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Research Article
Vermicomposting Derived Liquids: Fertigation Potential in Urban Farming

Shlrene Quaik, Kaizar Hossain and Mahamad Hakimi Ibrahim

Environmental Technology Division, School of Industrial Technology, Universiti Sains Malaysia,11800 Pulau Pinang, Malaysia

Abstract

Background: Currently, most farmers favour more on application of inorganic fertilizer compared to organic fertilizer. In the long run, utilization of inorganic fertilizer has raised concern towards health as well as environmental issues. More and more rural lands are turning unsuitable for farming due to the pollution of land and water by factory farms. Nonetheless, in urban agriculture, the use of inorganic fertilizer in such proximity to residential area is detrimental to health over a long period of time. In order of making urban farming viable in the sense of environmental friendly, alternatives of chemical fertilizers are getting acceptance. This project studied on the potential of utilizing vermicomposting derived liquids in urban farming fertigation. **Materials and Methods:** Pre-composted cow dung was used in the study. Liquids (vermiwash and vermicomposting leachate) collected were diluted to prevent leaf scorching. Chemical analysis showed the present of plant nutrients. Enhancement in chlorophyll contents (chlorophyll a, b and total chlorophyll) were observed as well as improvement in nutrients distribution in sweet potato leaf. **Results:** This study showed potential of vermiwash and vermicomposting leachate as organic foliar fertilizer. **Conclusion:** Hence, the application of these liquids in field scale urban farming fertigation is possible. For enriching the nutrients content of vermiwash and vermicimposting leachate, other nutrients rich substrate may be added.

Key words: Fertigation, urban farming, foliar fertilizer, organic waste, vermicomposting, vermiwash, derived liquids, nutrients

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Corresponding Author: Kaizar Hossain, Environmental Technology Division, School of Industrial Technology, Universiti Sains Malaysia,11800 Pulau Pinang, Malaysia

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

United Nations[1] predicted by 2050, our world population will achieve 9 billion. 70% of the population will be living in urban area. Densely developed city centres have piqued interest of urban agriculture in many cities of United States[2]. With the rising trend of world population, scarcity of land for agricultural production for meeting the population demand is inevitable. One of the solutions in used for increasing agricultural production is utilizing fertilizers. According to FAO[3], Asia region has turned into the largest consumer of fertilizer in the world, making up to 61% of the total world consumption. Agricultural industries have been too dependent on chemical fertilizer for better crops growth and yields. Demands of fertilizers are rising throughout the whole world. Animal waste and other agricultural waste generated in Malaysia each year is drastically increasing. Improper disposal of animal wastes has been reported to contribute towards the pollution of groundwater due to its bacteria and nitrates content[4]. Singh and Suthar[5] reported that recycling, reuse and resource recovery as great options for sustainable solid waste management. Most of the animal wastes cannot be used directly without any treatment. Direct disposal may cause environmental contamination problems especially in large amount.

In theory, foliar fertilization is a more targeted and environmental friendly approach since it possesses lower risk of soil contamination due to leaching. Most of the time, plant nutrients are lost due to this leaching problem as it is leached out before they are taken up by plants. Responses towards elements supplied through foliar application are normally more rapid compared to soil application[6]. In semi-arid region, nutrients availability in soil often decreased with the limited water availability in top soil especially during growing season. Nutrients deficiencies become limiting factor for growth even when water may still be available in subsoil. Therefore, in order to preserve the crop yield under such circumstances, foliar nutrients sprays are often applied[6].

Agricultural industries have been too dependent on chemical fertilizer for better crops growth and yields. Demands of fertilizers are rising throughout the whole world. Meanwhile, organic fertilizers also raise the concern of the presence of heavy metals due to the raw material or substrates used for deriving the organic fertilizers. Substrates that used in deriving organic fertilizer such as animal manures and sewage waste may contain components that are hazardous to human health, as well as to other animals and plants[7]. So far, majority of manure are used in land application. Beusen *et al.*[8] reported 84% of manures were spread on crop land and 16% on grassland. Selvam and Sivakumar[9] had come up with utilization of seaweed extract as organic liquid fertilizer. It has gain popularity as seaweeds are one of the important marine living resources with high commercial application. Seaweed extract liquid has found to be effective as it promotes faster seed germination and increment in yield in many crops. The upside of organic fertilizer is it biodegradable and is non hazardous to human health.

Therefore, with the increased awareness on this matter, organic fertilizers are getting more attention these days. Developing organic foliar fertilizer has gained researchers interest due to its rapid response on targeted nutrients deficiency. Studies on utilizing byproduct of two-step olive mill process[10], raw and diluted sewage effluent[11] and vermicomposting leachate from cow dung and green forage[12] had been conducted to show the potential of developing effective foliar fertilizer from waste materials.

Vermiwash and vermicomposting leachate are liquids that derived from vermicomposting process. These liquids contain valuable plant nutrients and have the advantage of homogeneity when applied to soil and as foliar spray compared to soil solid fertilizer. Application of plant nutrients-rich liquids such as vermiwash and vermicomposting leachate has great potential in overcoming the leaching problem and at the same time providing essential nutrients to plants. Potential of diluted vermicomposting derived liquids as nutrient solution in soil-less culture had been studied as part of this study[13]. Limited literatures are found on utilizing vermicomposting derived liquids as foliar spray as well as the applicability in fertigation. Sweet potato is one of the major crops that are largely cultivated. Besides its tuber, the leaves and stalk of sweet potato are also edible[14]. Sweet potato leaves can be harvested several times a year and produce much higher yield compared to other green vegetables[15]. Hence, the potential of vermicomposting derived liquids as foliar fertilizers, as well as the trace elements distribution in sweet potato leaf were explored in this present investigation.

MATERIALS AND METHODS

Vermiwash and vermicomposting leachate setup: The setup of vermiwash unit was a modified version of vermiwash unit as suggested by Ismail[16]. A plastic round-shape container (39×47 cm) of 50 L volume with a draining tap at the bottom of the container was prepared. Gravels were filled at the bottom of the container till approximately 3 cm higher than the draining point of the tap. A layer of pebbles (approximately 5 cm) were placed on top of the gravel layer as the second layer and followed by a layer of coarse river sand (approximately 5 cm, 8 kg). Gravels, pebbles and river sands were all washed with running water until the overflowing water was clear. Loamy soil were loosely filled up to 30 cm as the forth layer. The 50 *Eudrilus eugeniae* were then introduced to the vermiwash unit. A layer of pre-composted cow dung (5 kg) was introduced followed by a layer of straw. The unit was then covered with jute cloth that functions as moisture trap. Water was added daily to keep the reactor moist. Tap was kept open for the next 15 days as suggested by Ismail[16].

For vermicomposting leachate collection, a rectangular container was prepared (42×5×17.5 cm). A draining tap was installed at the bottom. Gravels were used as the most bottom layer to prevent water saturation. A layer of approximately 15 cm of loamy soil was introduced as the second layer. About 50 *Eudrilus eugeniae* were introduced. Followed by a layer of pre-composted cow dung, a layer of loosely arranged straws and lastly, covered with jute cloth. The vermicomposting leachate unit was tilted to prevent saturation of water as well as for easier leachate collection. Moisture level was maintained at 60-65% moisture content with periodically spraying of water (200 mL). Illustration of the setup is showed in Fig. 1 and 2. Both liquids were diluted (10% v/v) to prevent leaf scorching[17].

Experimental procedures: Sweet potato (*Lpomoea batatas*) tuber were placed and the bottom part was allowed to be submerged in distilled water. Sticks were used to hold the position of the sweet potatoes. All setup were left for 2 weeks for developing leaves and roots before foliar application of vermiwash and vermicomposting leachate. Sprayer bottles were used to apply vermiwash (VW) and vermicomposting leachate (VL) as foliar spray. Distilled water was used as foliar spray in control. Treatments were administered in 3 days interval for duration of 30 days. Young leaf sample (4-6) from growing tip were obtained for chlorophyll content determination[18] and leaf nutrients determination. Concentrations of photosynthetic pigments were calculated according to the formulae[19,20]. Leaf and root samples were oven dried at 80°C till constant weight was obtained. Acid digestion method[21] was used and the filtrates of all samples (dry root and leaf) were sent for analysis with atomic absorption spectrophotometer (Shimadzu AA-7000) for determination of Mn, Pb, Zn, Fe, Cu, Ca, Mg, K and Na.

Statistical analysis: All results were the means of three replicates. The data were analyzed with the SPSS for Windows statistical package (SPSS Inc., Chicago, USA). They were subjected to analysis of variance (ANOVA) and Duncan's multiple range test was used to compare means of data for the probability level $p<0.05$. An independent-samples t-test was conducted to compare the chemical properties of vermiwash (VW) and Vermicomposting Leachate (VL).

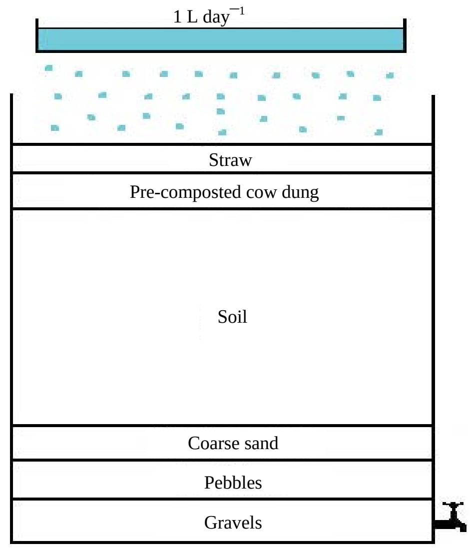

Fig. 1: Illustration of vermiwash reactor setup

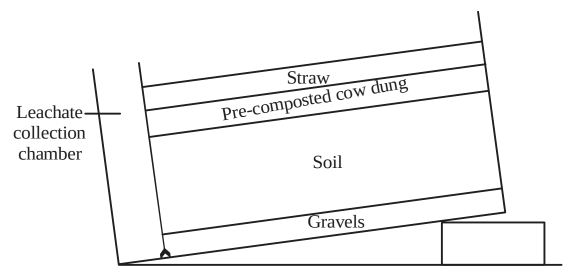

Fig. 2: Illustration of vermicomposting leachate reactor setup

RESULTS AND DISCUSSION

Chemical properties of vermiwash (VW) and vermicomposting leachate (VL): An independent-sample t-test was conducted to compare the selected chemical properties of VW and VL (Table 1).

Photosynthetic pigmentsand carotenoid concentration: Concentrations of photosynthetic pigments (chlorophyll a, chlorophyll b, total chlorophyll and carotenoid) were calculated. Chlorophyll a content of sweet potato leaf before and after foliar application is shown in Fig. 3. Chlorophyll a content in control did not differ after foliar spraying. There was no significant difference had been found to exist between chlorophyll a of control (0.139±0.03 mg g^{-1} fresh weight)

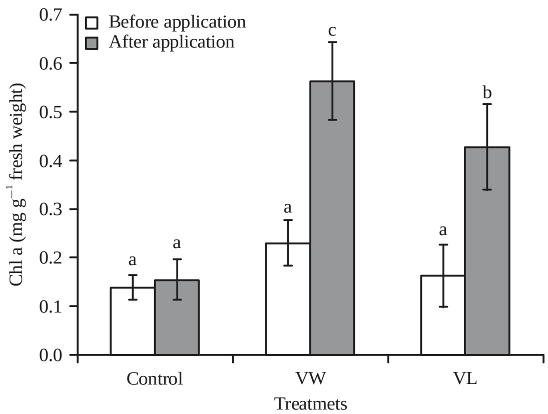

Fig. 3: Chlorophyll a content (Mean±1SD) of treatments before and after foliar application. Bars with different letters in each group show significant difference at p<0.05

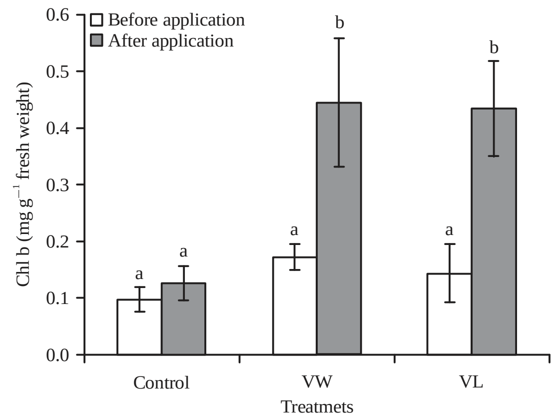

Fig. 4: Chlorophyll b content (Mean±SD) of treatments before and after foliar application. Bars with different letters in each group show significant difference at p<0.05

Table 1: Selected chemical properties of vermiwash (VW) and vermicomposting leachate (VL) (Mean±SD) (n = 3)

Parameters	VW	VL
pH	7.230±0.15	7.400±0.20
EC (dS m^{-1})	1.482±0.07*	1.659±0.02*
Total P (mg L^{-1})	4.360±0.00*	3.530±0.00*
K (mg L^{-1})	215.330±5.37*	90.200±7.01*
Ca (mg L^{-1})	172.870±6.43	167.630±1.95
Na (mg L^{-1})	107.930±2.27	111.730±3.02
Pb (mg L^{-1})	0.114±0.00*	0.105±0.00*
Mn (mg L^{-1})	0.030±0.00	0.028±0.00
Cu (mg L^{-1})	0.025±0.00*	0.030±0.00*
Zn (mg L^{-1})	0.114±0.01*	0.248±0.01*
Mg (mg L^{-1})	0.188±0.03*	0.217±0.00*
C (%)	2.857±0.19*	0.668±0.11*
N (%)	0.032±0.01*	0.013±0.01*

EC: Electrical conductivity, *Indicated the significant difference at p<0.05 by t-test

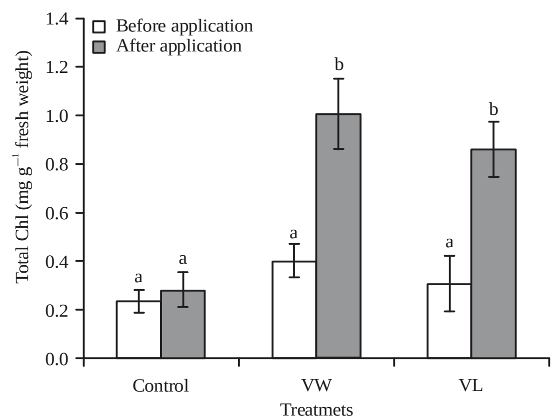

Fig. 5: Total chlorophyll content (Mean±SD) of treatments before and after foliar application. Bars with different letters in each group show significant difference at p<0.05

before foliar application (distilled water) and after foliar application (0.155±0.04 mg g^{-1} fresh weight). Chlorophyll a of VW (0.563±0.08 mg g^{-1} fresh weight) after foliar application was significantly higher compared to before application (0.230±0.05 mg g^{-1} fresh weight). For VL treatment, chlorophyll a after application (0.427±0.09 mg g^{-1} fresh weight) was significantly higher compared to before application (0.163±0.06 mg g^{-1} fresh weight). After foliar application, VW treatment exhibited significant improvement in chlorophyll a concentration compared to VL. After foliar application, chlorophyll b content of VW (0.445±0.11 mg g^{-1} fresh weight) and VL (0.434±0.08 mg g^{-1} fresh weight) treatments were significant higher compared to control (Fig. 4). However, no significant difference was observed between VW and VL treatment for chlorophyll b. Total chlorophyll content after VW and VL treatments were both significantly higher compared to control (Fig. 5). For carotenoid content (Fig. 6), VW treatment showed significant improvement compared to control and VL treatment. Results were in line with findings of Roosta and Hamidpour[22] who had reported improvement in chlorophyll b content with foliar application of Fe and Mg. Foliar application of Mg also increased the content of carotenoid in tomato. The Fe and Mg along with other nutrients were present in vermiwash and vermicomposting leachate. Therefore, the improvement in chlorophyll and carotenoid content of sweet potato leaf may be due to the present of Fe and Mg and other valuable plant nutrients in both vermiwash and vermicomposting leachate (Table 1).

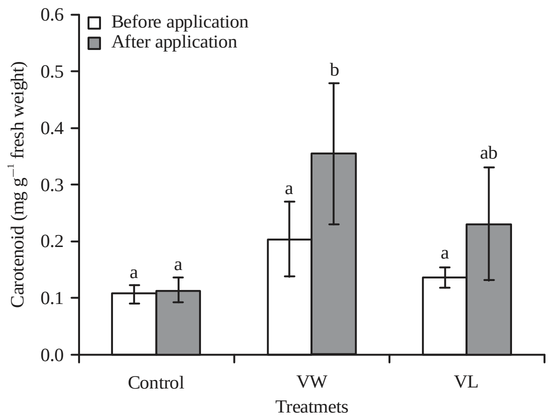

Fig. 6: Carotenoid content (Mean±SD) of treatments before and after foliar application. Bars with different letters in each group show significant difference at $p<0.05$

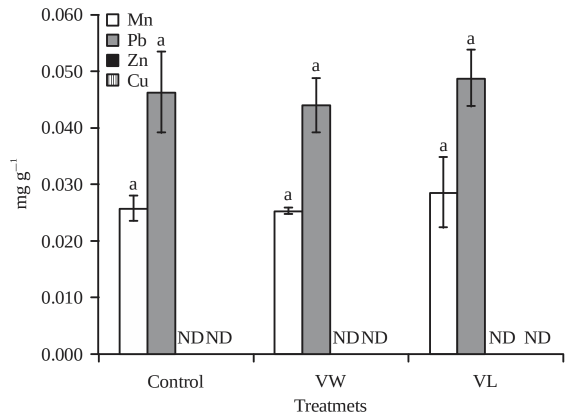

Fig. 8: Trace elements distribution (mg kg^{-1}) in sweet potato leaf. Bars with different letters in each group show significant difference at $p<0.05$

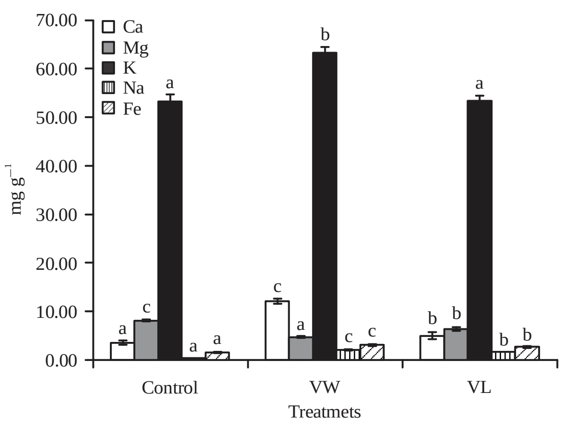

Fig. 7: Nutrients distribution (mg kg^{-1}) in sweet potato leaf. Bars with different letters in each group show significant difference at $p<0.05$

Literatures available were mostly on single nutrient foliar spray that utilized for targeting specific nutrient deficiency such as urea[23], Mn[24], Zn[25] and Fe[26]. Very few literatures available are on multi-nutrients foliar spray which is essential in fertigation study.

Nutrients and trace elements distribution in leaf of sweet potato: Both VW and VL treatments indicated higher concentration in sodium (Na) and iron (Fe) compared to control (Fig. 7). Findings showed that K content leaf of vermiwash was significantly higher (Fig. 7). This may be explained as the present of potassium in vermiwash was significantly higher (Table 1) compared to VL. Tejada *et al.*[12] had reported improvement in N, P and K content in leaves of tomato plant and chlorophyll production in leave through foliar application of vermicompost extract. Nutrients present in vermicompost are in the readily available form according to Edwards and Burrows[27]. Gutierrez-Miceli *et al.*[28] reported growth and total N, P and K of sorghum were significantly improved with the utilization of leachate derived from vermicompost.

Zinc (Zn) and copper (Cu) were not detected in sweet potato leaf in all treatment and no significant difference was observed in manganese (Mn) and lead (Pb) concentration in all treatments. Leaf of sweet potato is considered as a vegetable in some countries. Hence, the concentration of certain trace elements such as Pb, Cu and Zn should be taken into account as certain level of concentration were detected in the derived liquid fertilizers (Table 1). Wright and Boorse[29] and Ghosh[30] considered Hg, Cd, Pb, As, Cu, Zn, Sn and Cr as problematic heavy metals. While Pb is considered as unnecessary heavy metal which does not help in promoting plant growth, Cu and Zn are actually essential heavy metals (trace elements) for plant growth despite the minute amount needed[31,32]. Micronutrients such as Cu, Fe, Mn and Zn are essential at low concentrations (3-50 ppm). However, they can affect plant growth and become toxic at higher concentrations (20-500 ppm)[33].

Harmful effects of Pb include lead poisoning which will cause impaired development, learning disabilities and coordination impairment especially to children[34-37]. Elevated Cu level hasbeen reported to cause damage in kidney and brain, liver cirrhosis, chronic anemia and stomach and intestinal irritation[34,36]. Hess and Schmidt[38] reported overdose of Zn will cause dizziness and fatigue. Results in Fig. 8 indicated that Mn and Pbwere both within the limit of Malaysian Food Act 1983 (Act 281) and Regulations (2 mg kg^{-1}) as well as guidelines of permissible level in selected countries (Table 2). Sauerbeck[39], Kashem and Singh[40]

Table 2: Guideline on heave metal concentrations (mg kg^{-1}) for food safety set by selected countries (modified from Agrawal *et al.*[42])

References	Cd	Cu	Pb	Zn
	mg kg^{-1}			
Food and Drug Administration of the United States USFDA[43]	25	-	11.5	-
FAO/WHO (Codex Alimentarius Commission[44]	0.2	30	0.3	60
Minister of Public Health, Thailand MPHT[45]	-	133	6.67	667
Malaysia Food Act 1983 (Act 281) and Regulations[46]	1	-	2	-

and Chowdhury *et al.*[41] reported that the normal Cd and Zn level in plants should be within the range of 0.2-2 and 20-100 mg kg^{-1}, respectively. The toxic level for these metal (Cd and Zn) elements is range from 15-20 and 150-200 mg kg^{-1}. The findings in this study are within the normal range as suggested by these literatures.

Vermiwash and vermicomposting leachate used as foliar spray were diluted (10% v/v) as suggested for preventing leaf scorching[28]. One of the known disadvantages of foliar spraying is the leaf burn. However, no scorching or burning on leaf was observed in all treatments.

Results have shown improvement on total chlorophyll and carotenoid content through utilization of diluted (10%) vermiwash and vermicomposting leachate as foliar spray. Certain nutrients improvement was observed from nutrients distribution in sweet potato leaf (Fe, Ca and Na). However, there was no significant superiority between vermiwash and vermicomposting leachate towards photosynthetic pigments concentration and nutrients improvement. Due to the dilution, nutrients present in each application were relatively lower. This may explained the reason of no superiority was shown among treatments as the nutrient present in both liquids were low due to dilution and the duration of the treatment was relatively short (30 days). Nutrients present in the vermicomposting derived liquids vary and strongly depending on the substrate or raw material used. Hence, adding other nutrient-rich material as substrate during the vermicomposting process may help to enrich the vermicomposting derived liquids. Nevertheless, nutrient analysis of vermiwash and vemricomposting leachate showed present of high amount of plant nutrients and exhibited potential to be used in fertigation as nutrients were all water soluble.

Recent case study[47] has revealed the potential of vermicomposting as manure management strategy for urban small holder animal farms. Diet-related illness, environmental quality and climate change are providing chances to and reasons to expand urban farming[2]. Today, many modernized cities which are highly populated such as Stockholm and Adelaide are endeavoring to adapt zero waste practice; a more cost effective and sustainable approach[48]. Introducing the waste derived fertilizers such as vermiwash and vermicomposting leachate will be corresponding to the idea of zero waste approach. Animal dung does pose certain challenge towards solid waste management especially in urban surrounding. Transforming current practice to zero waste approach is challenging even with today's technology[49-52] nonetheless, many endeavors are still needed in order to achieve solid waste management maturity.

With more and more people moving into urban area, urban farming will no longer be a theoretical concept, even though there is no study currently quantifying or qualifying the validity of such idea[53].

CONCLUSION

Organic fertilizer is the main pursue of many researchers, as the importance of it especially in the rising of urban farming is major. This study revealed the potential of utilizing vermicomposting leachate and vermiwash as prominent organic fertilizers that derived from waste. They hold the possibilities to be incorporated into urban fertigation system with further study. The convenience of foliar application perhaps will be more appropriately suiting the urban lifestyle compared to conventional fertilizer application. The remarkable upside of these beneficial liquids that are pertinent for the concept of urban farming is their organic nature as rising health concern among public will not agree with the usage of chemical fertilizer with such proximity with residential area. The results obtained from this study have proven massive potential of these liquids. With further studies, low cost, environmental friendly, waste-derived liquid fertilizer may become main stream as well.

SIGNIFICANCE STATEMENTS

- Utilization of inorganic fertilizer has raised concern towards health as well as environment
- Eco-friendly, alternatives of chemical fertilizers are important to use
- Vermicomposting is an alternate

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