Low-cost Large Scale Vermicompost Unit

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Abstract. In the current process of producing vermicompost on a large-scale, the main challenge is to keep the worms alive. This is achieved by maintaining temperature and moisture in their living medium. It is a difficult task to maintain these parameters throughout the process. Currently, this is achieved by building infrastructure but this method requires a large initial investment and long-run maintenance. Also, these methods are limited to small-scale production. For large-scale production, a unit is developed which utilises natural airflow with water and automation. The main aim of this unit is to provide favourable conditions to worms in large-scale production with very low investment and minimum maintenance in long term. The key innovation of this research is that the technology used in the unit should be practical and easy to adopt by small farmers. For long-term maintenance of the technology lesser number of parts are used.

1. Introduction

In the current living scenario, every individual prefers the use of organic items in their diet for staying healthy. With this large requirement of organic items, most of the farmers switched to organic farming. But for producing organic items on such a large scale there is the requirement of a huge quantity of organic fertilizers [1]. Organic fertilizers are made from organic wastes. Compost is the nutrient-rich organic fertilizer made by the action of bacteria, fungi, and other decomposing organisms (such as worms, sowbugs, and nematodes) on organic residue. The process of introducing bacteria, fungi, and other items with an ideal environment on raw material for speeding up the decomposition process is called composting [2]. With the use of organic fertilizers, the structure of soil improves due to which the water holding capacity of soil along with nutrients increases [3]. The microbes which feed and grow rapidly on carbon, nitrogen, phosphorous, potassium provided by organic fertilizers help the plant [4] by making nutrients available to them in a natural way. Organic fertilizers remain in the soil for a longer duration and have their effect for a longer period. This has no side effect on plants from roots to leaves [5]. Vermicomposting is a process in which species of earthworm are used for converting organic waste like cattle manure [6][7], crop waste, leaves, wood dust, vegetables [8], fruit waste [9] etc. into nutrient-rich fertilizer. It is a mesophilic process that utilizes micro-organisms and earthworms. In this process, worms eat the organic waste and digest them to give the nutrient-rich cast behind. In vermicomposting after the digestion of waste by earthworms the volume is reduced. The vermicompost cast is rich in both macro and micronutrients along with nitrogen, phosphorous, and potassium which are already in readily available form and released within an amount after application as compared to other compost. Because it is richer in nutrients it is required in lesser quantity than any other organic fertilizers like compost and it requires less time and raw material for preparation [10][11].
Although vermicompost is required in lesser quantity than any other compost, there is always a shortage in supply of vermicompost due to lesser number of large-scale suppliers. Even though the time, raw material, and space required for preparing vermicompost is less, the number of the large-scale production unit of vermicompost is limited due to challenges faced during production which results in lack of interest of farmers to produce vermicompost on a large scale.

1.1. Current production method and challenges
The most preferred and reliable method of producing vermicompost on large scale is an open grave method. In this method, a long grave shaped beds of raw material or manure is prepared on a plastic sheet. This grave is usually 3 to 4 feet width and 1 to 2 feet height [12]. These graves are then provided with water from time to time so that the temperature increase in grave due to methane release can be lowered and sufficient moisture can be maintained. When temperature and moisture inside grave are favourable for worms the Night crawler earthworms are released and this parameters are maintained throughout the process. The time required in production depends on the number of worms per unit of raw material and their living condition [13][14].

The main challenge in the production of vermicompost is keeping the worms alive. For keeping worms alive it is required that proper temperature [15], moisture [16], and ventilation are maintained in grave all the time. Fluctuation in any of these parameters may lead to the vanishing of worms due to which production can stop [12]. As there is constant decay of the raw material in the grave, its temperature never remains the same. This fluctuation in the temperature of grave is shown in [Figure 1.]. For vermicompost to be formed on top of the graves, direct sunlight must be avoided as worms’ skin is photosensitive

1.2. Previous Solution to challenges
Currently, these challenges are solved by preparing this grave under the shed with regular supply of water so that low temperature can be maintained and sunlight can be avoided, which is also a reason for the increase in surface temperature of the grave [17]. This method works well in small-scale production but when it is taken to a large scale, the cost of creating such a large infrastructure becomes huge.

With the introduction of technology in agriculture, the production of vermicompost has also been automated with the use of parameter tracking sensors and parameter controllers using microcontrollers. This automation produces great results with reduction in manual individual effort [18]. The application of this automation on large scale is not feasible because each grave or bed in production has a different parameter value that cannot be monitored by a single sensor. Whereas increasing number of sensors also results in increased investment hence increasing the complexity of the system.
1.3. Proposed Solution to this challenge

For dealing with the above challenges a system is proposed for the production of vermicompost which uses natural airflow for maintaining temperature of graves. Jute fabric or old jute gunny bags are used for providing shed to the graves. Rain pipe and automation are used for supplying the required amount of water with water pumps in the graves and creating an evaporative cooling effect [20]. The graves are also prepared in an open field which eliminates the infrastructure cost so that the overall production of the system is minimum.

The key innovation of this research is the introduction of evaporative cooling, a water control system and monitoring of temperature and moisture of graves called control environment using sensors [21]. This feature helps producing nutrient rich vermicompost in large quantity with minimum labour, low maintenance and with a reduction in total production cost as compared to conventional methods. Properties of vermicompost produced at different parameters are shown below [Figure 2]. The best result of the cast can be produced by maintaining the temperature at 25 degrees Celsius. Maintaining a high temperature at the initial stage enhances microbial activity and earthworm growth [22].

| Parameters                      | Initial Sludge | Vermicomposting after 60 days |
|---------------------------------|----------------|-------------------------------|
|                                 |                | 15 °C | 20 °C | 25 °C |
| Water content (%)               | 80.38 ± 0.01   | 80.15 ± 0.0 | 80.37 ± 0.0 | 80.53 ± 0.0 |
| Organic matter (%)              | 68.0 ± 7.7     | 55.0 ± 1.16 | 51.7 ± 1.99 | 49.8 ± 1.42 |
| pH                              | 6.77 ± 0.005   | 6.53 ± 0.005 | 6.77 ± 0.00 | 7.01 ± 0.00 |
| Electrical conductivity [µS/cm] | 573 ± 8.49     | 911.5 ± 2.04 | 1097.5 ± 6.94 | 2100 ± 16.33 |
| Dissolved organic carbon (mg/kg)| 16.69 ± 0.13   | 14.05 ± 0.04 | 13.92 ± 0.04 | 9.17 ± 0.05 |
| Ammonium (ng/kg)                | 7.36 ± 0.08    | 103.79 ± 0.75 | 206.06 ± 0.23 | 238.91 ± 2.9 |
| Nitrate (mg/kg)                 | 10.26 ± 2.0    | 219.91 ± 45.15 | 285.10 ± 9.10 | 1389.49 ± 47.07 |
| Ammonium/nitrate               | 0.74 ± 0.19    | 0.24 ± 0.04 | 0.67 ± 0.04 | 0.13 ± 0.05 |
| Microbial biomass carbon (g/kg)| 105.61 ± 10.6  | 15.63 ± 0.98 | 8.50 ± 0.18 | 6.71 ± 1.08 |
| Dehydrogenase activity (mg/g/h)| 28.06 ± 1.34   | 0.49 ± 0.08 | 0.49 ± 0.02 | 0.27 ± 0.01 |

**Figure 1.** Variation in grave temperature of different waste [19].

**Figure 2.** Physicochemical properties of the initial material and final vermicomposting products at different temperature [22].
2. Proposed system

In the proposed system building of infrastructure which provided shed to the manure bed/grave is eliminated. The alternative way to provide shed is by building manure graves on the open field and covering it with gunny cloth for preventing sunlight. In this method, automation is used for providing sufficient amount of water to the graves and creating an evaporative cooling effect according to the wind flow. For this purpose, a control panel is designed with a microcontroller and some sensors for controlling the pump and keeping track of the grave with respect to temperature and humidity inside.

2.1. Grave preparation

Graves are prepared on an open field [12]. A layer of crop waste is spread on a plastic sheet before spreading on the raw material. This layer of crop waste provides drainage to excess water. These graves are covered with wet old jute gunny bags or jute gunny bag rolls from start to end. The bottom layer of plastic acts as a wall to prevent worms from escaping into the soil. When parameters of the grave become favourable for worms, the species of worms known as Eisenia Fetida or African night crawlers are introduced on the grave according to the weight of manure. Roughly, adult worms weighing 10Kg can convert up to 1000Kg of manure per month. The growth rate and production of Eisenia Fetida are shown in [Figure 3.] and [Figure 4.] [23].

![Figure 3](image_url). Produceof Eisenia fetida on different organic substrates [23].
Figure 4. The growth rate of Eisenia fetida on different organic substrates [23].

2.2. Watering system
Rain pipes are 40 mm diameter roll pipes with several holes throughout one side, water comes out from these holes in form of small water droplets which results in uniform distribution of water on graves and more evaporative cooling. These pipes are elongated between each pair of graves which provides water to both the graves. These rain pipes are connected to the mainline with a valve between each rain pipe and mainline. This provides the feature of controlling amount of water in every grave separately. The mainline is attached to a water supply pump which further operates with a timer operated by the microcontroller [20].

2.3. Automation system and control panel
A control panel is designed to measure the parameters of manure graves. Sensors are attached to few graves for monitoring the average parameters of all the graves. The temperature sensor (DS18B20) and capacitive soil moisture sensor V1.2 are attached to the panel for providing input. A real-time clock module provides the exact time of each reading. An anemometer sensor (wind speed sensor) is connected to the panel which gives the wind flow speed. A relay module is also connected to the panel for by-passing the timer connected with the water pump which causes evaporative cooling. The main controlling unit of the panel is NodeMCU which takes all the parameters input, operates, bypass relay furthermore also send data remotely to a mobile app.
Figure 5. Control Panel Circuit Diagram.

For water system control, a timer is attached to the Auto-switch of DOL starter of water pump supplying water to the graves. This timer has an inbuilt relay that engages when the timer is in the “ON” state. The relay is attached to an auto switch which helps the pump to start and stop according to the timer’s relay. The timer is programmed for supplying the required amount of water every day per week. The main advantage of a separate timer system is that if there is any malfunctioning of the control panel, the water can be still supplied to the grave according to the programmed timer every day.
3. Working of system

The graves are covered with gunny bags to prevent sunlight on the surface and provide shade to the grave. These gunny bags on the top are always wet which further makes sure the cooling below the bags. When air passes through these wet bags the temperature below the bags decreases, as water absorbs the heat and evaporates causing cooling of the graves. [24] For keeping these bags wet throughout the day just enough amount of water is spread on the grave every hour during the daytime to make sure that only the bags get wet. This action is achieved with the help of a timer. This timer controls the water pump which provides water to the rain pipe. The timer is programmed to turn on the pump each hour during the day for certain duration. During nights since the temperature is comparatively low, the bags already are wet and can remain wet for the whole night. Rain pipe also provides water in form of droplets when air is flowing above a certain speed. This can become a disadvantage while maintaining the water level. To detect this in time a threshold speed is set which can be sensed by anemometer. As when the speed measured by anemometer sensor passes a certain threshold value, the microcontroller attached to the anemometer bypasses the timer relay using the control panel relay module and starts the water pump for some time. When the wind flowing during day passes through this rain/droplets of water its temperature effectively reduces due to which when it strikes the surface of grave it causes more reduction in the temperature, ventilation inside graves and helps escaping methane gas produced [25]. This timer also starts pumps for a longer duration in a day or two to provide sufficient water in the grave so that proper temperature and moisture of the grave can be maintained. The cold water enters the grave, takes up the excess heat and escapes from the bottom in form of excess hot water. This method cools the grave from deep inside to a required temperature. The readings of temperature and moisture of the grave are measured and read by the temperature and moisture sensor [26]. Also, the readings of both parameters is to be taken by an individual manually. In this way, the temperature and moisture of each grave are known once a day. The reason behind doing this is to ensure the proper functioning of panel by comparing the manual readings of graves with the control panel reading. Further with the help of these noted parameters timer can be programmed accordingly and the amount of water can be adjusted for each and every grave with different temperature and moisture readings by adjusting rain pipe valves of the individual graves.

![Proposed Unit Diagram](image-url)
Results and Discussion

The on-field trial of this unit resulted in low cost of production as it didn’t require any shed to be built above the graves. When this unit is adopted, the cost of production decreased drastically since it doesn’t require any shed to be built above graves. As the unit is made in an open field and the sensor being used is based upon wind speed a larger area can be managed and maintained by a single individual since, noting down the readings and managing the timer is only major work on days for maintaining production. There is minimum fluctuation in temperature due to the automated watering system. Figure 8 represents the temperature of the grave during a period of vermicompost formation. Since the temperature of the grave is maintained near 25 degrees Celsius, the formed cast when provided to plants the leaves and root structure of these plants were better than plants with a conventional cast.

Figure 7. Working Unit.

Figure 8. Temperature readings of grave in on-field unit.
It is also seen that when worms work under such favourable condition provided by controlled environment their efficiency increases rapidly since worms death rate is minimal and in such favourable condition worms works efficiently during the day as well as in the night. Also, when favourable conditions are provided to worms they reproduce more causing a huge increase in population. When the grave’s temperature is uniform throughout the height, worms start eating from the top due to which a nutrient-rich cast begins to form right from the top. When the efficiency and population of worms increase the time required for producing the vermicompost also decreases effectively. Since the investment cost in the system is low and the automation side of the system is very easy, adaptability of the system becomes more by farmers for producing vermicompost in large scale for meeting huge demand of vermicompost.

5. Conclusion

Large scale vermicomposting unit is successful in meeting the demand for organic fertilizers. A large quantity of manure waste can be converted into vermicompost with low production costs. The production of vermicompost from this system can be approximately 5 times as compared to production from conventional methods with the same investment. The formed vermicompost is about 25% richer in colour, macro and micronutrients. Also, in manure with high nitrogen content like sheep and poultry waste the dying rate of earthworms receded up to 40%. Due to ease in adaptability, this method of production can be adopted by less skilled farmers also with 2 to 3 individuals require for managing a large-scale production. In future, tracking the temperature of all graves with a thermal camera can eliminate the use of multiple temperature sensors. Also, the timing of the water supply can be changed automatically according to temperature and moisture sensors’ data directly from a microcontroller using machine learning in future.

References

[1] Musshoff, O. and Hirschauer, N., 2008. Adoption of organic farming in Germany and Austria: an integrative dynamic investment perspective. Agricultural Economics, 39(1), pp.135-145.
[2] Pace, M.G., Miller, B.E. and Farrell-Poe, K.L., 1995. The composting process.
[3] Haynes, R.J. and Naidu, R., 1998. Influence of lime, fertilizer and manure applications on soil organic matter content and soil physical conditions: a review. Nutrient cycling in agroecosystems, 51(2), pp.123-137.
[4] Alidadi, H., Saffari, A.R., Ketabi, D., Peiravi, R. and Hosseinzadeh, A., 2014. Comparison of vermicompost and cow manure efficiency on the growth and yield of tomato plant. Health scope, 3(4).
[5] Lee, J., 2010. Effect of application methods of organic fertilizer on growth, soil chemi-cal properties and microbial densities in organic bulb onion production. Scientia Horti-culturae, 124(3), pp.299-305.
[6] Garg, V.K., Yadav, Y.K., Sheoran, A., Chand, S. and Kaushik, P., 2006. Livestock excreta management through vermicomposting using an epigeic earthworm Eisenia foetida. Environmentalist, 26(4), pp.269-276.
[7] Lazcano, C., Gómez-Brandón, M. and Dominguez, J., 2008. Comparison of the effectiveness of composting and vermicomposting for the biologi-cal stabilization of cattle manure. Chemosphere, 72(7), pp.1013-1019.
[8] Garg, V.K., Yadav, Y.K., Sheoran, A., Chand, S. and Kaushik, P., 2006. Livestock excreta management through vermicomposting using an epigeic earthworm Eisenia foetida. Environmentalist, 26(4), pp.269-276.
[9] Hemalatha, B., 2012. Vermicomposting of fruit waste and industrial sludge. Int J Adv Eng Technol, 3(II), pp.60-63.
[10] Abduli, M.A., Amiri, L., Madadian, E., Gitipour, S. and Sedighian, S., 2013. Efficiency of vermicompost on quantitative and qualitative growth of tomato plants.
[11] Domínguez, J., Aira, M. and Gómez-Brandón, M., 2010. Vermicomposting: earth-worms enhance the work of microbes. In Microbes at work (pp. 93-114). Springer, Ber-lin, Heidel-berg.

[12] Shivakumar, C., 2008. Production and marketing of Vermicompost in Karnataka: a case of Dharwad district (Doctoral dissertation, UAS, Dharwad).

[13] Munroe, G., 2007. Manual of on-farm vermicomposting and vermiculture. Organic Agriculture Centre of Canada, 39, p.40.

[14] Srinivasan, S.P., Shanthi, D.S. and Anand, A.V., 2017, June. Inventory transparency for agricultural produce through IoT. In IOP Conference Series: Materials Science and Engineering (Vol. 211, No. 1, p. 012009). IOP Publishing.

[15] Garg, V.K. and Gupta, R., 2011. Effect of temperature variations on ver-micomposting of household solid waste and fecundity of Eisenia feti-da. Bioremediation Journal, 15(3), pp.165-172.

[16] Palsania, J., Sharma, R., Srivastava, J.K. and Sharma, D., 2008. Effect of moisture content variation over kinetic reaction rate during vermicom-posting process. Applied Ecology and Environmental Research, 6(2), pp.49-61.

[17] Rathore, M.S. and Srinivasulu, Y., 2018. Vermicomposting bed types for recycling of sericul tural waste. Int Res J Eng Technol, 5(8), pp.1484-1488.

[18] Aquino, A.U., Baylon, D.G., Cruz, F.P.B.D., Medina, M.A.H.J.M., Reyes, G.A., Tulauan, J.M.L., Amado, T.M., Ramos, J.P.M., Tolentino, L.K.S. and Fernandez, E.O., Development of a Solar-Powered Closed-Loop Vermicomposting System with Auto-matic Monitoring and Correction via IoT and Raspberry Pi Module. In 2019 IEEE 11th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM) (pp. 1-5). IEEE.

[19] Lokeshwari, M. and Swamy, C.N., 2008. Vermicomposting of municipal and agricultural solid waste with sewage sludge. Journal of Environment Research and Development, 3, pp.51-61.

[20] Bayindir, R. and Cetinceviz, Y., 2011. A water pumping control system with a programmable logic controller (PLC) and industrial wireless mod-ules for industrial plants—An experimental setup. ISA transac-tions, 50(2), pp.321-328.

[21] Ding, J.T., Tu, H.Y., Zang, Z.L., Huang, M. and Zhou, S.J., 2018. Pre-cise control and prediction of the greenhouse growth environment of Dendrobium candidum. Computers and electronics in agriculture, 151, pp.453-459.

[22] Zhang, H., Li, J., Zhang, Y. and Huang, K., 2020. Quality of vermicom-post and microbial community diversity affected by the contrasting tem-perature during vermicomposting of dewatered sludge. International jour-nal of environmental research and public health, 17(5), p.1748.

[23] Vodounnou, D.S.J.V., Kpogue, D.N.S., Tossavi, C.E., Mennsah, G.A. and Fiogbe, E.D., 2016. Effect of animal waste and vegetable compost on production and growth of earthworm (Eisenia fetida) during vermicul-ture. International Journal of Recycling of Organic Waste in Agriculture, 5(1), pp.87-92.

[24] Sibanda, S. and Workneh, T.S., 2020. Performance evaluation of an indirect air cool-ing system combined with evaporative cooling. Heliyon, 6(1), p.e03286.

[25] Gandhi, N. and Suresh, S., 2020. Effect of mist concentration on the cooling effective-ness of a diffused hole mist cooling system. Journal of Thermal Analysis and Calorimetry, 141(6), pp.2231-2238.

[26] Tan, W.Y., Then, Y.L., Lew, Y.L. and Tay, F.S., 2019. Newly calibrated analytical models for soil moisture content and pH value by low-cost YL-69 hygrometer sensor. Measurement, 134, pp.166-178.