ORIGINAL ARTICLE

Increasing Earthworm Product Yield by Temperature and Moisture Control System

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Abstract: The bodies and droppings of the earthworms produce benefits and income. A mature earthworm can breed continuously, and when they exceed their maturity, they can be used as animal feed, and their droppings can be used to increase nutrients in the soil. Humidity and temperature are the two most important factors influencing earthworm development. The automation system uses a microcontroller to detect data and make decisions to control the ventilation fan to decrease temperature and the springer system to increase moisture in the bedding basin. The internet of things is used to monitor and send a manual control signal to the culturing system via the mobile phone. The experiment compares the traditional and control environments using culture. The controlled temperature is between 28 °C and 32 °C, and the controlled moisture is between 75% and 80%. The results show the weight of the controlled culturing process is higher than the traditional culturing process at 27.66%. The length of the controlled culturing process is longer than the traditional culturing process at 9.89%. And the weight of the total earthworm droppings in the control experiment had a higher value than the traditional experiment at 5.08%.

Keywords: Environment control; Automation; Internet of things; Earthworm cultured; Process monitoring

Introduction

In Thailand, the cultivation of vegetable crops has been used with chemical fertilizers and chemicals to accelerate growth, eliminate plant diseases and insect pests that destroy crops, improve quality, and have sufficient quantity without considering the dangers to themselves and the consumers. Including the long-term negative effects on soil conditions and the environment of using chemical fertilizers and chemicals. Therefore, new alternative farming methods are used by turning to the use of compost and manure instead of chemical fertilizers and various chemicals to improve the quality of the deteriorated soil, increase productivity, and most importantly, reduce the use of chemicals that are harmful to the health of producers and consumers, which meet the needs of health-conscious consumers, and these product markets are expanding rapidly today [1].

Earthworms are used for structural improvements and to increase soil fertility. As a result of these benefits, some countries widely produce commercial vermicomposting for use in farm work [2]. [3] Vermicomposting is a simple biotechnological process of composting in which certain species of earthworms are used to enhance the process of waste conversion and produce a better product. Earthworm manure compost contains almost all the nutrient components required by plants in a form that can be absorbed by plants and can improve the physical properties of the soil as a food source for soil microorganisms [4]. Including substances that have properties similar to auxin, a hormone that stimulates plant growth. Various properties affect plant yields and indirectly affect the improvement of soil quality to be fertile and suitable for plant cultivation [5-7].

In Thailand, the farming of earthworms can be done easily and at a low cost, and the farmer does not need an experience [8]. Even as a foreign species, it can reproduce and thrive in the climate of Thailand as well [9-10]. Earthworms are therefore very useful for agriculture. Farmers, on the other hand, continue to lack information on the best environment for earthworm growth in order to obtain vermicomposting [11-12]. Many of the constituents with the uncertainty of values detected inside bedding are analyzed by environmental diagnosis and the sensor device diagnostic method, which is based on experience or agricultural knowledge bases. Currently, technology based on the theory of knowledge-based instruction sets transfers the actual input value to the device system input value to meet the specified conditions [13]. After processing the database, the sensor system values are converted back to the actual output values displayed through the IoT (Internet of Things) [14-15]. As a result, this research was carried out to study and experiment with the environment suitable for the good growth of earthworms, with research planning and theoretical data collection as a guideline for farmers or those interested in further study.

Methodology

The research starts with the study of theories and a review of related literature on the earthworm nursery and culturing process. The researchers had been taught the traditional culturing process of earthworms by the farmer.

Traditional earthworm culturing process

Farmer knowledge was used to develop traditional earthworm culture processes. The culturing process is the result of much research and experiments until the farmer gained confidence in the process.

Equipment

Plastic basins measuring 50 cm in diameter with a drainage hole drilled at the bottom of the basin are used in the culturing process. The cow dung, which looks like a golden yellow lump, used to be the bedding of the earthworms. Cow dung must not contain contaminants such as caustic soda, lime, or pineapple. The chopped vegetable waste used to be a food supplement. The earthworm breeders are equal parts African Night Crawler (Eudrilus eugeniae) and Tiger (Eisenia foetida).

Earthworm nursery

The location should have moderate ventilation, temperature, moisture, and light control, as well as protection from rain and sun. The process to prepare the bedding for the earthworms starts by soaking cow dung in water for 8 to 10 hours to moisten, cool down, and decompose into small lumps. Release water from the cow dung infusion tank. After that, put it in a container that is cultured according to the cultural characteristics. Scoop the cow dung that has been soaked in water and put about half of it in a basin. Add vegetable waste in a ratio of 1 per. 2 parts cow dung and make a circle in the middle of the basin. Place the earthworm in the center with an average weight of 250 grams per basin. Make a cover with cow dung. Arrange the basins on a shelf to allow the water to drain through the drilled holes. Do not place it on the floor.

Traditional watering

Watering is used to increase moisture in the bedding. The farmer waters the bedding for about 7 days, and for 8 to 20 days, he uses less water by using sprinklers or spray. After 20 days of no watering, and looking at the bedding transformed from cow dung to earthworm droppings, you can put your finger down to the bottom of the basin and feel that there are no lumps of cow dung. If there is still something to eat, then throw it out and sprinkle water for the earthworms to eat it all. The last day of watering collects the mucus of the earthworms in the basins. Then fill the tank and close it with a lid for fermentation. After one month, filter the liquid with a thin white cloth. The filtered liquid is the vermicompost from the earthworm.

Earthworm dropping

The earthworms take about 25 days or more to eat all the cow dung and vegetable waste. After that, the farmer will separate the earthworm droppings and the body. The moisture in the basin does not exceed 35%. The moisture content of the worm droppings can be checked by clenching your hand and observing whether the earthworm droppings do not stick to your hand or feel wet. The earthworm droppings should not be exposed to sunlight or stored in the shade. In case an earthworm drops excess moisture, it dries in the air for one day, is re-sifted, and then packed in bags.

Design of controlled temperature and moisture earthworm culturing process

Prepare earthworm nurseries, bedding, and equipment the same as for the traditional culturing process. Install temperature and moisture sensors in all basins. Connect the sensors to the cloud. The results obtained from the measurements are sent to the microcontroller via the cloud. The microcontroller uses the programmed conditions to control the springer system (to increase moisture) and ventilation fans (to decrease temperature). The farmer can monitor data from sensors that are stored via the cloud by using the application on the smartphone. The new data will be sent after the measurements are made, and the measurements will be processed every 10 minutes.

The controller controls temperature and moisture by comparing measurement data from the cloud with reference conditions. The control range of the temperature by the ventilation fan is between 28 °C and 32 °C and the control range of the moisture by the springer system is between 75% and 80% [16]. After 20 days of no watering but still control the temperature. On the last day of watering collect the mucus of the earthworms. After 25 days or the earthworm eats all the cow dung and vegetable waste, the farmer separates the earthworm dropping and the body. In case an earthworm drops excess moisture, dries in the air for one day, then re-sifted and packed in bags.

The earthworm nursery and control environment systems

The shelf in Figure 1 used to be an earthworm nursery. The shelf (number 1) is designed to place the plastic basins (number 2) higher than the floor. The temperature and moisture sensors (number 3) are installed on the shelf, and the measurement probe is put into the basin. The sensors connect to the internet and store measurement data on the cloud every 10 minutes. The controller (number 5) connects to the internet and reads measurement data to compare the measurement temperature and moisture with the reference condition. The controller sends a signal to the control water valve (number 4) and ventilation fan (number 7). The water from the valve is released to the top of the basin by using a springer (number 6). Figure B shows the flow of data. Begin by measuring temperature and moisture in basins and sending them to the cloud for storage. The farmer monitors measurement data by using an application and manually turning on and off the water valve and ventilation fan. The controller reads data from the cloud via Firebase and sends a signal to the control water valve and fan using the relay.

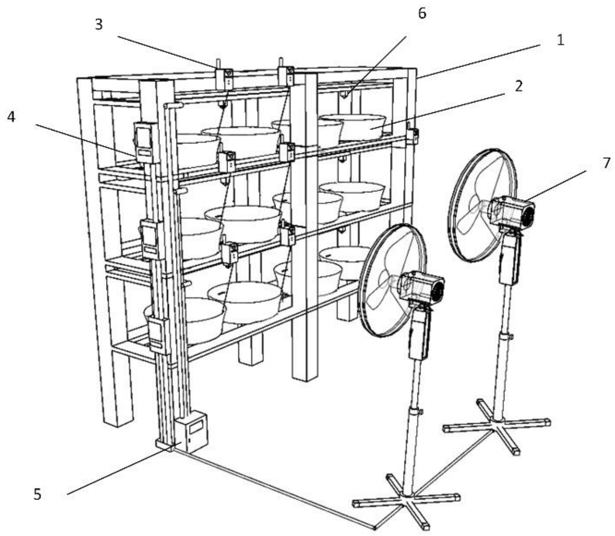

Figure 1. Earthworm nursery

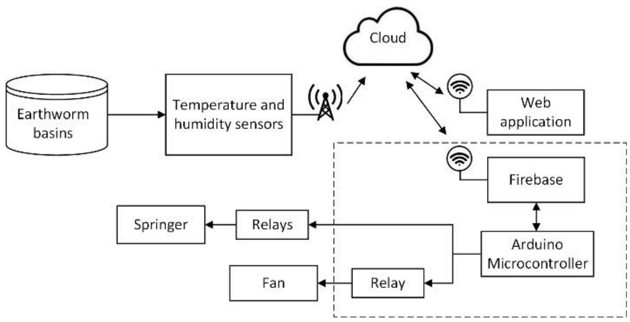

Figure 2. Control environment systems

Experimental design

The aim of the experiment is to compare the results of the traditional and controlled culturing processes. To prove the temperature and moisture range from the literature review, the researcher conducted an experiment on earthworm culture. Moisture control is more common in Thailand than temperature control, and in cases of low value, a moisture control system is made.

Proportional moisture experiment

Moisture is classified into three types. There is low moisture (moisture less than 75%), middle moisture (moisture 75% to 80%), and high moisture (moisture higher than 80%). The three basins for each condition. In each basin, put cow dung (3 kg), vegetable waste (1.5 kg), and earthworms (250 g). Feed within 20 days. On each experiment day at about 7 o'clock, 20 earthworms were drawn, weighed, and measured for length. Then calculate the average values. Table 1 shows the temperature on each day and the controlled moisture for three conditions.

After weighing and measuring the length of the earthworm under three conditions, the average weight from Table 2 shows that moisture between 75% and 80% results in the highest average weight of the earthworm. And the length from Table 3 shows that moisture between 75% and 80% results in the highest average length of the earthworm. Then, moisture between 75% and 80% is used in the experiment.

Table 1. The temperature and moisture recorded

Days	*Temp.*[a]	*Low*[b]	*Middle*[b]	*High*[b]
1	33.56	70%	78%	89%
2	33.42	70%	79%	85%
3	33.51	69%	78%	91%
4	33.43	69%	79%	87%
5	33.53	72%	79%	86%
6	33.06	71%	80%	87%
7	33.18	70%	78%	88%
8	33.55	71%	79%	90%
9	33.32	71%	79%	83%
10	33.25	69%	78%	86%
11	33.52	69%	80%	92%
12	33.53	73%	80%	83%
13	33.44	69%	78%	91%
14	33.3	72%	79%	88%
15	33.2	70%	79%	92%
16	33.31	69%	78%	85%
17	33.5	72%	80%	88%
18	33.22	72%	80%	85%
19	33.09	72%	79%	83%
20	33.38	69%	78%	89%
Average	**33.37**	**70%**	**79%**	**87%**

a: The temperature in degrees Celsius.

b: The moisture of each condition in percent.

Table 2. The average weight of earthworms at low, middle, and high moisture

Days	*Low*[a]	*Middle*[a]	*High*[a]
1	3.50	3.54	3.58
2	3.56	3.89	3.62
3	3.64	4.01	3.73
4	3.68	4.21	3.75
5	3.70	4.45	3.82
6	3.74	4.59	3.95
7	3.76	4.70	4.07
8	3.82	4.76	4.15
9	3.85	4.89	4.23
10	3.89	4.94	4.40
11	3.93	4.99	4.43
12	3.97	5.10	4.50
13	4.01	5.16	4.56
14	4.10	5.35	4.64
15	4.14	5.52	4.66
16	4.17	5.59	4.80
17	4.21	5.67	4.98
18	4.20	5.75	5.12
19	4.23	5.85	5.27
20	4.28	6.00	5.42
Average	**3.92**	**4.95**	**4.38**

a: The weight in grams of each moisture level.

Table 3. The average length of earthworms at low, middle, and high moisture

Days	*Low*[a]	*Middle*[a]	*High*[a]
1	12.59	12.32	12.62
2	13.29	13.19	13.26
3	13.37	13.81	13.62
4	13.45	14.36	13.80
5	13.55	14.57	13.88
6	13.63	14.77	13.97
7	13.72	14.97	14.02
8	13.80	15.09	14.11
9	13.90	15.21	14.19
10	13.98	15.36	14.26
11	14.03	15.41	14.32
12	14.08	15.46	14.41
13	14.15	15.52	14.55
14	14.21	15.61	14.60
15	14.32	15.71	14.76
16	14.36	15.49	14.84
17	14.53	15.92	14.96
18	14.57	16.02	15.10
19	14.69	15.80	15.22
20	14.75	16.14	15.34
Average	**13.95**	**15.04**	**14.29**

a: The Length in centimeters of each moisture level.

Traditional and controlled earthworm culturing experiment

The experiment is divided into two processes. 1) The traditional culturing process follows the farmer's process. 2) Control temperature and moisture in the culturing process. Each condition uses four basins with the same quantity of cow dung, vegetable waste, and earthworms. The controlled temperature is between 28 °C and 32 °C, and the controlled moisture is between 75% and 80%. Experiment with two processes within 20 days, and at about 7 o'clock every day, 20 earthworms were drawn, weighed, and measured for length. Then calculate the average values. No watering after day 20. Allow the earthworm droppings to dry before weighing them.

Result

The comparison of two processes, the traditional culturing process and the control culturing process, with a sample size of 20 days per process. The temperature and moisture were recorded, and the weight and length were measured every day. The result was the difference between temperature and moisture, as shown in Table 4. The temperature and moisture of traditional cultivation depend on each day's environment, but in controlled cultivation, the temperature was controlled between 28 °C and 32 °C, and moisture was controlled between 75% and 80%.

Table 4. The Temperature and moisture of traditional and controlled culturing process

days	***Traditional culturing***		***Controlled culturing***	
	Temp.[a]	***Moist.***[b]	***Temp.***[a]	***Moist.***[b]
1	33.12	72.3%	31.66	78.0%
2	33.22	72.0%	31.42	79.0%
3	33.24	72.0%	31.53	78.0%
4	34.33	71.3%	31.44	79.0%
5	33.98	71.3%	31.33	79.0%
6	33.65	72.0%	31.24	80.0%
7	33.99	71.8%	31.54	78.0%
8	33.80	72.0%	31.41	79.0%
9	33.99	71.8%	31.43	79.0%
10	33.80	71.3%	31.53	78.0%
11	33.35	71.8%	31.04	80.0%
12	32.89	72.8%	31.17	80.0%
13	34.47	71.3%	31.54	78.0%
14	34.08	71.8%	31.33	79.0%
15	34.48	71.3%	31.36	79.0%
16	33.08	72.0%	31.53	78.0%
17	33.24	72.0%	31.24	80.0%
18	33.22	72.0%	31.08	80.0%
19	33.07	71.8%	31.43	79.0%
20	33.24	72.0%	31.65	78.0%
Average	**33.61**	**71.8%**	**31.39**	**78.9%**

a: The temperature in degrees Celsius.

b: The moisture in percent.

Table 5 shows the traditional culturing process. The weight was 3.94 g, and the length was 13.65 cm. In the controlled culturing process, the weight was 5.03 g, and the length was 15.00 cm. The weight of the controlled culturing process was higher than the traditional culturing process at 27.66%. The length of the controlled culturing process was higher than the traditional culturing process at 9.89%.

The comparison of weight and length between the traditional and controlled culturing processes used t-test statistics. The results were significant at the 0.05 level. That means the weight and length of the two culturing processes were different. After drying the earthworm droppings, the weight of the total earthworm droppings in the control experiment was higher than in the traditional experiment at 5.08%.

Table 5. The Weight and length of traditional and control experiment

days	***Traditional culturing***		***Controlled culturing***	
	Weight[a]	***Length***[b]	***Weight***[a]	***Length***[b]
1	2.83	12.92	3.95	14.00
2	3.03	13.00	4.08	14.30
3	3.25	13.10	4.30	14.38
4	3.30	13.18	4.50	14.54
5	3.45	13.30	4.63	14.62
6	3.58	13.37	4.65	14.73
7	3.65	13.39	4.68	14.82
8	3.75	13.44	4.75	14.87
9	3.80	13.46	4.85	14.91
10	3.88	13.54	4.95	14.94
11	3.93	13.58	5.00	14.98
12	4.00	13.62	5.03	15.02
13	4.03	13.65	5.13	15.09
14	4.05	13.85	5.25	15.15
15	4.23	13.89	5.45	15.26
16	4.33	13.95	5.55	15.38
17	4.45	14.07	5.75	15.43
18	4.60	14.30	5.90	15.68
19	5.18	14.52	6.03	15.87
20	5.53	14.84	6.28	15.99
Average	**3.94**	**13.65**	**5.03**	**15.00**

a: The weight in grams.

b: The length in centimeters.

Conclusion

The construction of the earthworm farm is wild in Thailand. The farmer's knowledge is the cultivation process. The farmer spends time every day watering the bedding basin to increase moisture and uses a ventilation fan to decrease the environmental temperature when they feel that temperature is high. Microcontrollers were used in the automation systems to retrieve data from temperature and moisture sensors and automatically control the springer system to increase moisture and the ventilation fan to decrease environment temperature. The microcontroller connects to the internet via an IoT system and shows data on mobile phones via a Line application or web application.

The experiment compared traditional and controlled culturing processes. The traditional culturing process used knowledge from farmers. The controlled culturing process used a microcontroller to control the temperature between 28 °C and 32 °C and the moisture between 75% and 80%. The weight of the controlled culturing process was higher than the traditional culturing process at 27.66%. The length of the controlled culturing process was higher than the traditional culturing process at 9.89%. The weight of the total earthworm droppings in the control experiment was higher than in the traditional experiment at 5.08%. The controlled culturing process increases the yield of vermicomposting compared to the traditional culturing process and can also reduce water and electricity costs because the system will water when the humidity is below 75% and only open the ventilation system when the temperature is above 32 °C.

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