Influence of composting methods on compost maturity and quality

Abstract

An investigation entitled 'Influence of composting methods on compost maturity and quality' was conducted at Plant Propogation and Nursery Management Unit, Vellanikara to study the effect of composting methods on compost maturity and quality and to evaluate the suitability of compost obtained from various composting methods as organic manure on the growth and yield performance of Okra crop. The experiment on influence of composting methods on maturity and stability parameters of compost consisted of eight methods of composting (T_1-Aerobic composting using cow dung, T_2- Aerobic composting using *Bacillus subtilis* (KAU culture), T_3- Composting using effective microorganisms, T_4- Composting with *Trichoderma* and worms, T_5 - Vermicomposting, T_6- Varanashi composting, T_7- Heap and T_8- Pit method of composting). The experiment to evaluate the suitability of compost as organic manure in the performance of Okra crop consisted of nine treatments including compost obtained from all the composting methods and farm yard manure. The organic manure requirement of the crop was substituted by compost and the quantity was decided in comparison to nitrogen content of farm yard manure (FYM) requirement of Okra (12t/ha). Results of the study indicated that compost obtained from all the composting methods helped to attain physical, chemical and biological parameters of compost maturity at varying degree. The highest yield was recorded in Varanashi composting followed by aerobic composting using cow dung. Based on the recovery percentage, the highest compost recovery was noticed in aerobic composting using cow dung. The nutrient content of compost obtained from all the composting methods was in the permissible limit. Even though the quantity of compost produced was less using microbial culture, compost produced has attained all the maturity parameters. Hence in the absence of cow dung, composting using *Bacillus subtilis* (KAU culture) and *Trichoderma* and worms can be used as substitute for cow dung. Germination studies using compost extract and compost as potting mixture revealed that the compost produced were not phototoxic in nature and also the heavy metal content were in the permissible limit. Based on the compost yield and better parameters of maturity, aerobic composting, varanashi composting and vermicomposting was found superior. Crop performance was significantly higher with varanashi compost, vermicompost and compost using EM. There was a positive and significant increase in available soil nutrient content after the addition of all the compost.

Key words: Composting methods, compost maturity, quality, phytotoxicity, crop yield

Introduction

Composting has been recognized not only as a promising attempt for processing and disposal for biodegradable solid waste but an absolute imperative for nutrient recycling and soil improvement in an agricultural economy. Recently new methods have been developed for speedy composting and also utilize certain microbes as a substitute for cow dung for initiating the microbial decomposition. Effective microorganisms, *Trichoderma* and microbial culture are utilized for substituting cow dung owing to its decreased availability. Vermicomposting is a well-established method for composting but need more efforts from the part of composter. Though different methods of composting have been developed, none of the methods have been tested frequently for its maturity and stability at frequent intervals. Iqbal *et al.* (2012) reported that composting methods differ in duration of decomposition and potency of stability and maturity and the compost prepared by different methods yield chemically different products. One of the important factors affecting the successful use of compost for agricultural purpose is compost maturity. The application of immature compost to the soil causes severe damage to plant growth (Wu *et al*., 2000). Maturity is assessed by measuring various physico-chemical parameters, seedling emergence, root elongation and phytotoxicity (Mathur *et al*., 1993). Seal *et al*. (2012) opined that presence of a very large and diverse population of self-generated microorganisms in the end product of compost indicated its potential in terms of fast and effective soil application. Compost obtained from many of the rapid methods is found to be coarser and need to be evaluated for maturity and quality prior to its agricultural use. Hence it is highly essential to study the influence of various composting methods on its end product quality, particularly in terms of its stability and maturity status and to evaluate whether the compost obtained from these methods can be directly used as manure.

Materials and methods

An investigation entitled "Influence of composting methods on compost maturity and quality" was carried out to study the effect of different composting methods on compost maturity and quality and to evaluate the suitability of compost obtained from various composting methods as organic manure at Plant Propagation and Nursery Management Unit Kerala Agricultural University, Vellanikkara, Thrissur. Treatments consisted of 8 methods of composing viz., Aerobic composting with cow dung; Aerobic composting with Bacillus subtilis; Composting using effective microorganisms; Composting with Trichoderma & worms; Vermicomposting; Varanashi composting; Heap method and Pit method Banana pseudostem both fresh and 2-5 week old and green leaves of glyricidia (2kg leaves along with 100kg pseudostem) was used as common substrates for all the methods of composting. Cow dung containing NPK in the range of 0.8:0.5:0.6 (%) and microbial content of 16.1 X 105 cfu/g were used as inoculum in aerobic composting with cow dung, vermicomposting, varanashi composting as well as heap and pit methods of composting. Microbial culture of Bacillus subtilis developed in the Department of Agricultural Microbiology, College of Horticulture was used as inoculum in aerobic composting using Bacillus subtilis. The inoculum used has an initial microbial count of 13 X 106 cfu/ml. An EM preparation containing microbial count of 83 X 104cfu/g was used in composting using effective microorganisms. A composite culture of *Eudrillus euginae* and *Isenia foetidae* was used in vermicomposting and composting using *Trichoderma* and worms. *Trichoderma* containing microbial count of 2 X 104 cfu/g was used in composting with *Trichoderma* and worms. Varanashi composter containing microbial count of 12.5 X 105 cfu/g was used as inoculum in varanashi composting. Composting was carried out in tanks constructed in the compost sheds available at Coconut Development Farm of PPNMU. The tanks were partitioned internally using bricks. The size of the tank for each treatment was 156cm*75cm width and 50 cm height. 100Kg waste including fresh and 2-5 old banana pseudostem and glyricidia leaves were added uniformly. The height of the heap was 15cm. Since temperature was not developed, gunny sacks were placed over the all the treatments except Varanashi composting.

Aerobic composting with cow dung

Aerobic composting was carried out in tanks provided with sufficient holes for aeration.10 Kg of cow dung was added as inoculants in alternate layer with the substrate. Turning was given at 2 weeks intervals.

Aerobic composting with Bacilllus subtilis

Aerobic composting with *Bacillus subtilis* was carried out in tanks provided with sufficient holes for aeration and the inoculants used for composting was microbial culture of *Bacilllus subtilis.* 200ml of the culture was diluted to 1 litre and 300ml was sprinkled as alternate layer above the crop residues. Turning was given at 2 weeks intervals.

Composting using effective microorganisms

Composting using effective microorganisms were carried out in tanks provided with sufficient holes for air circulation. ENVIRON was used as inoculum and 50 ml was diluted to 1000 ml and 300ml of which was added as alternate layers to the substrate. Turning was given at 2 weeks intervals.

Composting using Trichoderma and worms

The inoculant used in the experiment was Trichoderma and composite culuture of *Eudrillus euginae* and *Isenia foetidae* earthworms. Trichoderma was added at the rate of 100gm per treatment and applied as alternate layers .The worms were introduced @ of 100 worms per treatment each during the first week and one month after composting. Turning was also given at 2 weeks intervals.

Vermicomposting

The inoculums used were cow dung and culture of *Eudrillus euginae* and *Isenia foetidae* earthworms. Cow dung @ 10 Kg was added as alternate layers over the substrate. The worms were introduced @ of 100 worms per treatment each during the first week and one month after composting

Varanashi composting

UV stabilized plastic sheet was used for composting. The sheet was spread on the levelled area under thatched shed. The composter was added at the rate of 100gm over the substrate and 15 Kg of cow dung was added over it. Rock phosphate was sprinkled over the layer at the rate of 500g. In this manner the heap was built up to a height of 15 cm spreading the material and additives layer by layer. The heap is covered fully with UV stabilized plastic sheet. As the heap was prepared under thatched shed, additional covering to protect the heap from direct sunlight was not required.

Heap method

Substrate (100Kg) was heaped at a length of 156cm and breadth of 75 cm and 15 cm height over the levelled land to get the same volume as in the above treatments. 10 Kg of cow dung was added as inoculums in alternate layers. No turning was given.

Pit method

The pits were taken at a dimension of 156 cm*75 cm under open condition. Pits were covered with a tarpaulin sheet to protect it from direct sunlight and rainfall. The substrate used fro composting (100Kg) was added in the pit to a height of 15 cm and cow dung was added as inoculum in alternate layer.

Phytotoxicity studies

Seed germination test using compost extract

A modified phytotoxicity test employing seed germination was used (Zucconi *et. al*., 1981). Tomato seeds (*Lycopersicon esculentum* L.) were used for seed germination test in compost extract. No. 2. Whattman filter paper was placed inside 90mm UV sterilized, disposable Petri dish. The filter paper was wetted with 9 ml of 1:10 compost/water extract and 30 tomato seeds were placed on the paper. Distilled water was used as control in the experiments and were run in triplicate. The petri dishes were sealed with para film to minimize water loss while allowing air penetration and then were kept in the dark for 4 days at room temperature. At the end of 4^{th} day, the percentage of seed germination in compost extract was compared with that of control.

Seed germination test using Potting mixture

The potting mixture was prepared using compost and soil in the ratio of 1:1 and were taken in the UV sterilized petri dishes and 30 tomato seeds were placed in it. Soil was used as control. It was placed under dark and germination was noted on the fourth day and compared with that of the control.

Suitability of compost as organic manure

Compost obtained from the above composting method were tested as organic manure by growing Okra in pots using compost obtained from the above method and the quantity of compost will be decided in comparison to N equivalent of farm yard manure recommendation of okra and it was compared with ordinary potting mixture (Sand soil and cow dung in the ratio 1:1:1) as control.

Main items of observations taken to assess the Compost quality include Chemical composition of the substrates used for composting (Total content of carbon, N, P, K and pH); composition of EM; Indicators of maturity (at different stages of composting) viz., Physical parameters such as daily temperature, moisture content, particle size, odour, colour, and volume reduction, compost yield; Chemical parameters such as pH, CEC, total volatile solids (TVS), total organic carbon and CN ratio; Biological parameters such as presence of micro and macro organisms (Microbial and earthworm count at compost maturity), dehydrogenase enzyme activity; N, P, K, and micronutrients and Phytotoxicity studies using seed germination in compost extract and in potting mixture made from compost and presence of heavy metals using standard procedures. Biometric observation and yield of okra were recorded at various growth stages

Results and Discussion

Influence of composting methods on maturity and stability parameters of compost

A number of criteria and parameters are proposed for testing compost maturity and stability, but no single method has been universally applied due to the difference in substrate composition and composting methodologies. Evaluation of compost stability and maturity will help in standardization of the quality of compost obtained from different methods of composting. The maturity and stability of compost depends upon the chemical constituents present in the initial substrate as well as the intermediates formed during different stages of composting. The rate or degree of organic matter decomposition is known as compost stability and the degree of decomposition of phytotoxic organic matter produced during the active composting stage is known as compost maturity.

Influence of composting methods on Physical parameters

Physical characteristics such as temperature, colour, odour, moisture content, particle size, volume reduction, bulk density etc. (Table1) gives a general idea of decomposition stage, but little information on the degree of maturation.

The initial temperature of the substrate use for composting was28.5ºC. Temperature change from 27ºC to 33ºC was observed in all the methods of composting during the initial few weeks of composting. Temperature increased to 31ºC up to one month after composting. The highest temperature of 31.41ºC was observed in pit method of composting followed by heap method of composting (30.18ºC). Varanashi composting and vermicomposting showed a temperature of 29.6ºC and 29.06ºC respectively. In all other methods of composting the temperature developed after one month of composting was 28ºC. The temperature decreased slowly after 2 months of composting. The highest temperature was observed in pit method of composting (28.66ºC). In all the other methods, the temperature was 27ºC. The temperature after three month of composting was more in pit method of composting followed by heap, varanashi and vermicomposting methods.

Composting is an exothermic process and temperature development is as a result of microbial activity followed by decline in temperature due to the less availability of organic carbon. Variation in temperature with respect to the ambient temperature was recorded in all the method of composting.

Compared to ambient temperature, the temperature of compost material was high in all the methods of composting. This may be due to the decomposition of organic matter. However in none of the method of composting, temperature development was not more than 32ºC. The non-development of temperature beyond 32°C in the composting methods may be due to the small heap and frequent rain observed during the month of June and July. Taiwo and Oso, (2003) reported that large heaps lead to generation of high temperature and small heaps generate low temperature. After 60 days of composting, the temperature development in all the composting methods almost equalled to that of ambient temperature. Minimum temperature levels has been achieved towards the end of composting period in all the methods of composting, which is essential for an effective composting process to take place. Since this time, evidence has accumulated supporting the above findings. (Finstein *et al*., 1986) .Except in varanashi method of composting, decrease in temperature was noted after each turning, indicating a decrease in easily decomposable organic matter.

The initial moisture content was 86.78%. The moisture content was reduced to the range of 40-60% which was thereafter maintained continuously throughout the composting period by sprinkling water. Adequate moisture content (40-50%) was maintained throughout the composting period in all the methods as it is required for metabolic and physiological activities of the microorganisms as it provides a medium for the transportation of nutrients. The moisture content was high in varanashi method and was not able to sieve the compost on the same day. The high moisture in varanashi composting may be due to the complete covering of the heap by UV sheet and hence the evaporation loss may be less. Hence cover was removed and kept as such for another 2 weeks for sieving.

Colour change of compost is used as a parameter for compost maturity. Colour change was observed in all the methods of composting. A dark brown colour was observed in all the methods of composting, indicating that decomposition had taken place in all the methods. Sughara and Inoko (1981) reported that colour of composting material changes to dark or grayish black with advancing maturity. No odour was noticed in compost obtained from any of the methods except an earthy smell for the pit method of composting. Conversely, compost with an obnoxious odour indicates instability. (Henry and Harrison, 1996). Even though colour and odour are the simplest physical parameters to evaluate the maturity and stability of compost obtained from different methods, some additional physical, chemical and biological methods were also determined for confirmation.

The volume reduction during composting may be attributed to decomposition of organic matter by the microorganisms during different stages of composting. The composting methods were in earthworms were introduced recorded the highest reduction in volume after 60 days of composting with volume reduction percentage of 88.76% (Composting using *Trichoderma* and worms and vermicomposting). The lowest volume reduction (66.29%) was recorded in varanashi composting. The excess moisture content and lack of aeration in varanashi composting might have caused unfavourable condition for the microorganisms to multiply. Iyengar *et al* ., (2006) also reported that volume reduction depends upon the input of waste and the type of composting methods adopted. He also recorded more than 90% volume reduction in aerobic reactor as compared to 12.58% in anaerobic reactor. Except varanashi and heap method of composting, volume reduction was more than 80% in all the other methods of composting.

In vermicomposting, more than 82% of the particles were of size less than 2mm size. Particle size reduction was highest in treatments were earthworms were introduced (vermicomposting and composting using *Trichoderma* and worms). Although biochemical degradation of the organic matter is carried out by microorganism, earthworms fragment the substrate drastically altering the microbial activity and increasing the surface area (Dominguez *et al.,* 1997). Compost obtained from varanashi composting with larger particle size and comparatively higher moisture content had the lowest bulk density among the different method of composting. Schaub-Szabo and Leonard (1999) also reported that the amount of moisture and particle size strongly affects bulk density. The pore space between the compost particles should be such that the optimum retention of water and air are retained. If the particles are too close to each other, then the compost tend to compact, resulting in low air capacity, low infiltration rate and water holding capacity.

The highest compost yield was obtained from varanashi method (15.47 Kg) followed by aerobic composting (15.12 kg) and vermicomposting (13.42 kg). The lowest compost yield was noticed in composting using EM. Yield from 100 kg substrate along with inoculum was high in varanashi method of composting. The yield was less from composting methods without addition of cow dung (*viz*., composting using Effective microorganisms, *Bacillus subtilis*). This indicates that the final yield of compost obtained increased with addition of cow dung. Hence, in varanashi composting yield increase was noted mainly due to addition of three times more cow dung compared to other methods. Undecomposed material was also highest in varanashi composting compared to other methods. Even without the addition of cow dung, composting using *Trichoderma* and worms produced comparable yield to that of aerobic composting using cow dung and vermicomposting. When we consider the compost yield from the substrate alone, the compost yield was higher in aerobic composting with cow dung, vermicomposting and composting using Trichoderma and worms. Undecomposed portion were also less in these methods.

All the composting methods attained physical parameters of maturity at varying degree. The physical parameters like colour and odour of compost obtained from different methods did not show any variation. The mature compost obtained from all the method of composting was odourless and dark brown in colour. Physical parameters such as volume reduction, particle size, bulk density, yield and undecomposed material left after composting varied with composting methods. Varanashi composting yield high when total material added for composting was taken into consideration. But volume reduction and particle size reduction were also less in varanashi composting method. Considering the compost yield from 100 kg substrate used for composting and undecomposed material left after composting, aerobic composting using cow dung and composting using *Trichoderma* and worms was found equally efficient. The volume reduction and particle size reduction were high in these treatments. Hence wherever there is no availability of cow dung for composting, composting with *Trichoderma* and worms is suggested as an alternative method. Based on physical parameters of maturity, aerobic composting using cow dung, vermicomposting and composting with *Trichoderma* and worms are suggested as good methods of composting compared to other methods.

Table 1 Influence of composting methods on physical properties of compost

Treatments	**Volume reduction (Mature compost) %)**	**Compost yield (kg)**	**Bulk density (g/cc)**	**Particle size less than 2mm**
Aerobic composting with cow dung(T1)	83.15a	15.12ab	0.61ab	77.50
Aerobic composting with *Bacillus subtilis* (T2)	83.15a	8.30cd	0.61ab	79.60
Composting using effective microorganisms (T3)	88.76a	6.76d	0.68ab	61.30
Composting using *Trichoderma* and worms (T4)	88.76a	11.32abcd	0.66ab	79.90
Vermicomposting (T5)	83.15a	13.42ab	0.65ab	81.90
Varanashi composting (T6)	66.29b	15.47a	0.58b	70.70
Heap method (T7)	83.15a	10.72abcd	0.70a	68.60

Pit method (T8)	71.91b	12.58abc	0.70a	79.60

*The data followed by same superscript do not vary significantly

Influence of composting methods on Chemical parameters

Chemical parameters like pH, Cation Exchange Capacity (CEC), Total Volatile Solids (TVS), organic carbon, C:N ratio, (Table 2) NPK content and micronutrient analysis give more information on compost stability and maturity.

Compost obtained from different composting methods had attained a peak to alkaline pH (7.97-8.0). Alkaline pH of 7.97 and 8.00 was observed in composting using Trichoderma and worms and vermicomposting respectively. The alkaline nature of compost obtained composting using Trichoderma might be due to the action of talc used as a carrier in the preparation of Trichoderma. The pH of aerobic composting using cow dung recorded almost neutral (pH→7.07) during the final stage of composting, Iqbal *et al*., (2012) has reported that during the final stages of composting, pH becomes neutral when organic acids get converted to CO_2 by microbial activity. However none of the methods of composting is found to have significant influence on pH of the compost.

Cation Exchange Capacity (CEC) is a chemical parameter used to determine the quality of compost as an organic manure. CEC measures the quantity of negative charges in the matrix to hold the negative charges. It not only reflects the decomposition rate, but also measures the capacity of compost to hold nutrients. Though none of the methods could attain CEC greater than 60 C mol kg^{-1}, among different methods of composting, highest CEC was noticed in aerobic composting using cow dung. This might be due to the rapid formation of humic fraction produced by degradation of organic matter. Moreover higher CEC in aerobic composting is an indicator of more rapid decomposition of organic matter than in other methods. Iqbal *et al., (2012)* has stated that higher CEC in aerobic sample during active composting stage is an indicator of more rapid decomposition of organic matter. Except pit and heap method, all the methods of composting showed CEC in the range of 20-24 meq/100 gm of compost. Lax *et al*., (1986) reported that CEC in organic material increases as function of humification due to the formation of carboxylic and phenolic functional groups. CEC value greater than 60 C mol kg^{-1} (on an ash-free material basis) was suggested as the minimum value needed to ensure an acceptable degree of maturity (Harada and Inoko*.,* 1981). CEC greater than or approximately 60 is considered to be sufficiently matured for the application of cropland. (Baca *et al.,* 1992). However the compost obtained from different methods did not show CEC greater than or approximately equal to 60, the compost obtained from different composting methods has helped in attaining other parameters of maturity.

C:N ratio has been used as an index of compost maturity in composting process. Carbon reduction was greater when compared to nitrogen content in all the methods of composting. This might be due to the use of carbon as source of energy and nitrogen for building cell structure in decomposition process. Percentage reduction in C:N ratio one month after composting was 22.39%, 23.11% and 24.47% for pit, aerobic composting using cow dung and aerobic composting using effective microorganisms respectively. Higher reduction of C:N ratio in aerobic composting was due to the nature of aeration and the same became stable earlier than in all other process. The C:N ratio showed a decreasing trend in all the stages of composting. There was a rapid reduction in C:N ratio of composting using effective microorganisms. This may be due to the high count of microorganisms in the initial inoculants which might have led to the consumption of large quantity of carbonaceous material. The reduction in carbon content when compared to the initial content was greater in all the methods of composting which might be due to the use of carbon as a source of energy by microorganisms. Use of effective microorganisms as inoculants has helped in increasing microbial activity. Except Varanashi composting (16.05%), all the other method of composting had lower C:N ratio. The lack of sufficient aeration might have hindered the decomposition process in varanashi composting which resulted in higher C:N ratio. As there is excess carbon, the nitrogen utilized was also less. Iqbal *et al.* (2012) have reported lesser utilization of nitrogen in anaerobic composting. C:N ratio <20, preferably <10 was established by Bernal *et al*., (1998) as a maturity index for composts of all origins.

The intense microbial activity during composting process lead to the production and release of volatile organic compounds. Total volatile solids are found decreasing as the composting proceeds in all methods. Kumar *et al.* (2011) reported high emission rate of volatile organic compounds at early stage of composting than in the later stage. Aeration substantially influences emission of volatile solids. Total volatile solids was higher in varanashi composting and less in heap method. Muller *et al.* (2004) reported that excessive aeration speed up the process of emission of total volatile solids from compost pile. The total volatile soilds and organic carbon content was higher in varanashi composting. Kilikowska and Klimiuk (2011) have reported that volatile organic compounds is significantly correlated with organic matter degradation

Table 2 Influence of composting methods on chemical properties of mature compost

Treatments	**CEC (meq /100gm of compost)**	**pH**	**Total volatile solids**	**Organic carbon %**	**CN ratio**
Aerobic composting with cow dung(T1)	24.17^{a}	7.07^{a}	38.00^{ab}	21.59^{a}	9.62^{bc}
Aerobic composting with *Bacillus subtilis* (T2)	22.57^{a}	7.67^{a}	32.00^{bc}	18.18^{b}	10.17^{bc}
Composting using effective microorganisms (T3)	20.26^{abc}	7.67^{a}	26.00^{cd}	14.77^{cde}	6.37^{c}
Composting using *Trichoderma* and worms (T4)	21.97^{ab}	7.97^{a}	31.33^{bc}	17.80^{bc}	9.93^{bc}
Vermicomposting (T5)	20.62^{abc}	8.00^{bc}	32.00^{bc}	18.18^{b}	11.03^{b}
Varanashi composting (T6)	22.80^{a}	7.43^{a}	40.66^{a}	23.11^{a}	16.41^{a}
Heap method (T7)	17.41^{bc}	7.90^{a}	25.33^{cd}	14.39^{de}	7.44^{bc}
Pit method (T8)	16.50^{c}	7.83^{a}	20.66^{d}	11.74^{e}	7.56^{bc}

*The data followed by same superscript do not vary significantly

Composting methods showed significant variation in nitrogen content. Nitrogen content was highest in compost obtained using effective microorganisms followed by aerobic composting using cow dung. This was a consequence of strong degradation of organic carbon compounds at early stage of composting, which reduced the weight of dry mass. Supporting findings were given by (Bustamante et al., 2008). Nitrogen content was significantly less in varanashi composting. The anaerobic nature of varanashi composting have resulted in lower reduction of C:N ratio which in turn resulted in lesser utilization of nitrogen by microorganism for building body structure. Phosphorus content was highest in varanashi composting. This might be due to the addition of rock phosphate present in the inoculums. Among the methods of composting vermicompost had the highest potassium content. This might be attributed to the direct action of worm gut enzymes. Vermicomposting involves bio-oxidation and stabilization of organic material by joint action of microorganism and earthworms (Gandhi and Sundari, 2012). Rao *et al*. (1996) has reported that the increase in K in vermicompost in relation to that of the simple compost and substrate was probably because of physical decomposition of organic matter of waste due to biological grinding during passage through the gut, coupled with enzymatic activity in worm's gut, which may have caused its increase

But P & K content of compost was found less than the initial content in all the methods of composting. Copper was highest in treatments were earthworms were introduced. This might be due to the biological activity of the microorganisms leading to increased nutrient availability. Freely available ions and minerals have been produced during ingestion and excretion of organic matter by earthworms. Zinc content was highest in composting using cow dung and varanashi composting.

Table 3. Nutrient composition and micronutrient content of mature compost

Treatments	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Cu (ppm)	Zn (ppm)
Aerobic composting with cow dung(T_1)	2.13^{a}	0.21^{bc}	0.36^{c}	24.37^{c}	20.68^{a}
Aerobic composting with *Bacillus subtilis* (T_2)	1.80^{cd}	0.17^{cd}	0.56^{abc}	25.30^{c}	14.24^{bc}
Composting using effective microorganisms (T_3)	2.33^{a}	0.08^{f}	0.41^{bc}	23.35^{c}	7.33^{d}
Composting using *Trichoderma* and worms ($T_{4)}$	1.81^{cd}	0.15^{de}	0.66^{ab}	31.46^{ab}	10.60^{bcd}
Vermicomposting (T_5)	1.65^{de}	0.24^{b}	0.700^{a}	34.05^{a}	14.91^{b}
Varanashi composting (T_6)	1.44^{e}	0.33^{a}	0.68^{ab}	28.60^{bc}	22.86^{a}
Heap method (T_7)	1.93^{bc}	0.18^{cd}	0.59^{abc}	24.84^{c}	14.57^{b}
Pit method (T_8)	1.55^{de}	0.11^{ef}	0.45^{abc}	16.34^{d}	9.33^{cd}

*The data followed by same superscript do not vary significantly

Influence of composting methods on Biological parameters

Presence of large and diverse population of self-generated microorganism in the end product of compost indicates its potential in terms of fast and effective soil application. (Table 4) Microorganism and macro organism present in the compost vary with method of composting. Earthworm count was found higher in composting method using earthworm.

The earthworm count was found to be higher in all the composting methods were earthworms were introduced. Earthworms were also noted in other methods of composting, though it was not introduced. The experimental site selected was frequently used for vermicomposting and this might be the reason for entry of earthworms in those methods of composting were the same was not introduced. But at the advanced stages, earthworms, millipedes, centipedes and silverfish were noticed in all the method of composting, with relatively more number in heap method of composting. This might have resulted in the considerable reduction of carbon content in heap method of composting due to the consumption of the carbonaceous material by these organisms.

Microbial colonies like bacteria, fungi and actinomycetes were also present in large numbers in mature compost. This shows the suitability of compost as an organic manure. The fungal activity was higher in composting using Trichoderma and worms. De Bertoldi *et al*. (1983) reported that fungi increase normally when remaining substrate in the compost are predominantly cellulose and lignin, which normally occurs during the later stages of composting. The highest activity of actinomycetes was found in vermicomposting and varanashi method of composting. Actinomycetes also tend to grow in the later stages of composting and have been shown to attack polymers such as hemicelluloses, lignin and cellulose. They tend to grow in the later stages of composting (De Bertoldi *et al*., 1983). The bacterial count was highest in varanashi composting. Golueke (1992) reported that fungi are involved in the decomposition of cellulose and lignocellulosic compounds of the compost, and they provide more readily available carbon to the bacteria.

The dehydrogenase activity was found to be maximum in aerobic composting using cow dung followed by varanashi method of composting and vermicomposting and were on par with each other. The enzyme activity was significantly less in pit method of composting. Forster *et al*., (1993) reported that dehydrogenase activity can be chosen as an index of microbiological activity because it refers to a group of mostly endocellular enzymes which catalyse the oxidation of soil organic matter. Highest dehydrogenase activity was noted in aerobic composting using cow dung followed by varanashi method of composting. The dehydrogenase activity was significantly less in pit and heap method of composting. The lack of air circulation to deep inside the layers of these methods might have caused an unfavourable condition for active microorganisms to multiply resulting in reduced activity of dehydrogenase. Sufficient air circulation and more number of active bacteria in the cow dung used as inoculants resulted in high dehydrogenase activity in composting using cow dung. Though varanashi method is anaerobic, the high enzyme activity may be due to the more number of active bacteria harboured in the immature cattle manure which was used as inoculants in the above method. In varanashi composting, the quantity of cow dung added was three times as that of other methods.

Immature cattle manure harboured high number of active bacteria and as the digestion proceed, the bacterial number decreased. (El-Shinnawi *et al*., 1988). In addition to it, air circulation facilitated the growth and colonization of organisms. Tiquia and Tam (2002) have reported that oxygen transformation is necessary for the growth of aerobic organism. In varanashi composting the dehydrogenase activity (484.59 ug g^{-1} compost day^{-1}) reached its optimum on the 114th day. Here the substrate remained undisturbed as it was an anaerobic method of composting. Moreover towards the end of composting, no further decomposition is taking place as carbon and nitrogen became stabilized, no more heat will be released, as a result of microbial activities and dehydrogenase activity stabilized to optimum levels. Dehydrogenase activity is the simplest, quickest, and cheapest method that can be used to monitor the stability and maturity of compost. Dehydrogenase activity, demonstrates that it is possible to monitor the composting process more easily and rapidly by avoiding longer and more expensive analytical procedures.

Table 4. Microbial count and dehydrogenase activity in the mature compost

Treatments	**Bacteria (10^6) (cfu/g)**	**Fungi 10^4 (cfu/g)**	**Actinomycetes 10^5 (cfu/g)**	**Dehydrogensae activity (ug g^{-1} compost day^{-1})**
Aerobic composting with cow dung(T_1)	7.6^{abc}	7.47^{abc}	6.47^{c}	626.76^{a}
Aerobic composting with *Bacillus subtilis* (T_2)	5.23^{c}	9.00^{ab}	2.73^{d}	302.13^{d}
Composting using effective microorganisms (T_3)	5.43^{c}	7.47^{abc}	7.00^{c}	322.83^{c}
Composting using *Trichoderma* and worms (T_4)	10.03^{ab}	9.37^{a}	11.10^{b}	344.72^{cd}
Vermicomposting (T_5)	5.63^{bc}	4.00^{de}	24.13^{a}	407.80^{bc}
Varanashi composting (T_6)	11.67^{a}	6.57^{bcd}	24.60^{a}	484.59^{b}
Heap method (T_7)	4.17^{c}	1.83^{e}	10.17^{b}	292.73^{d}
Pit method (T_8)	7.47^{abc}	1.77^{e}	10.13^{b}	130.60^{e}

*The data followed by same superscript do not vary significantly

Phytotoxicity studies

Phytotoxicity caused by the presence or absence of organic chemicals in stable compost impair germination and plant growth. More than 90% germination of tomato seeds was noticed in compost extract and potting mixture obtained from all the methods of composting. The response of germination in tomato seeds using compost extract and potting mixture differed at day 1, but increased to about 100% by day 5. Germination studies using compost extract indicated that compost obtained from none of the method is phytotoxic. When seed germination using compost as potting mixture was carried out, high germination percentage was observed in all the methods of composting. In varanashi composting, germination of 96.67% was noted on 4th day. The high germination percentage indicates that compost obtained from all the methods of composting can be safely applied to soil due to absence of phytotoxicity. It is found that the phytotoxicity is not present in any of the compost, but the quality was not the same as the germination percentage was different on the first day in both the test.

Heavy metals

The data on heavy metal content is presented in Table 5. Lead content was significantly higher in aerobic composting with *Baciluus subitlis* followed by aerobic composting with cow dung. Chromium content was on par and significantly higher in composting with *Trichoderma* and worms and in vermicompostimg. Nickel content was observed higher in varanashi composting which is on par with composting using effective microorganisms and *Trichoderma* and worms. All the heavy metals were found to be significantly less in pit method. Table 4.15 (a) Heavy metal content and CEC of mature compost. The heavy metal content values (Chromium and Nickel) were within the ranges of those compiled in other works (FCO, 1985). However the lead content in aerobic composting using cow dung and aerobic composting using *Bacillus subtilis* was greater than the limit prescribed by FCO. (Greater than 100ppm). The presence of metals in manure may be due to animal (e.g., cattle, pig, and poultry) excretion of trace elements contained in their diet or other health supplements.

Table 5. Heavy metal content of mature compost

Treatments	**Pb (ppm)**	**Cr (ppm)**	**Ni (ppm)**	**As (ppm)**	**Cd (ppm)**	**Hg (ppm)**
Aerobic composting with cow dung (T_1)	239.40^{b}	9.38^{bc}	1.27^{c}	-0.03	-0.10	-0.015
Aerobic composting with *Bacillus subtilis* (T_2)	358.90^{a}	9.11^{bc}	1.19^{c}	-0.04	-0.17	-0.02
Composting using effective microorganisms (T_3)	65.90^{d}	9.27^{bc}	2.21^{ab}	-0.03	-0.18	-0.013
Composting using Trichoderma and worms ($T_{4)}$	98.23^{c}	13.19^{a}	2.31^{ab}	-0.02	-0.17	-0.03
Vermicomposting (T_5)	73.70^{cd}	12.75^{a}	1.30^{c}	-0.03	-.0.13	-0.02
Varanashi composting (T_6)	94.80^{cd}	9.34^{bc}	2.62^{a}	-0.03	-0.151	-0.02
Heap method (T_7)	88.30^{cd}	10.86^{ab}	1.55^{bc}	-0.036	-0.08	-0.02
Pit method (T_8)	17.97^{e}	5.92^{d}	0.79^{c}	-0.04	-0..15	0.0.02

*The data followed by same superscript do not vary significantly

Influence of composting method on the suitability of compost as organic manure for Okra crop

Influence of composting methods on Yield and Yield attributes

Application of compost obtained from different composting methods has significant influence in the yield of Okra crop. Varanashi composting, vermicomposting and composting using effective microorganisms produced higher yield in Okra compared to other components. The lowest yield was obtained by adding compost from pit method. As the quantity of compost applied to each treatment was based on the nitrogen content of the final compost obtained from different method of composting in comparison with nitrogen (N) content of farm yard manure (FYM), due to the low nitrogen content in varanashi composting, the quantity of varanashi compost added to crop in comparison to N content of

FYM was higher. This in turn benefited the crop in obtaining other nutrients present in the compost, which in turn resulted in more number of branches and leaves. Except N, all the other nutrients in varanashi compost was comparatively higher. Hence by applying higher quantity of varanashi compost, the crop gets higher quantity of OM and other nutrients. This may be the reason for higher yield in varanashi compost applied crop. The dry matter content was also higher in varanashi method of composting. It might be due to the availability of more mineral nutrients in the rhizosphere and flux of nutrients to into the root due to the addition of more quantity of compost.

Even though the quantity of compost obtained from pit method of composting, was applied in higher quantity, the other nutrient elements in compost obtained from the above method was less. The yield increase in varanashi compost, vermicompost and Effective Microorganism (EM) compost may be the result of higher production of leaves and branches in these compared to other treatments. This increase in growth parameter is due to the increased NPK uptake by plants in these treatments. N uptake was higher in crops treated with EM compost and varanashi composting. P uptake was higher varanashi composting. This might be due to the higher content of P content in varanashi composting, in which rock phosphate (RP) was an ingredient during the compost preparation

The favourable effect of compost on the growth characteristics of plant may be due to the ability of the compost to enhance the physical, chemical and biological properties of soil. Similar findings were reported by Hanafy *et al*. (2002) on rocket plants. Different compost were added based on nitrogen equivalent basis. The improvement in yield and yield attributes made after addition of organic manure not only depends on nitrogen content alone, but also on the quantity of compost added. The higher the quantity added, higher will be the improvement in the soil chemical and physical properties, which in turn resulted in higher yield. Comparatively higher quantity of compost was added in plant grown using vermicomposting.   The earthworm count was higher in vermicomposting, composting using Trichoderma and varanashi method of composting. The compost attracts earthworms and provides them with a healthy diet. The presence of earthworms, centipedes, sow bugs, and other soil critters means that there is still some organic material being slowly broken down releasing nutrients as food pass through their digestive tracts. This might have resulted in more balance soil ecology for the growth of plants which resulted in higher yield. Moreover, this has also reflected in the yield and morphological characters of the plant growth in the above treatments. . The increase in yield in other treatments may be contributed to the increased fruit weight in addition to the nutrient supply from the addition of compost obtained from different method of composting.

Compost amendments to soil either stimulated or inhibited growth and nutrient uptake in Okra. Potassium uptake was comparatively higher in vermicomposting. This might be due to the availability of potassium in easily available form in the compost. Atiyeh *et al*. (2002) has reported that during vermicomposting, the nutrients locked up in the organic waste are changed to simple and more readily available and absorbable forms such as nitrate or ammonium nitrogen, exchangeable phosphorus and soluble potassium, calcium, magnesium in worm's gut.   However phosphorus uptake was higher in aerobic composting using cow dung. This might be due to the presence of higher CEC in the same. Epstein *et al*. (1976) reported that compost may affect the release of nutrients to plants directly through the nutrients present in them or indirectly by their effect on the cation-exchange capacity. Thus, a cation-exchange capacity effect may have been reflected in the nutrient uptake by plants in aerobic composting using cow dung.

Results of the study suggested that compost obtained from none of the composting methods has detrimental effect on plant growth. Varanashi compost, vermicompost and composting using effective microorganisms significantly improved plant growth and yield.

Influence of composting methods on nutrient uptake of okra

As regard to the effect of treatments on chemical composition of plants, significant difference was found in N and K uptake, in plants treated with different compost, while only small significant difference was observed in P uptake in plants treated with compost. The increase in the nutrient content might be due to the positive effect of compost and microorganisms in increasing the surface area of root per unit of soil volume, water-use efficiency and photosynthetic efficiency, which directly affects the carbohydrate utilization and physiological processes. El-Ghadban et al. (2002), reported that application of compost and biofertilizer led to an increase in carbohydrate percentage and some macro nutrients in marjoram. N uptake was higher in plant received compost obtained from effective microorganism and the lowest uptake was recorded in compost prepared using heap method. The phosphorus uptake was highest in compost prepared using varanashi method. The compost prepared from heap method showed lowest K uptake.

Influence of composting methods on nutrient status of the soil

Even though the quantity of organic matter applied is different, no significant difference was noticed in soil organic carbon after the harvest of the crop among different treatments. But there was an increase in organic carbon than the initial organic carbon of the growth media. There was a significant increase in available soil nutrient content after the addition of compost as compared to the initial nutrient content in all the treatments.

Conclusion

The results of the study indicated that composting methods has significant influence on physical, chemical and biological parameters of maturity. Even though the yield produced vary with composting methods, all the methods helped to attain maturity and stability parameters. Quality of compost as organic manure also varied with the method of production Compost obtained from none of the composting methods had phytototxicity and the heavy metal content were in the permissible limit thereby no detrimental effect on plant growth. Based on the compost yield and better parameters of maturity, aerobic composting, varanashi composting and vermicomposting was found superior. Crop performance was significantly higher with varanashi compost, vermicompost and compost using EM. The growth and yield performance of crop depended not only on the nutrient content of the compost but the quantity of compost added as organic manure. There was a positive and significant increase in available soil nutrient content after the addition of compost as compared to the initial soil nutrient status in all the treatments.

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Competing Interests

There is no conflict of interest in this work

Authors' Contributions

First author did this project work for the partial fulfilment of her PG Degree and the second author guided her for the PG work

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