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Small-Scale Turned Windrow to Manage Residue Waste of Curcuma Nursery

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Abstract

A small-scale of turned windrow system was applied to recycle the residue waste from curcuma nursery as compost material. The mixture was piled with cow manure, pig manure, residue waste, and used sawdust at the ratio of 1:0.1:0.9:0.6 (wet weight basis), and adjusted to the initial C/N ratio of 30 and moisture content between 50-60%. The performance of two replicates of composting piles (width 1.5m, length 2 m and height 1.5m) was investigated by measuring physical and chemical parameters including temperature, moisture content, pH, C, and C/N. The effect of composting ages to plant toxicity including seed germination, root length, and germination index of three plant species (Canton lettuce, Chinese spinach, and Cucumber) was examined. The result indicated that both piles achieved thermophile phase (50-60^{o}C) within 3 days and remained at this level for 20 days, thus satisfying the PFRPs (Process to Further Reduce Pathogens). The rate constant (k rate) for organic C decomposition which follows first-order kinetic model and the dry mass loss of both piles were about 0.013 day^{-1} and 24-33%, respectively. The phytotoxicity test indicated that the inhibitory effects of compost on seed germination, root length, and germination index (GI) of three plant species were observed in the first 20 days of composting and decreased with the age of compost onwards. The qualities of final compost of replicates were acceptable and similar to the recommended criteria regulated by Department of Agriculture of Thailand (2548 B.E.). It is also recommended that two months is suitable composting period for this investigation and turning every 15 days should be adopted for an effective process.

Keywords : Composting turned windrow, Curcuma, Nursery.

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1. Introduction

From an engineering point of view, the management of residue wastes from horticultural nurseries needs a promising way to meet economic profit and pollution control simultaneously. As the fertilizer prices raised as well as organic farming promoted nationwide, composting is one of suitable biological treatment processes for recycling these wastes into valuable organic amendment. There are many applications that are commonly used for composting of agricultural wastes such as turned windrows, aerated static or dynamic piles, and vessel composting etc [1-5]. Each application also provides different levels (low, immediate, and high) of composting technology operated [1]. In agro-society of the third world, the development of technology should be dealt with the perspectives of inexpensive, simple, environmentally, and beneficial sound process in order to achieve successful implementation. Composting of non-mechanical turned windrow is therefore one of the most promising methods to transform organic wastes into compost. Since, the immature composts can present phytotoxins such as ammonia, heavy metals, phenolic compounds, and salts, causing detrimental effect on seed germination and development, maturation, root and shoot growth for agricultural use [6-8]. In order to assess the maturity and utilization of compost, testing the phytotoxic effect on seed germination index at different ages of compost is the important criteria to ensure a final quality of compost for crop production.

The goal of this study was to investigate the performance of small-scale turned windrow system to manage residue waste from curcuma nursery in Thailand. The effectiveness of two replicates was evaluated by monitoring the physical and chemical changes of compost. The degradation of organic matter and phytotoxicity test of three plant species (Canton lettuce, Chinese spinach, and Cucumber) were also examined.

2. Materials and Methods

2.1 Materials

Animal wastes studied such as cow and pig manure were used as raw materials and N sources for composting. Residue waste coming from curcuma nursery and used sawdust from the mushroom nursery were added as bulking agent. The initial properties of composted materials are shown in Table 1. All the ingredients were mixed at the wet weight ratio of 1:0.1:0.9:0.6 (cow manure: pig manure: residue waste: used sawdust) to adjust proper initial C/N of 30 and moisture content of 50-60%.

2.2 Composting performance

Two replicates exterior windrows (Pile A and Pile B) were demonstrated to investigate the performance of composting process and final quality of compost. Each windrow (1 ton) measured 1.5m in width, 2 m in length, and 1.5m height was manually turned once every 10 days. After Day 20, the frequency was changed to once every two weeks until the end of composting. During the composting, the samples of both piles were subjected to physical and chemical analyses. The assay of phytotoxicity was examined at the different ages of compost and the test conditions are summarized in Table 2. The filtrated solution after shaking the fresh compost with distilled water at 1:10 w/v for 10 min was prepared as aqueous extracts for this study. The percentage of relative seed germination, relative root growth, and germination index (GI) of three plant species chosen including Canton lettuce, Chinese spinach, and Cucumber were calculated as following [7].

Relative seed germination (%)
= (number of seeds germinated in aqueous extract / number of seeds germinated in control) x 100 (1)

Relative root growth (%)
= (mean root length in aqueous extract / mean root length in control) x 100 (2)

Germination index (GI)
= [(% seed germination) x (% root growth)] / 100% (3)

2.3 Analyses

Changes in temperature at various points of both piles were monitored. Samples for analysis, well-mixed as composite samples, were removed from several parts of each pile. Physical and chemical parameters, such as the moisture content, ash content, carbon (C), total Kjeldahl nitrogen (TKN), and pH were analyzed according to the Handbook of Reference Methods for Soil Analysis Rev.Ed (2000). The means and standard deviations for all parameters were calculated. The rate constants (k, day^{-1}) for waste degradation was obtained by plotting logarithmic graph between degraded C contents (C) versus time (t). The slope of the graph is k value. Equation (4) described the first order kinetic reaction and Equation (5) presented the solution of Equation (4) by integration method [10]. Loss of dry mass was also measured as an indication of organic matter decomposition.

$$dC/dt = -kC \quad (4)$$

$$C = C_o e^{-kt} \quad (5)$$

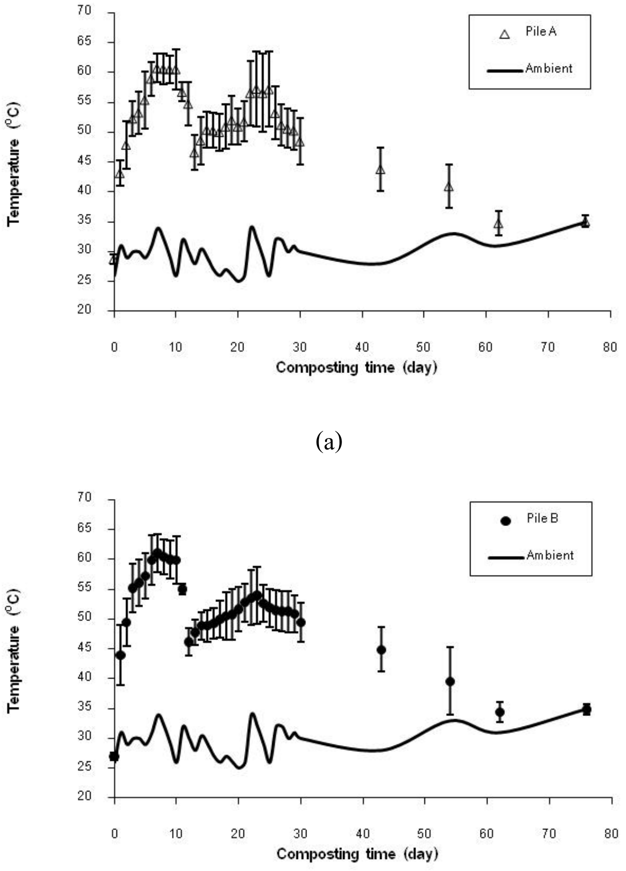
where C is the carbon content (%, dw) at any time t and C_o is the initial carbon content (%, dw) at t_o.

3. Results and Discussion

3.1 Temperature and moisture content

The temperature evolutions of two replicates (Pile A and Pile B) were similar as shown in Fig. 1. During the composting period, the ambient temperature fluctuated within a narrow range of 27-35 °C. The thermophilic temperature regime of both piles were reached after 3 days and leveled off at 50-61°C from Day 3 until Day 10 before dropping to 46-48 °C when the first turning was performed. The second increase in temperature was observed from Day 12 to Day 23 (47-54°C) before declining to the ambient temperature from day 24 to day 76. As the composting proceeded, the initial moisture content (50-55%) of both piles decreased continuously until Day 7 (37-42%). Adding of water adjusts the level of moisture contents of both piles ranging around 57-58% thereafter the moisture profiles were declined gradually to 37-38% at the end of observation (Fig. 2).

A rapid increase in temperature in both piles resulted from the rapid breakdown of degradable organic matters in composting mixture by microbes. In addition, an availability of wastes at early stage of composting provided substrates for microbial growth that enhanced biological activities as well as the production of heat [11-12]. Turning performance particularly on the first 10 days might be improper managed for this study as indicated by cooling effect detrimental to the composting process. However, for both experiments, a temperature of 55°C was reached and maintained above this level for 10 days thus satisfying the PFRPs (Process to Further Reduce Pathogens) composting process. A dramatic loss of water in early stage of composting (7 days) indicated that the moisture evaporation was associated with the heat production from microbial activities and heat ventilation caused by the porosity of compost [13]. For this investigation, a high ratio of residue waste and used sawdust amended not only corrected the proper C/N, but also promoted porous structure and aeration efficiently. It should be noted that the frequency of turning was important and should be performed carefully for small scale composting, particularly high porous composting wastes.



(a)

(b)

Fig. 1 Temperature profiles with time: (a) Pile A, (b) Pile B

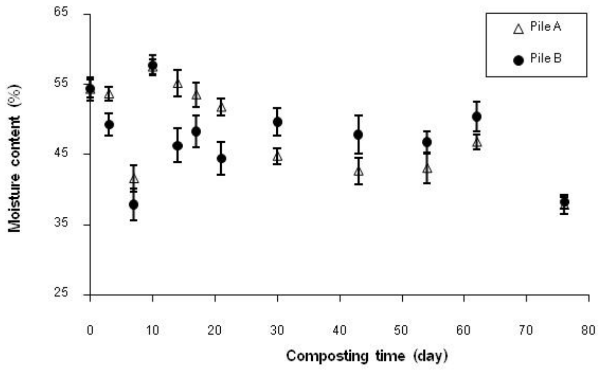


Fig. 2 Moisture profiles with time

3.2 Carbon to nitrogen ratio (C/N) and pH

The initial C/N ratios (23-25) of replicates (Pile A and Pile B) decreased continuously to 13-15 (Day 21) before slightly increasing from Day 20 onwards to 15-19 until the end of observation (Fig. 3). The pH of both piles leveled off at pH 8-9 from Day 0 until Day 21 before dropping below the pH 8 by Day 30 of the composting. The final pH of compost were slight alkaline ranged between 7.4 and 7.6 (Fig. 4).

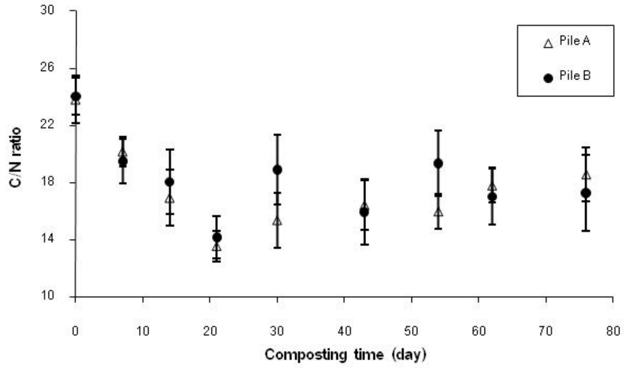


Fig. 3 C/N profiles with time

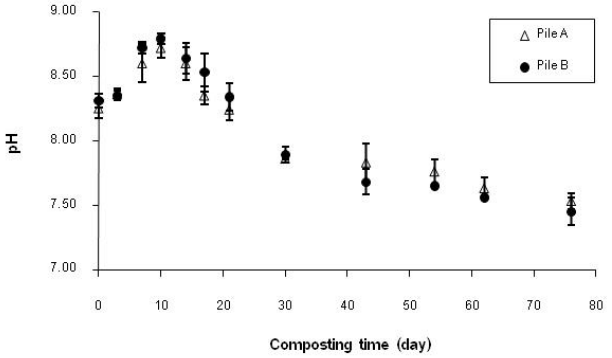


Fig. 4 pH profiles with time

In the early stage of the composting, an increase in pH values resulted from the degradation of nitrogen compounds, in which a large amount of NH_4-N was liberated into the system and caused an increase in pH [8, 11-12]. The increase in temperature and pH in the early stage of composting indicated the activation of organic matter decomposition as confirmed by a decrease in the C/N ratios. For the later stage of composting, a slight increase in the C/N ratios might caused by the porous structure of compost enhanced the loss of nitrogen as an ammonia gas (NH_3-N) through volatilization [4-5]. Decreasing the C/N ratio and pH (neutral) could result in further immobilization of NH_3-N by nitrification suggesting that the chemical properties of materials of both piles had been more stabilized [3-4, 8].

3.3 Degradation of organic matter

The losses of dry mass and rate constant (k) of organic matter degradation are shown in Fig.5. It was found that absolute amount of removal (119-164 kg) and removal percentage (24-33%) of dry mass of replicates were similar. When microorganisms are incubated in the presence of two or more substrates, the substrates will be degraded in the order of their ease of degradation. The major part of residue waste and used sawdust are made up of inorganic and resistant materials (lignocelluloses), which require more time for biological degradation [14]. Hence, the degradation rate is a function of time and limited by substrate concentration was derived from Day 0 until Day 43 of composting. The kinetic plot of both piles followed a first-order model as indicated by high linear regression coefficients ranging between 0.6 and 0.8 could be calculated as 0.013 day^{-1}.

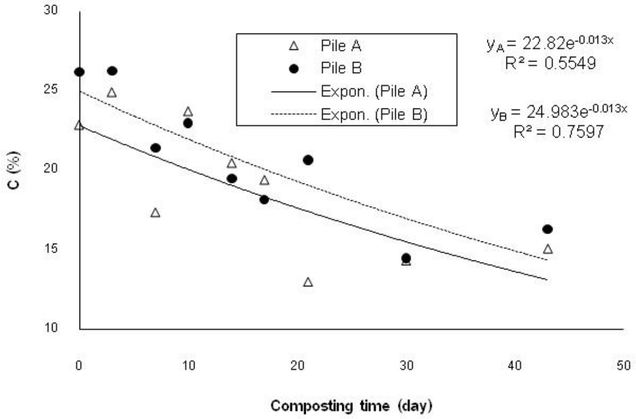


Fig. 5 Kinetic plots with time

3.4 Phyto-toxicity assay

Tend of changes in concentrations of NH_3-N of replicates (Pile A and Pile B) was similar (Fig. 6). The initial NH_3-N content (24-50 mg kg^{-1}) of both piles decreased continuously to below 10 mg kg^{-1} towards the end of observation. On the contrary, the concentrations of extractable Zn and Cu increased slightly from 8.1-8.2 mg kg^{-1} to 17.1-18.1 mg kg^{-1} and from 1.8-2.2 mg kg^{-1} to 3.7-3.9 mg kg^{-1} respectively (Fig. 7-8).

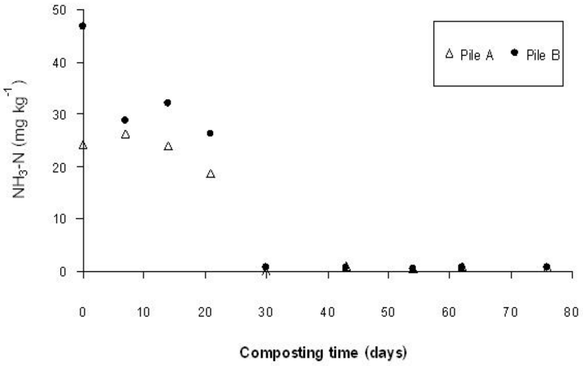


Fig. 6 Changes in NH_3-N with time

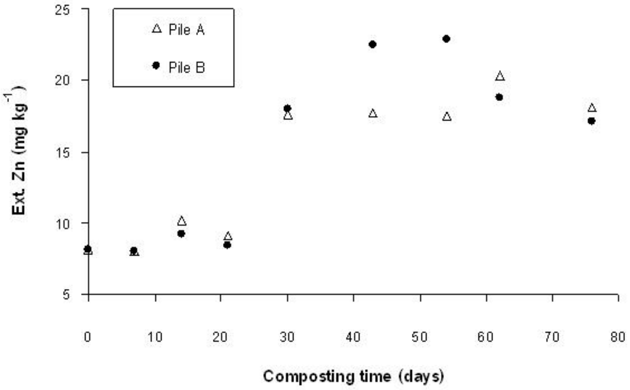


Fig. 7 Changes in Extractable Zn with time

As the composting proceeded, the values of germination index (GI) of three plant species (Canton lettuce, Chinese spinach, and Cucumber) increased (Fig. 9-11). However, Cucumber, on the other hand, it had an initial GI of about 70-

80% and thereafter the index dropped rapidly to about 20-40% by Day 7 before increased gradually with time from Day 14 onwards. The germination index of Canton lettuce and Chinese spinach of both piles increased from the beginning (50-60%) onwards and reached over 100% by Day 30 of composting.

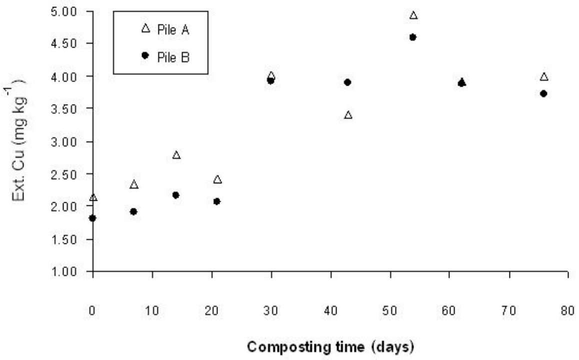


Fig. 8 Changes in Extractable Cu with time

Results of three plant species assay revealed that the phytotoxic effects caused by chemical properties (NH_3, Extractable Zn and Extractable Cu) appeared evidently during the early stage of composting (first 20 days), however these decreased and gradually eliminated with time as indicated by the increase in the germination indices of all plant species tested over 100% by Day 30. These were agreed with those reported by Tam and Tiquia [7]. Although, the concentrations of Extractable Zn and Extractable Cu seemed to increase from the beginning towards the end of composting that might be attributed to the phytotoxicity, but the appearances were not detrimental to seed germination and seedling growth as shown in Fig. 9-11. These observations confirmed that NH_3-N content was major phytotoxic substance affecting seed germination index of tested plant species [7-8].

As well-known that the occurrence of sensitivity of plant species to toxicity depends on a capacity of its food reserves as well as its tolerance to toxicity [7-8, 15]. However, this study showed that seeds of Canton lettuce and Chinese spinach with very small size and lower food reserves, presented lower sensitivity to toxicity than Cucumber seeds particularly the first 20 days of composting. Different findings might be attributed to the effect of ammonia toxicity on shoot and root growth of Cucumber plants [16].

3.5 Quality of compost

With the composting process ongoing, the replicates demonstrated good visual quality of compost after 20 days based on its pleasantly earthy smell, dark brown in color, and no longer distinguishable residues, thus the compost resembled as humus like in its appearance. The quality of final compost obtained was qualified the recommended criteria set by Department of Agriculture of Thailand (2548 B.E.) as shown in Table 3.

In case of local technology transfer in developing countries, from an engineering point of view, implementing simple and practical process while maintaining a good product quality and requiring less energy is advantageous. Small-scale turned windrow is therefore viewed as appropriate technology for horticultural nurseries in rural Thailand.

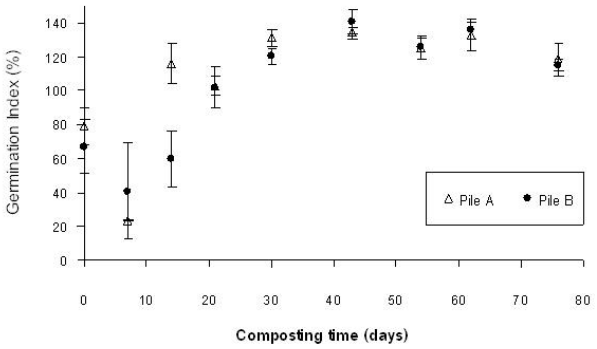


Fig. 9 Germination indices of aqueous extract on Cucumber plant specie

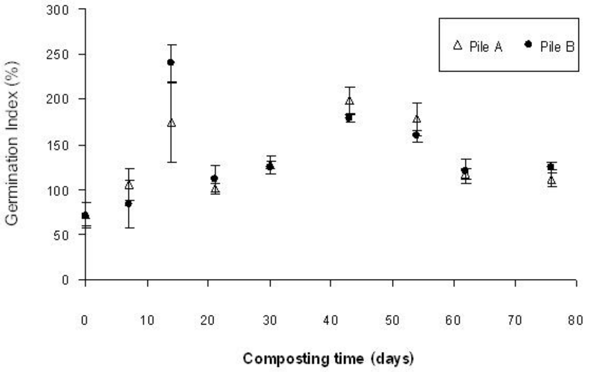


Fig. 10 Germination indices of aqueous extract on Canton lettuce plant specie

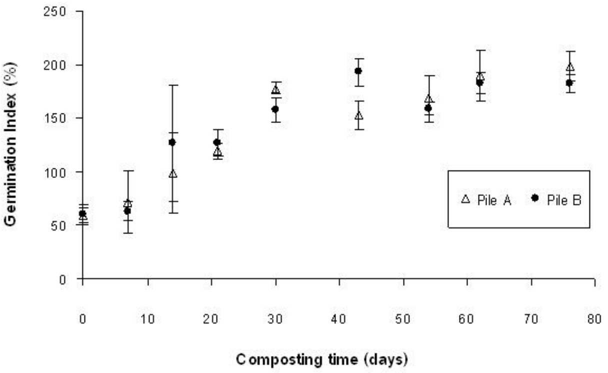


Fig. 11 Germination indices of aqueous extract on Chinese spinach plant specie

4. Conclusions

Replicates of small-scale turned windrow demonstrated practically to manage residue wastes from curcuma nursery and to apply for other agricultural wastes. The temperatures of above 50^{o}C were reached within 3 days and leveled off at this level for 20 days thus the requirements for a Process to Further Reduce Pathogens (PFRP) were met. Germination index (GI) combining germination and root length of tested plant species was negatively affected by NH_3-N substance as the GIs increased and as the NH_3-N decreased from 20 days onwards. Among three plant species assayed found that seeds of Cucumber were the most sensitive to ammonia toxicity, however these disappeared as the age of compost increased from Day 20 until the end of composting. Final qualities of compost of replicates were quite similar and qualified the recommended criteria regulated by Department of Agriculture of Thailand (2548 B.E.). This study is also recommended that two months is suitable period for composting residue waste of curcuma nursery and turning every 15 days should be adopted for effective small-scale composting.

5. Acknowledgements

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Table 1 Characteristics of composted materials

Parameter	Materials			
	Cow manure	Pig manure	Residue waste	Used sawdust
Bulk density (g cm^{-3})	0.37±0.06	0.52±0.01	0.69±0.03	0.35±0.01
Moisture content (%,w/w)	20.7±0.88	12.5±0.52	3.1±1.02	20.7±0.41
pH	7.8±0.12	7.8±0.69	7.5±0.40	8.5±0.49
Organic matter content (%)*	45.6±1.04	48.1±0.57	12.2±0.88	42.1±0.32
C (%)*	24.1±0.76	26.3±0.52	7.4±1.02	20.3±0.79
N (%)*	1.4±0.32	2.5±0.92	0.4±0.12	0.9±1.44
C/N	17.9±1.02	10.6±0.82	19.4±0.72	23.4±1.61

* dry basis

All values are mean ± standard deviation.

Table 2 Seed germination test conditions [7]

Items	Conditions
Test type	Batch
Pre-treatment	Soak in distilled water overnight
Temperature	22±3°C
Light	None
Test vessel	10x100 mm Petri dish plus Whatman no. 1 filter paper
Test volume	10 ml per dish
Number of seeds	10 per dish
Replicates	3
Control	Distilled water
Test duration	5 days
End point	Germination, primary root > 5 mm

Table 3 Final properties of compost and Thai standard criteria for organic compost product

Parameters	Pile A	Pile B	Thai standard criteria [17]
Size (% passing sieve 12.5x12.5 mm)	100%	100%	100%
Foreign materials (glass, plastic, metal)	none	none	none
Stones and other consolidated mineral contaminants >5 mm	<5%	<5%	<5% by weight
Moisture content (%)	37%	38%	<35%
Bulk density (g cm^{-3})	0.59	0.66	NR
pH	7.5	7.4	5.5-8.5
Ash (%)*	63%	68%	NR
C (%)*	20%	18%	NR
TKN (%)*	1.08%	1.05%	NR
C/N ratio	18.6	17.3	20
Organic matter (%)*	36%	32%	>30
N:P:K*	1:1.8:1.3	1:1.9:1.3	1:0.5:0.5
EC (dS m^{-1})	2.52	2.39	<6
NH_3-N (mg kg^{-1})	8	7	NR
Copper (mg kg^{-1})	4.0	3.7	500
Zinc (mg kg^{-1})	18.1	17.1	NR
Salmonella sp.	ND	ND	NR
Shigella	ND	ND	NR
Staphylococcus	ND	ND	NR
Fecal Coli form	ND	ND	NR
Total Coli form	ND	ND	NR

* dry basis

NR = No recommendation

ND = No detectable