes and other materials, the composting system and the environmental conditions. It may range from a few weeks to several months (Cesaro *et al.* 2015).

Curing: This step involves the maturation phase of composting where the organic materials are further stabilized by microorganisms under aerobic conditions. The curing phase is characterized by lower temperatures (30-40°C), lower microbial activity and slower reduction of organic matter.

Screening: This step involves the separation of the finished compost from any remaining uncomposted materials or contaminants such as stones, plastics or metals. The screening may be done manually or mechanically using sieves of different sizes depending on the desired particle size of the final product. The screening may also involve testing the quality parameters of the finished compost (Cesaro *et al.* 2015).

Compost analysis

To determine the physico-chemical quality of different feedstocks, the samples (about 20 gm) were drawn from each compost bin. Samples were oven dried, ground and stored in airtight plastic containers for further analysis. Dried compost samples were used for analysis. pH and EC (μS/cm) was analysed with the help of digital pH and EC meter respectively, using double-distilled water suspension of dry sample in the ratio of 1:10 (w/v). Total Kjeldahl nitrogen and total organic carbon (TOC) of the pre-decomposed natural fibre waste residue and the compost were measured using Kjeldahl method (Shaw and Beadle, 1949) and Walkely and Black's Rapid titration method (Nelson and Sommers,1982), respectively. Total phosphorus (TP) was determined spectrophotometrically (Fiske and Row Subha, 1925) while total potassium (TK) was detected by the flame emission technique by Flame photometer (Pearson, 1952). Heavy metals like Zn, Al, Cd & Pb were quantified by using AAS (after digesting the sample in nitric acid: perchloric acid mixture having 9:1 ratio). The quality standards for compost prepared from natural fibre wastes may vary depending on the type of the natural fibre wastes used for experiment.

The compost or organic manure prepared from the natural fibre wastes were compared with the standard of organic manure as laid down by Fertilizer Control Order, 1985.

RESULTS AND DISCUSSION

Nutrient content of different natural fibre waste

The different waste from natural fibre and natural fibre processing was assessed for different nutrient content like carbon, nitrogen, phosphorus, potassium. Carbon to nitrogen ratio was also calculated to assess the rate of biodegradability. The C: N (Carbon to Nitrogen) ratio of the substrate is a critical factor in the composting process, as it directly affects the rate of decomposition and the quality of the final compost. The ideal C:N ratio for composting is between 25:1 to 30:1. When the C:N ratio is too high, the decomposition process is slowed down, as the microorganisms responsible for breaking down the organic material require nitrogen as a source of energy. A high C:N ratio means that the substrate is too rich in carbon and too low in nitrogen, resulting in a lack of nitrogen for the microorganisms to use, causing the decomposition process to slow down. On the other hand, if the C:N ratio is too low, the substrate is too rich in nitrogen, which can result in a loss of nitrogen through leaching, ammonia volatilization, or denitrification. This can cause an unpleasant odor and may result in the loss of valuable nutrients. The major nutrient content of the substrate is also an important factor in compost preparation. A substrate that is rich in nitrogen will result in a compost that is high in nitrogen, which can be beneficial for plants that require a lot of nitrogen, such as leafy vegetables. Conversely, a substrate that is low in nitrogen will result in a compost that is low in nitrogen, which may be more suitable for plants that require less nitrogen, such as root vegetables. Among various compost prepared from natural fibre waste, jute leaf compost showed lowest C:N ratio due to which it can be decomposed faster (~15 days earlier) than other wastes (Table 1).

Physical and physico-chemical properties of compost

Physical properties of compost are highly dependent on it processing technique and handling. Incorporation of coarser materials into compost could improve the aeration status of the media. Low bulk density media may be required for frequently irrigated greenhouse to avoid oxygen deficiency. Mixing and transportation of low bulk density media are much easier than those of high bulk density. However, media with a low bulk density may not provide adequate support for the plant and the plant may be top heavy (Holcomb, 1994). Aeration depends mainly on the size of pores in a medium. Irrigating media to the point of saturation fills the total pore space with water. As the media drains by the force of gravity, smaller pores remain filled with water while larger pores emptied and fill with air. However, materials with small particles tend to fill up the pores, thus lowering the porosity.

pH and Electrical Conductivity

The initial pH and EC of the media are two

Table 1: Major nutrient composition of different natural fibre wastes

Type of nutrients	Jute Leaf Waste	Pineapple Leaf Fibre Waste	Banana Pseudo stem Waste
C (%)	41.1 ± 5.37	48.8 ± 6.53	43 ± 5.22
N (%)	0.97 ± 0.11	0.78 ± 0.058	0.59 ± 0.062
P (%)	0.41 ± 0.056	0.32 ± 0.042	0.74 ± 0.065
K (%)	2.53 ± 0.36	2.57 ± 0.32	1.77 ± 0.15
C:N ratio	**42.4 ± 5.66**	**62.56 ± 7.55**	**72.88 ± 9.21**

**Data are mean ± SEM.*

important properties of any growing media as these parameters directly influenced the availability and indicate inherent nutrient status in the media, respectively. Variations in composition of the media markedly affected the initial pH and EC values of the media. The lowest pH recorded was 6.7 in banana pseudo stem compost and highest in pineapple leaf compost (7.1) and all the values were in neutral range which is good for seedling growth (Table 2). During composting production of carbon dioxide, ammonia and nitrate have significant effect on pH. Organic matter decomposition indicates formation of humic acids and ammonium ions which exerts opposite effect on the pH of the feedstock. Carboxylic, phenolic, and humic acids reduce the pH value; however, ammonium ions increase the pH value of the compost. Hence, in the final compost, pH tends toward neutral (Elvira *et al.* 1998).

The EC values reflect the total inorganic ion concentration in the media extracts. Low EC value indicates that the media did not contain excessive salt that could cause salinity injury to the plants but at the same time contains insufficient amount of nutrients to support healthy plant growth. Higher EC in jute and pineapple compost reflects that jute and pineapple compost contains relatively high concentration of soluble ions which could be beneficial for seedling growth (Table 2). The beneficial effects of increasing nutrients by directly incorporated slow released fertilizer into the cocopeat-based media on ornamental plants under Malaysian conditions were reported by Yahya *et al.* (1999).

The lowest pH recorded was 7.1 in pineapple retting liquor and highest in whole jute retting liquor (7.8) and all the values were in neutral range which is good for crop growth (Table 3). The EC values reflect the total inorganic ion concentration in the retting liquor. TDS was highest in jute ribbon retting liquor due to higher amount of organic extracts releasing to retting water. Nitrogen content was found maximum under whole jute retting liquor, which can be beneficial for better crop stand (Ray *et al.* 2015).

Microbial activity

Microbial activity in terms of bacterial and fungal population (Fig. 2) was maximum in pineapple retting liquor thus attributed to the fact that there may be higher release of nutrient due to increased microbial activity.

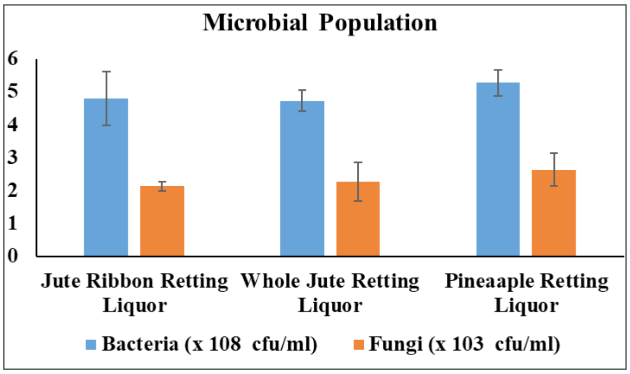

Fig. 2: Microbial populations in retting liquors

Table 2: Moisture, bulk density, porosity, pH and EC of different compost

Type of compost	Jute Leaf Waste compost	Pineapple Leaf Fibre Waste Compost	Banana Pseudostem Waste Compost	Standard of Organic Manure as per FCO, 1985
Moisture (%) by weight	21.5	20.7	28.9	**≤ 25.0**
Bulk Density (g/cm^3)	0.1	0.1	0.11	**<1.0**
Porosity (%)	77.21	77.68	76.34	—
pH	7	7.1	6.7	**6.5-7.5**
EC (µS/cm)	42.7	45.1	34.2	**4000**

Table 3: Physico-chemical properties of retting liquors

Retting liquors	Properties			
	pH	EC (ds/m)	TDS (mg/l)	N (%)
Jute Ribbon Retting Liquor	7.5 ± 0.25	0.71 ± 0.065	215 ± 18.33	0.78 ± 0.067
Whole jute Retting Liquor	7.8 ± 0.18	0.68 ± 0.073	201 ± 22.14	0.84 ± 0.071
Pineapple Retting Liquor	7.1 ± 0.15	0.65 ± 0.055	194 ± 21.07	0.79 ± 0.077

**Data are mean ± SEM.*

The actinomycetes populations were not detected at 10^{-4} dilution. Results indicate that retting liquor contain lot of bacteria and can be utilized as bio-enhancer for crop growth (Singha *et al.* 2022).

Nutrient composition of different natural fibre waste compost

Composting is a natural process that breaks down organic materials into a nutrient-rich fertilizer that can be used to improve soil health and support plant growth. The nutrient composition of the compost is a critical factor in determining its suitability for various applications. Nitrogen content: The nitrogen content of the compost is important because nitrogen is a primary nutrient required for plant growth. Compost with high nitrogen content is beneficial for plants that require a lot of nitrogen, such as leafy vegetables. Compost with low nitrogen content may be more suitable for plants that require less nitrogen, such as root vegetables. Phosphorus is another essential nutrient required for plant growth, particularly for root development. Compost with a high phosphorus content is beneficial for plants that require a lot of phosphorus, such as fruiting vegetables and legumes. Compost can also contain other important micronutrients, such as calcium, magnesium, and sulphur, which are required for healthy plant growth. The nutrient composition of compost can vary depending on the source of the organic materials used in the composting process.

As per standard laid down by FCO, 1985, the C:N ratio for organic manure should be <20 for optimum plant growth and jute leaf compost and pineapple leaf compost both qualified well (Table 4). Jute leaf compost showed lowest C:N ratio, followed by pineapple leaf compost and banana pseudostem compost showed highest C:N ratio.

Compost is a nutrient-rich fertilizer that can provide a range of essential macronutrients and micronutrients for plant growth. The presence of aluminum (Al), lead (Pb), and cadmium (Cd) in compost can have both positive and negative effects on plant growth and the environment. In small quantities, aluminum can have a positive effect on plant growth by improving soil structure and increasing soil acidity, which can benefit certain plants. However, excessive amounts of aluminum can be toxic to plants, leading to stunted growth and reduced yields. In terms of environmental pollution, excessive amounts of aluminum in compost can lead to the accumulation of aluminum in soils, which can be harmful to soil microorganisms and can cause soil acidification. Lead is a toxic heavy metal that can have harmful effects on human health and the environment. The presence of lead in compost can come from contaminated organic materials or from environmental pollution. Lead can be taken up by plants, leading to potential health risks for humans who consume contaminated plants. In addition, lead can accumulate in soils and waterways, causing environmental pollution and potential health risks for wildlife and aquatic organisms. Cadmium is another toxic heavy metal that can have harmful effects on human health and the environment. Like lead, cadmium can be taken up by plants and can accumulate in soils and waterways. Exposure to cadmium can lead to potential health risks for humans who consume contaminated plants and can cause environmental pollution and potential health risks for wildlife and aquatic organisms.

Pineapple leaf compost was found to be better in terms of Zn, Pb and Cd content than other composts though all the compost qualifies as per FCO, 1985 in terms of maximum heavy metals content (Table 5).

Table 4: Nutrient composition of different natural fibre waste compost

Type of nutrients	**Jute Leaf Waste Compost**	**Pineapple Leaf Fibre Waste Compost**	**Banana Pseudostem Waste Compost**	**Standard of Organic Manure as per FCO, 1985**
C (%)	18.48 ± 2.11	22.00 ± 2.57	22.42 ± 2.24	≥ 14%
N (%)	1.21 ± 0.17	1.17 ± 0.18	0.99 ± 0.062	≥ 0.5%
P (%)	0.69 ± 0.076	0.83 ± 0.042	0.71 ± 0.066	≥ 0.5%
C:N ratio	**15.18 ± 2.66**	**18.77 ± 2.15**	**22.64 ± 2.91**	**< 20**

**Data are mean ± SEM.*

Table 5: Micro-nutrient & Heavy Metal composition of different natural fibre waste compost

Type of nutrients	Jute Leaf Waste Compost	Pineapple Leaf Fibre Waste Compost	Banana Pseudostem Waste Compost	Standard of Organic Manure as per FCO, 1985
Zn (ppm)	1.31 ± 0.17	1.41 ± 0.13	1.08 ± 0.22	**≤ 1000**
Al (ppm)	23.93 ± 2.12	33.16 ± 2.58	37.81 ± 3.62	—
Pb (ppm)	0.087 ± 0.006	0.013 ± 0.0014	0.048 ± 0.0016	**≤ 100**
Cd (ppm)	0.0033 ± 0.00012	0.0021 ± 0.0001	0.0132 ± 0.0015	**≤ 5**

**Data are mean ± SEM.*

CONCLUSION

The above study was designed to evaluate the characteristics of compost prepared from natural fibre waste. The compost prepared from natural fibre wastes qualifies the standard laid down by the Fertilizer Control Order (FCO), 1985 regarding nutritional and other physiochemical proerties. Among various compost prepared from natural fibre waste, jute leaf compost showed minimum C:N ratio. Jute leaf waste decomposes faster (60 days) than others (75 days) due to lowest C:N ratio. Physico-chemical properties of retting liquor shows alkaline pH due a greater number of bacterial growths. The actinomycetes populations were not detected as they suppressed by increased bacterial population. Results indicate that retting liquor contain lot of bacteria and nitrogen and thus can be utilized as bio-enhancer for crop growth. Pineapple leaf compost contains lowest amount of heavy metals like Zn, Pb and Cd than other composts. The use of compost-amended soil as a means of reducing heavy metal pollution in soil can be a promising approach to soil remediation. However, it is important to note that compost should not be used as a substitute for proper waste management practices and measures to reduce environmental pollution. Instead, it should be seen as a complementary tool for managing contaminated soils.

ACKNOWLEDGEMENTS

The authors acknowledged The Director, ICAR-NINFET, Kolkata for the necessary fund & his constant support.

REFERENCES

Abdallah, A. *et al.* 2019. The potential of recycling wool residues as an amendment for enhancing the physical and hydraulic properties of a sandy loam soil. *Int. J. Recycl. Org. Waste Agric.*, **8**(Suppl. 1): S131–S143.

Adekiya, A.O., Ejue, W.S., Olayanju, A. *et al.* 2020. Different organic manure sources and NPK fertilizer on soil chemical properties, growth, yield and quality of okra. Sci. Rep., **10**: 16439.

Ali, N., Khan, M.N., Ashraf, M.S. *et al.* 2017. Evaluating the potential organic manure for improving wheat yield and quality under agro-climatic conditions of Pakistan. *Adv. Crop Sci. Tech.*, **5**: 349.

Cesaro, A., Belgiorno, V. and Guida, M. 2015. Compost from organic solid waste: Quality assessment and European regulations for its sustainable use. Resour. Conserv. Recycl., **94**: 72–79.

Doraiswami, I. and Chellamani, P. 1993. "Jute/cotton blends." *Asian Text J.*, **1.8**: 53-56.

Elvira, C., Sampedro, L., Benitez, E. and Nogales, R. 1998. Vermicomposting of sludges from paper mill and dairy industries with *Eisenia andrei*: a pilot-scale study. *Biores. Technol.*, **63**(3): 205-211.

Essien, J.P., Akpan, E.J. and Essien, E.P. 2005. Studies on mould growth and biomass production using waste banana peel. *Biores. Technol.*, **96**: 1451–1456.

Garg, V.K., Kaushik, P., Kaur, R. *et al.* 2006. Composting of wool waste: Optimization of process parameters using response surface methodology. *Biores. Technol.*, **97**: 2061–2066.

Gill, H.K. and Garg, H. 2014. Pesticides: environmental impacts and management strategies. *In:* Soloneski S, Larramendy ML (eds) Pesticides - toxic aspects. InTechOpen. https://doi.org/10.5772/57399

Jakubus, M. 2020. A comparative study of composts prepared from various organic wastes based on biological and chemical parameters. *Agron.*, **10**: 869.

Kumar, S., Sharma, R., Sharma, S. *et al.* 2017. Evaluation of different organic manure mixtures in vegetable amaranth production system under mid hill conditions of Himachal Pradesh. *J. Hortic. Sci.*, **12**: 1–6.

Kumar, S., Singh, S., Singh, A. *et al.* 2019. Composting of jute waste using microbial inoculants: Effect on quality parameters of jute waste based composts under different treatments conditions. *J. Environ. Manage.*, **231**: 1–8.

Mridha, N., Ray, D.P., Singha, A., Manjunatha, B.S., Biswas, S., Saha, B., Roy, A.N. and Shakyawar, D.B. 2021. Prospects of Natural Fibre Crop Based Plant Growth Substrate in Soilless Crop Production System: A Review. *Int. J. Bioresource Sci.*, **08**(02): 129-139.

Nauman, A., Khan, M.N., Ashraf, M.S. *et al.* 2020. Influence of different organic manures and their combinations on productivity and quality of bread wheat. *J. Soil Sci. Plant Nutr.*, **20**: 1949–1960.

Nelson, D.W. and Sommers, L.E. 1996. Total carbon, organic carbon, and organic matter. Methods of soil analysis: Part 3 Chemical methods, **5**: 961-1010.

Patil, R.G. and Kolambe, B.N. 2011. "Development of value-added products from banana pseudostem." An Overview of Progress. *National Agricultural Innovation Project (Component 2)*: 1-23.

Pearson, R.W. 1952. Potassium-supplying power of eight Alabama soils. *Soil Sci.*, **74**(4): 301-310.

Quality Protocol Compost, 2012. Quality protocol: Compost - GOV.UK https://www.gov.uk/government/publications/quality-protocol-for-the-production-and-use-of-compost-from-waste

Ray, D.P., Banerjee, P., Ghosh, R.K. & Nag, D. 2015. Accelerated retting of jute for economic fibre yield. *Econ. Aff.*, **60**(4): 693.

Shaw, J. and Beadle, L.C. 1949. A simplified ultra-micro Kjeldahl method for the estimation of protein and total nitrogen in fluid samples of less than 1.0 μl. *J. Experimental Biol.*, **26**(1): 15-23.

Singha, A., Das, A., Manjunatha, B.S., Bhowmick, M., Ray, D.P., Thakur, A.K., Saha, B., Das, R., Das, R., Das, A. and Shakyawar, D.B. 2022. Softening of Barky Root Cuttings of Jute by Pectinolytic Bacterial Strains for Better Spinability and Industrial Uses. *Econ. Aff.*, **67**(04): 439-444.

Sivakumar, K., Selvam, A. and Wong, J.W.C. 2018. Co-composting of cotton waste with chicken manure: Effect on quality parameters of final product under different initial C/N ratios conditions. *J. Clean Prod.*, **172**: 1537–1544.

Tiwari, S.C., Tiwari, B.K. and Mishra, R.R. 1989. Microbial populations, enzyme activities and nitrogen-phosphorus-potassium enrichment in earthworm casts and in the surrounding soil of a pineapple plantation. *Biology and Fertility of Soils*, **8**: 178-182.

Zheljazkov, V.D. 2005. Assessment of wool waste and hair waste as soil amendment and nutrient source. *J. Environ. Quality*, **34**(6): 2310-2317.

Zheljazkov, V.D., Cantrell, C.L., Ebelhar, M.W., Rowe, D.E. and Coker, C. 2008. Productivity, oil content, and oil composition of sweet basil as a function of nitrogen and sulfur fertilization. *Hort. Sci.*, **43**(5): 1415-1422.