# Efficiency of Pusa Compost Inoculant Along with Windrow Turner for Rapid Degradation of Paddy Straw

**Muzamil Bhat[1], Indra Mani[2], Livleen Shukla[3] and Satish Lande[2]**

[1]IARI, Pusa New Delhi - 110 012, India.
[2]Agricultural Engineering Division IARI, New Delhi, India.
[3]Microbiology Division, New Delhi, India.

(Received: 09 October 2013; accepted: 19 November 2013)

**The effect of Pusa compost inoculant coupled with windrow turner was studied to reduce the time of composting and for producing the better quality compost. An experimental setup with trapezoidal piles set at 30 m long, 1.2 m high, 2 m bottom width and 1.5 m top width and three levels of culture inoculum (500 ml, 1000 ml and 1500 ml) utilizing approximately 44.44 tonne of agro-waste and 24 tonne of 3-4 days old raw cow dung was laid. The pile was mixed at regular interval of 10 days using the windrow turner powered by 55.95 kW tractor. This operation ensured proper aeration and creating favourable conditions for microbial growth. The peak temperature of 68°C was attained at 1000 ml inoculated cultured pile within 15 days. The reduction in density as 21.98% and 49.0% in the subsequent turnings reduced the power consumption from 7.93 kW to 6.13 kW and composting time to 45 days. The same pile also showed an increase in electrical conductivity from 1421 μS/m to 1640 μS/m, nitrogen availability from 0.31% to 0.672%, potassium from 0.51% to 1.33% and phosphorus from 0.18% to 0.61% , C: N ratio from 53:1 to 18:1 with neutral behaviour. The per cent moisture loss was 13% only. All the measured parameters showed the conformity with the BIS standards for efficient composting and product formation. Thus, 1000 ml culture dose per tonne of material gave better results for all measured parameters and is recommended for efficient and nutritious composting to ensure sustainability in crop production.**

**Key words**: Paddy straw degradation, Windrow turner, C: N ratio, Compost inoculant.

The food grain production of India has now touched the landmark of 250.47 mt in 2011-12 (Economic survey, 2011-12) and consequently, the amount of agro-waste started to escalate and has reached about 889.71 mt annually (Agricultural Statistics at a glance, 2010). Globally, biomass is ranked fourth as an energy resource, providing approximately 14% of the world's energy needs and can be efficiently used as an alternative for fossil fuels.

The conventional and traditional method of burning agro-waste remains a constant hazard to human and animal health and represent a major source of environmental pollution (El-Shimi, 2007). Owing to the hazardous potential of using the ordinary mineral fertilizers in the soil and its surroundings including ground water and open drains, organic manure through compost application was found to be a suitable substitute for such mineral fertilizers (Abbas *et al*., 2006 and 2010). Composting is a process by which organic wastes are decomposed through the activities of successive groups of microorganisms (Gajdos, 1992) and converted into organic manure rich in plant nutrients and humus (Sharma *et al*., 2011).

* To whom all correspondence should be addressed.
Mob.: +91-8800878018;
E-mail: muzamil4951@gmail.com

Although, there exists a number of different composting methods and technologies, there are three main systems of centralized composting: aerated static pile process, windrow process and enclosed systems (Martin and Gershung, 1992 and Hong *et al*., 1983). Merkel (1981) reported that the rate at which organic matter decomposes is affected by the moisture content, C: N ratio of the organic matter, temperature, availability of oxygen, pH value, and particle sizes.

The decomposition of agro-residues is enhanced by the addition of lignocellulolytic fungi which speeds up the process of composting. The effect of fungal inoculation on composting of cellulosic material is well documented (Gaur, 2002; Mishra *et al*., 1982). Cellulolytic fungi like *Aspergillus awamori*, *Trichoderma viride*, *Phenerochaete chrysosporium* and *Aspergillus nidulans* were added for recycling organic matter and to convert it into nutrient rich compost.

About 100-150 man hours are required for preparing compost by pit (10 m x 1 m x1 m) method and requires continuous monitoring. The pile method of compost involves laying the material in the form of piles and subsequent mixing with the help of compost turner-cum-mixer. The compost turner-cum-mixer consisting of mixing rotor, hydraulic system to operate the rotor, water tank to store water and culture, and side tank for weight balancing. The machine employed for turning helps to increase the capacity, timeliness, precision and uniformity of mixing and creating favourable conditions for microbial growth. The turner-cum-mixer reduces the energy consumption per tonne of the material handled and is used for mass production of compost. The compost turner-cum-mixer is having provision of adding moisture during operation that adds extra feather to its working ability. The study was undertaken with broad objectives:

1) To determine the optimal quantity of the inoculant for effective compost preparation.
2) To study the impact of turning and inoculant dose on the compost parameters.

## MATERIALS AND METHODS

The experiments were conducted in the biomass utilization unit of IARI campus. This necessitated the collection of input raw material as paddy straw from the premises of the IARI, New Delhi. The material laid in 30 m long, 1.2 m high, 2 m bottom width and 1.5 m top with trapezoidal pile was mixed with 3-4 days old cow dung with the help of a loader. The total amount of material utilized in 30 m pile was 44.44 tonne approximately. The cow dung of about 6 trolleys were added which constituted about 24.0 tonne. The 80 litre concentrated culture was mixed with 300 litres of water and sprayed on the top of the piles in three different doses (500, 1000 and 1500 ml). The materials were turned and the scattered materials were kept in place with the help of loader which lifts and carries material upto a height of 3 meter. The piles containing raw material were turned with the help of the windrow turner with following specifications instead of manual turning, Table 2.

Random samples were collected periodically with the help of soil sampler to achieve the uniformity and analysed for determining the impact on various parameters. The temperature of the pile was measured with dial thermometer. The moisture content was measured with the gravimetric soil moisture method and pH with digital pH meter. The diffusivity of the nutrients in terms of electrical conductivity was determined with the digital conductivity meter. The density of the compost was measured by mass obtained by the digital balance and dividing by the volume of the compost which is obtained from the measured cylinder. Organic carbon was determined by Walkley and Black method, Nitrogen by Kjeldahl distillation and Phosphorus by Olsen's method.

## RESULTS

The culture and machine parameters affecting the proper turning and mixing of compost were studied as follows;

**Influence of the time duration on the compost density and on moisture**

The density of the compost indicates the mass per unit volume of the material handled for compost making. The density of the compost decreases with the time in view of the decrease in size created by the action of the cutting forces of the rotor of windrow turner.

The data obtained reveals that increasing the number of turnings with the period of composting decreased the compost density manifoldly (Fig 1). The turning of piles using compost turner mixer after every 10 days interval, the compost density decreased from 724.4 $kgm^{-3}$ to 562.3 $kgm^{-3}$, showing a decrease of 22.37% with the reduction in the power requirement from 8 kW to 7.36 kW during the first 15 days and then to 440 $kgm^{-3}$, a further decrease of about 39.26% with reduction in power to 6.93 kW during the next 15 days in treatment where 500 ml of culture was inoculated in the pile. In 1000 ml cultured pile, the density decreased from initial 615.55 $kgm^{-3}$ to 480.2 $kgm^{-3}$ (decrease of 21.98%), power requirement to turn decreases from 7.93 kW to 7.31 kW and further to 6.13 kW causing the density to reduce to 313.8 $kgm^{-3}$ (decrease of 49.0%) while in 1500 ml cultured pile there was reduction in density from 684.0 to 521.0 $kgm^{-3}$ (decrease of 23.83%), power consumption decreased from 6.87 kW to 6.23 kW and further to 5.29 kW causing the density to reduce further to 328.8 $kgm^{-3}$ (decrease of 51.92%). The statistical analysis reveals the inoculum dose with 1000 ml gives the better performance.

The moisture content is the most important component for efficient composting as the growth of the fungus also depends on the availability of sufficient moisture to maintain metabolic activities. However, the major disadvantage of turning is the reduction in the moisture level due to the exposure of the inner layers to the sunlight. The moisture migrates from the inner layers to the outer surface from where it gets evaporated. The variation of moisture content in the 1.2 m high pile decreased with the advancement of the composting period and subsequent turning by windrow turner (Fig. 2). The decrease is mainly attributed to the shifting of inner moist layers to the top layers and subsequent moisture removal.

**Table 1.** Specifications of the compost turner-cum-mixer

| S. No. | Components | Dimensions |
|---|---|---|
| 1. | Mixing rotor diameter (mm) | 400 |
| 2. | Length and shaft diameter of rotor (mm) | 2670 , 63 |
| 3. | Length of rotor shaft(mm) | 2870 |
| 4. | Hydraulic system with base plate, hoses (5 nos.) and direction control valve (5 nos.) | 1000 mm stroke,63 mm cylinder dia. |
| 5. | No. of blades over rotor surface | 42(nos.) |
| 6. | Length and width of blade (mm) | 260, 80 |
| 7. | Dimension of Water tank (mm) | 1220 × 1350 × 1250 |
| 8. | Side tank(mm) | 1250 × 730 × 760 |

**Changes in temperature during paddy straw degradation**

The temperature was measured at the end of each turning operation accomplished by windrow turner. The temperature profiles at the centre of the piles varies with the composting period. In the pile with 500 ml culture, the initial atmospheric temperature being 39° C increased to 61° C due to microbial activity in the first 10 days where all the pathogenic microbes were eliminated. The subsequent turnings resulted a decrease in temperature to 50° C in next 10 days and finally to 43°C due to decrease in microbial activity. The pile with culture dose of 1000 ml showed increase in temperature from 38°C to 68°C within the first 10 days till sufficient moisture was available and then temperature profile showed the downward trend and reduced to 56°C in next 10 days and finally reduced to 50°C till composting was over. The third pile with 1500 ml culture dose, the initial temperature rose from 40°C to 63°C in first 10 days and then decreased to 56°C in the next 10 days and finally to 53°C in the last period of composting, Fig. 3. The statistical analysis of the data shows 1000 ml culture dose assisted to attain the peak temperature in pile.

**Degradation of paddy straw with variation in electrical conductivity**

The variation of the electrical conductivity with the increase in the composting time, Fig. 4. The electrical conductivity of the pile with the culture dose of 500 ml per tonne increased from 1359 µS/m to 1437 µS/m in the first 15 days due to high temperature and reduction in particle size and further to 1484 µS/m in the next 30 days of composting. The electrical conductivity of the second pile with 1000 ml culture varied from 1421 µS/m to 1546 µS/m in first 15 days and further increased to 1640 µS/m in the next 15 days of operation while the electrical conductivity of the third pile with 1500 ml dose varied from 1468 µS/m to 1531 µS/m and increased to 1656 µS/m, respectively, in the entire composting period of 45 days. The statistical analysis determines 1000 ml as optimal culture dose for enrichment of the compost.

**Effect of degradation of paddy straw on pH during composting**

The pH is also an important parameter as it determines the final quality of the prepared compost. The data obtained shows the variation of the pH value with composting time, Fig 5. The pH of the 500 ml cultured pile decreased from neutral (pH 7.0) to acidic (pH 6.5) in first 15 days and remained acidic throughout the period of 45 days of composting due to release of organic products. The pH of 1000 ml pile remains neutral for most part of the composting period and starts to reduce to 6.5 at the end of 30 days and finally becomes neutral in the last 15 days of composting. The pH of the 1500 ml decreased from alkaline (pH 7.5) to neutral (pH 7.0) in the first 15 days and remained neutral till the end of the 45 day long composting process. According to BIS standard for composting, the pH should lie in between 6.5 to 7.5 and the measured pH showed the conformity with BIS.

**Availability of Nitrogen, Phosphorus and Potassium (NPK %) content during degradation of paddy straw**

The data collected demonstrates that the availability of the Nitrogen gets affected with

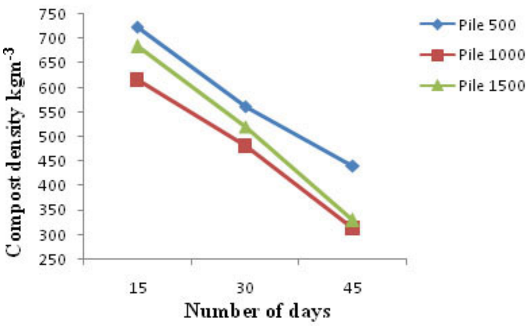


**Fig. 1.** Loss of moisture content during paddy straw degradation

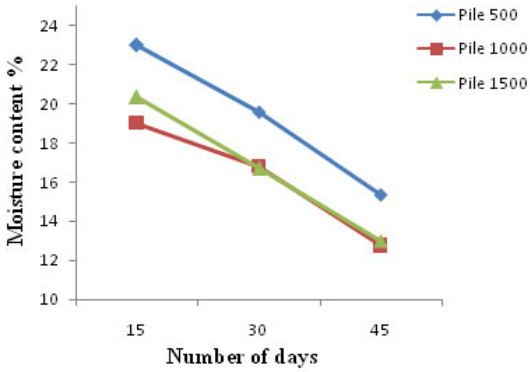


**Fig. 2.** Loss of moisture content during paddy straw degradation

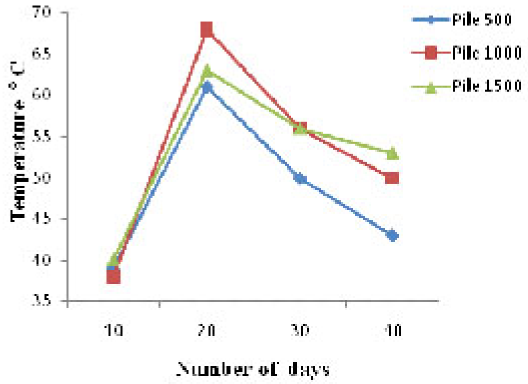


**Fig. 3.** Change in temperature in different piles during composting

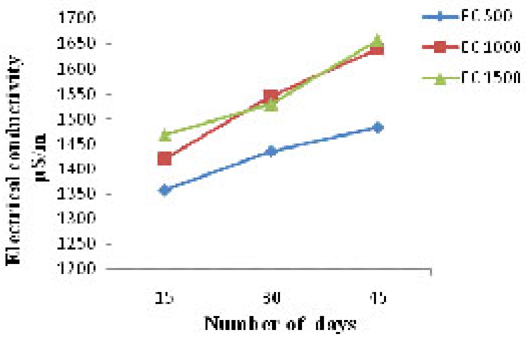


**Fig. 4.** Variation in Electrical Conductivity during paddy straw degradation

composting time, Fig 6. The Nitrogen content of the 500 ml culture pile increased from 0.208 % to 0.33 % in the first 15 days and then finally increased to 0.498% in the next 15 days of composting. The 1000 ml culture pile showed a slight variation from the 500 ml cultured pile where nitrogen content increased from 0.31% to 0.373% in the first 15 days and improved to 0.672% in the next 30 days while nitrogen content of the pile with highest culture media of 1500 ml varied from 0.33% to 0.384% in 15 days and further improved to 0.629% in the next 15 days of composting, respectively. The statistical analysis showed the 1000 ml culture dose as optimal for improvement of Nitrogen percentage in the compost.

**Potassium**

The availability of the potassium is also affected with the advancement of the composting time, Fig 7**.** The pile with 500 ml culture dose contains 0.33% of potassium in the first 15 days which increased with the first turning to 0.76% and further to 1.02% in the next 15 days of composting. Similarly, the potassium content of the 1000 ml cultured pile varied from 0.51% to 1.10% in the 30 days and further to 1.33% during the last phase of 15 days. The 1500 ml pile had a potassium content of 0.58% in the first 15 days which increased to 1.2% and then to 1.42% in the next 15 days of the composting period, respectively. The statistical analysis shows 1500 ml culture dose helps in the improvement of the available potassium as compared to 1000 ml and 500 ml culture dose.

**Phosphorus**

The phosphorus is considered as the energy currency for the plants and the availability at optimum concentration is essential for proper growth and metabolic activities. The variation of the phosphorus content with the time of composting is shown in Fig 8. The phosphorus content of pile of 500 ml culture varied from 0.21% to 0.33% in the first 15 days of composting and increased to 0.45% in the next phase of 15 days interval. The pile of 1000 ml culture showed variation from 0.18% to 0.43% in the first 15 days

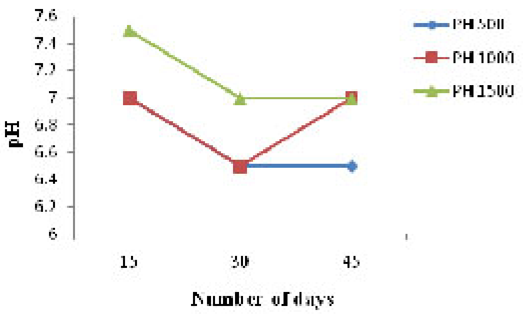


**Fig. 5.** Changes in pH during paddy straw degradation

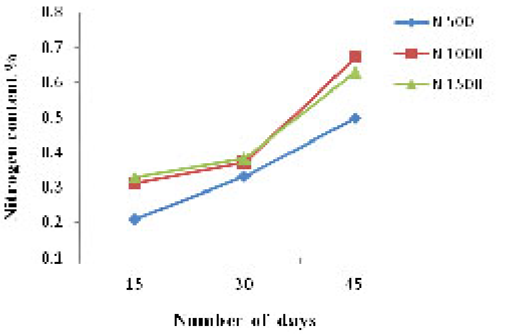


**Fig. 6.** Variation of available Nitrogen % content during composting

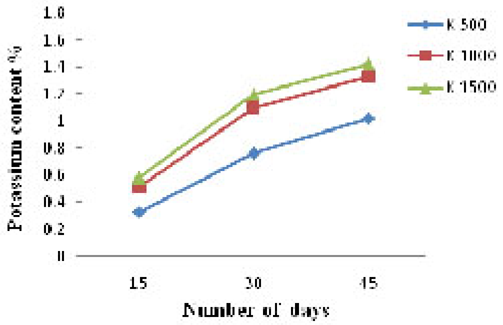


**Fig. 7.** Availability of Potassium % during composting

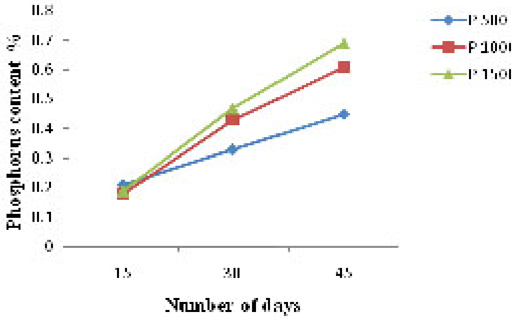


**Fig. 8.** Changes in Phosphorus availability during composting

which then improved to 0.61% after the next turning in 15 days. The pile with 1500 ml culture had a phosphorus content of 0.19% which increased to 0.47% in the first 15 days and further to 0.69% in the next 15 days, respectively. The statistical analysis indicates the 1000 ml culture dose to be optimal for enrichment of the compost.

**Influence of C: N ratio on compost quality**

The change in the C: N ratio with the composting time shown, Fig. 9. The C: N ratio of the 500 ml cultured pile decreased with the time of composting from 55:1 to 35:1 by the breakdown of larger molecules into simpler ones and finally to 22:1. The 1000 ml culture pile showed the decrease in C: N ratio from 53:1 to 31:1 in the first 15 days and finally to 18:1 in the next 15 days while the C: N ratio of 1500 ml culture pile drastically reduced from 54:1 to 28:1 and then to 16:1. The statistical analysis indicates that the 1000 ml pile and 1500 ml cultured pile showed better performance as compared to 500 ml culture pile. In view of cost and application, the 1000 ml culture is viable and is recommended for getting acceptable C: N ratio.

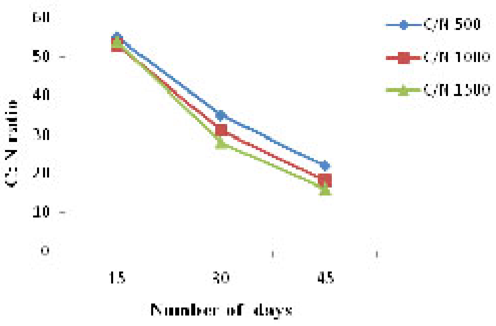


**Fig. 9.** Changes in C: N ratio during composting

## DISCUSSION

The application of the efficient microbial culture enhanced the composting process and provided the impetus to the microbial growth, which ultimately improved the quality of the final compost. The success of the windrow/pile composting depends on the degree of turn provided by the blades of the rotor of windrow turner. The addition of the culture helps to increase the microbial number which, in turn, decomposes the material at the faster rate than usual process. The multiplication of microbes led to increase in temperature due to availability of sufficient moisture and raw materials. As the pile is turned, the moisture level starts to decrease and finally the microbial growth gets affected.

With advancement of time, the particle size starts to decrease which was mainly attributed to the breakdown of complex molecules into smaller ones by the inoculated fungal culture and the impacting forces of the rotor blades per unit volume of the disturbed compost. These two actions accelerated the composting period and the mature compost was ready in 45 days which would otherwise takes more than 120 days for complete degradation. The breakdown of the particle and subsequent turnings increases the surface area and exposed the inner surfaces to the sunlight resulting in decrease in moisture content. The initial moisture content which was kept at 80% in all the piles and were irrigated after every turning operation.

The smaller particles supply the nutrients to the soil easily, once it is applied. The piles of 1000 ml and 1500 ml showed better performance in terms of electrical conductivity. The essential nutrients like NPK follows the upward trend in view of richness enshrined to it by the metabolic activities of the microorganisms.

The power consumption to turn the piles is of significant importance as it governs the amount of energy consumption for composting. The windrow turner utilized for turning and mixing the composting materials was operated by 55.95 kW new Holland tractor. The energy consumption to turn the materials is the governing factor in the adoption of windrow composting. In the initial stage, the power consumption is high due to the presence of harder and dry materials. The power consumption reduces with the subsequent turnings due to the metabolic decomposition by the microorganisms in presence of moisture, resulting in reduction in total power consumption.

The C: N ratio of the pile decreased due to volatilization of the gases and utilization by the microorganisms. Microorganisms use carbon for both energy and growth, while nitrogen for protein production and reproduction. All the measured parameters showed the proximity with the BIS standard for efficient composting.

At lower culture dose of 500 ml, sufficient microorganisms are not available to multiply rapidly and raised the temperature by utilizing the moisture available, increase the time of composting. At higher dose of the 1500 ml culture, high number of the microorganisms utilize the available raw materials rapidly and increase their number. However, the continuous consumption reduced the availability of the moisture, which is governing factor for metabolic activities and takes longer time for the composting process.

Keeping in view the cost-benefit ratio of the culture preparation, 1000 ml pile showed promising behaviour than 1500 ml and 500 ml culture dozed pile and is recommended for effective and efficient composting of paddy straw.

## CONCLUSION

The efficient preparation of the compost by the minimum of the input resources can reduce the overall cost of production. The study determines the optimum dose of the inoculated culture to enhance the process of composting. The application of the inoculant at 1000 ml per tonne of the material handled coupled with turning and mixing operation three times per cycle of compost production was found optimum.

**Highlights**

- The rate of composting is influenced by the quantity of the inoculated culture applied.
- The availability of high moisture plays a deciding role in enhancing the process of composting.
- The decrease in density for 1000 ml inoculated culture dose was observed and varies from initial 615.55 $kgm^{-3}$ to 480.2 $kgm^{-3}$ (decrease of 21.98%) and finally reduce to 313.8 $kgm^{-3}$ (decrease of 49.0%) which was observed to resemble closely with 1500 ml culture dose and varies from 684.0 to 521.0 $kgm^{-3}$ (decrease of 23.83%) and finally to 328.8 $kgm^{-3}$ (decrease of 51.92%).
- Power requirement for 1000 ml inoculated culture dose showed a downward trend and decreased from 7.93 kW to 7.31 kW and further to 6.13 kW while for 1500 ml it varied from 6.87 kW to 6.23 kW and further to 5.29 kW.
- The loss in moisture after irrigating to 80% of the capacity varies from 19.0% to 12.76% in 1000 ml pile.
- The better C: N ratio reduction was observed in 1000 ml cultured pile and varies from 53:1 to 18:1.
- The piles need to be irrigated after every turning operation to maintain 80% of the moisture content in the pile.
- Based on the cost of preparation and application, 1000 ml inoculated culture dose was found to give best performance.

## ACKNOWLEDGMENTS

I would express my venerable gratitude and indebtedness to Dr. Indra Mani , Dr. Livleen Shukla, Dr. Satish Lande, Dr. Shiva Dhar, Dr.Cini Varghese and my friends for their inspiring, enthusiastic guidance, meticulous suggestion, enduring encouragement and constructive criticism which led to successful completion of the work.

I will ever remain indebted for the facilities and knowledge, IARI provided to me. Also, I express my sincere thanks and gratitude to the Indian Agricultural Research Institute (IARI) for providing financial assistance in the form of Junior Research Fellowship during the work.

## REFERENCES

1. Abbas, H.H., E. H.A. Noufal, I.M. Farid and I. M. E. Ali., Organic manuring and bio–fertilization approaches as potential economic and safe substitutes for mineral nitrogenous fertilization. *Egyptian Journal of Soil Science*., 2006; **46**(2): 219-135.
2. Abbas, H. H., I. M. Farid and Ali, M. M. E. Growth of maize and its uptake of some macro and micronutrients under different untraditional fertilization treatments. Minia 2nd Conf. *Agric. Environ. Sci*., 2010.
3. Abd El–Mottaleb A.F., and Kotob M. M. Engineering and economical study on compost agitation systems under Egyptian conditions, *Misr Journal of Agricultural Engineering.*,2004; **21**(1): 33:52.
4. Allam, E. 2005.Studies on Recycling Of Some Agricultural Environment Wastes For Organic Fertilizers Production. Thesis.Department of Soils, Faculty of Agriculture, Benha University.
5. Anonymous, Agricultural Statistics at a Glance, Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India (Website:

http//www.dacnet.nic.in/eands), 2010.
6. Bitton G. . Public health aspects of wastewater and sludge disposal, p. 347.In Bitton G (ed.) Wastewater microbiology.JohnWiley& Sons Inc.,New York, 1999.
7. Cooper band, L., The Art and Science of composting a resource for farmers and compost producers.University Of Wisconsin Madison. Center for Integrated Agricultural Systems, 2002.
8. Edwards, C. A. and Fletcher, K. E., Interactions between earthworms and micro-organisms in organic-matter breakdown.*Agricultural Ecosystems andEnvironment.*,1988; **24**: 235-47.
9. El-Shimi, S., The economic and environment impact of biogas technology in Egypt. Biogas Unit, soils and water Res. inst. Agric. Res. Center, Giza, Egypt, 2007.
10. Gajdos R., The use of organic waste materials as organic fertilisers-recycling ofplant nutrients. *Acta Horticulture.*,1992; **302**: 325-331.
11. Gaur, A.C., Microbial phosphate solubilisation-overview. Natl. Symp. On mineral phosphate solubilisation UAS, Dharwad, India, 2002.
12. Hansen, R. C., Keener, H. M. and Hoitink, H. A.J., Poultry manure composting. An exploratory study.*Transactions of the ASAE.*, 1989; **32** (6): 2152-2157.
13. Hong, J.H., Matsuda, J. and Ikeuchi, Y., High rapid composting of dairy cattle manure with crop and forest residues. *Transactions of the ASAE.*, 1983; 533-545.
14. Martin, D. L. and Gershung, G., The Rodale Book of composting.Rodal press, Emmaus, Pennsylvania, 1992.
15. Mani, Indra., Development of compost making machine. Annual convention of ISAE, 26-29, February, 2012.
16. Mishra M. M., Kapoor K. K., Yadav K. S., Effects of compost enriched with Mussoorie rock phosphate on crop yield. *Indian Journal of Agricultural Sciences*.,1982; **52**: 674-678.
17. Pace, M. G., Miller, B. E & Farrell- Poe, K. L. The composting process. Utah State University Extension, October 1995.
18. Ravindranath N.H. and Hall D. O., Biomass Energy and Environment- A Developing Country Perspective from India, Oxford University Press, Oxford.
19. Seki, H., Stochastic modelling of composting processes with batch operation by the Fkker – Plant equation *Transactions of ASAE.*, 2000; **43**(1): 169-179.
20. Sartaj, M., Fernandes, L. and Patni, N. K. Performance of forced,passive, and natural aeration methods for composting manure slurries. *Transactions of ASAE*.,1997; **40**(2): 457-463.
21. Sharma, D., Katnoria, J.K., Vig, A.P., Chemical changes of spinach waste during composting and vermicomposting. *African Journal of Biotechnology*., 2011; **10**(16): 3124-3127.