Development of an Automated Production of African Night Crawler's Vermicast with Android Application

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***Abstract*--Vermicomposting is the process of breaking down biodegradable matter by earthworms to convert the contained nutrients in the organic matter to vermicast. In this paper, the proponents introduced the development of an automated production of vermicast. Four subsystems were designed namely: irrigation, sensor network, worm migration, and communication subsystem to minimize human intervention. The communication system involved the use of 2.4 Ghz. The study uses Arduino uno and Arduino mega microcontrollers, an android phone and liquid crystal display (LCD) for monitoring. The automated project improved the manual process of vermicomposting by eliminating 4 processes from the manual system.**

***Index Terms*- vermicast, vermicomposting, soil moisture, arduino**

I. INTRODUCTION

Organic farming is a classification of agricultural production that aims to produce food and fiber, it was conceived to be the best alternative production method for a healthier life, since it prohibits the use of synthetic pesticides or fertilizers. This is expected to have high rise in demand. For organic farming, castings of earthworms also known as vermicomposting is an excellent soil enhancer and bioactive high quality fertilizer. Vermicomposting is the process of breaking down biodegradable matter by earthworms to convert the contained nutrients in the organic matter to vermicast.

Eudrilus eugeniae or commonly known as African night crawler is an earthworm species indigenous to Africa but extensively bred in the USA, Canada, Europe and Asia [1]. It has high-production rates and is capable of decomposing large quantities of organic wastes quickly and incorporating then to topsoil [2]. It shows preferences for high temperature, with maximum biomass production occurring at 25^0C – 30^0C, while growth rates were very low at 15^0C [3].

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It can tolerate moisture between 70%-80%, the optimum being 80%-82%. It can also tolerate pH levels from 5-9, but they move on more acid material, with pH material of 5 [4].

There are around 4000 species of Earthworm worldwide and 400 of them can be found in the Philippines. In 1982 Dr. Otto Graff introduced African Nightcrawler (ANC) in the Philippines which originated in West Africa. In tropical country like the Philippines, ANC increases rapidly due to favorable weather condition. The vermicast production is an emerging farming observed in the developing country like the Philippines and is still in manual system. Region 3 and Region 12 of the country are agriculture-based industry area, where vermiculture and vermicast production industry displays good potentials in the local market. Vermiculture is the culture of earthworms. The goal is to continually increase the number of worms in order to obtain a sustainable harvest [5].

The authors conducted site survey of a local vermicast farm industry in Region 3 of the country. The manual process starts by laying of blocks as perimeters for compost. This also serves as the structure for the worm bed. Substrates are then prepared and placed in the whole area of the worm bed. Upon equal distribution of substrates, a net is then placed before placing the earthworms. The net serves as the means in separation of the worm and the harvest vermicast. The vermicompost is watered three times a day and once the compost becomes a pellet-like mixture, the worms are manually removed from the vermicompost and vernicast harvesting begins. Turning organic wastes into casts takes 22–32 days, depending on density of waste and earthworm maturity-45 days [6]. African Night Crawler can consume 1 kilogram of organic material, while research suggests that the earthworms ingest about 75% of their body weight/day and a 0.2 gram worm eats about 0.15 gram per day.

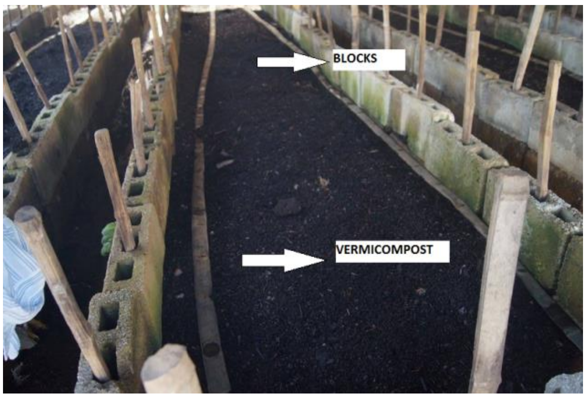

Fig. 1. Manual system vermicast production. Blocks are used as fenced for the worm bed and substrates.

Regular composting requires 30 to 40 days, and additional 3 to 4 months of curing. However, the advantage of vermicast is that it does not require to be cured before it is used as fertilizer.

Fig. 2. African Night Crawler (ANC). A one kilogram of ANC can consume 1 kilogram of organic material.

An automated system of producing organic fertilizer can greatly increase the development of the current agricultural technique. One example is found at a cabbage farm at Murcia, Sapin, where wireless sensor network is used in detecting different agricultural factors such as water content, temperature and salinity of soil [7]. The production of vermicompost for organic farming still demands further study and improvement in the developing country like. From the two site survey on vermicast farm that the authors conducted, manual systemof vermicomposting are being practiced. Hence, it is evident that there is limited application of electronics technology adapted with the existing process. The study aims to provide an automated system for vermicast production that may improve the whole concept of organic farming.

II. CONCEPT AND SUBSYSTEM

The design and development of the study consists of considering the control variable. ANC was considered as major concern for the vermicast production. In which, their environmental conditions to sustain their growth rates is vital. The authors consider soil moisture as primary considerations followed by the soil temperature, light intensity and pH levels.

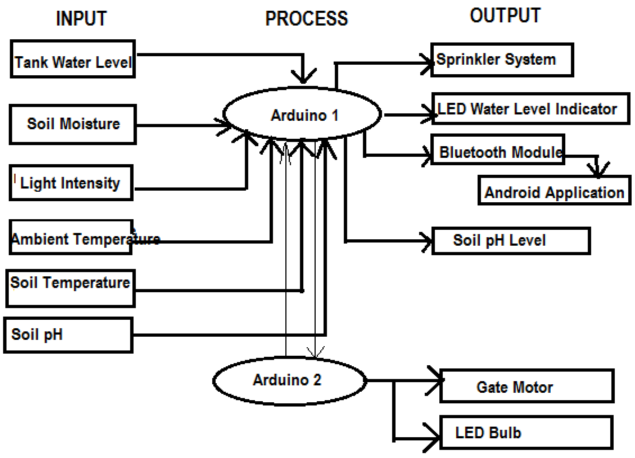

Fig. 3. Conceptual Framework of the study. Two Arduino microcontroller were used for the study to control two worm bins and input parameters

Two Arduino microcontrollers were used in the project. Arduino 1 was used to receive signals from the input sensor networks and processed these signals to trigger the desired output. Arduino 2 was used as a timer for the gate of the worm bins. A simplex communication between the two arduino was established to coordinate the time programmed to open and to closed the worm bin's gate.

A. *Soil Moisture and Soil Temperature*

Soil moisture and soil temperature sensors monitor the status of the vermicompost in the worm bin. If the soil temperature reached 33 degrees Celsius and soil moisture goes below 60 %, the sensors will send the data to the arduino microcontroller for condition checking. The set condition will then trigger the water pump to activate the sprinkler to maintain the soil temperature and soil moisture, thereby avoiding the death of the earthworms.

Moisture content of 40% and 50% slows decomposition [8]. Moisture level must be maintained at around 50% so that microbial activity is high and the food matter is easy to feed up [9]. However, in Philippine settings, worms thrive best with moisture content with 60-80 %. The more worms stocked, the faster the production of casting when substrate is fully composted in 4 to 5 weeks (25-35 days) the vermicompost can be harvest. The data that the sensors detect is also processed by the arduino mega and is transmitted via Bluetooth to android phone for monitoring purposes.

B. Sensor Network

The study uses five kinds of sensors namely: soil moisture sensor, ambient and soil temperature sensor, light intensity sensor and water level sensor.

The soil moisture sensor that was used consists of two electrodes. Prior to embedding it into the vermicompost, these electrodes are coated with plaster of Paris to enable it to absorb water from the vermicompost before exposing the sensors to the soil moisture. This eliminates fluctuations of value read by soil moisture sensor. The sensor was programmed to read values from 0% - 100% soil moisture.

Determination of soil moisture minimum and maximum threshold was done using two pint calibration. A ratio of 1: 1 was used, that is, 3500 ml of soil was sun-dried for 48 hours. A measured value of 0% soil moisture indicates the baseline or minimum soil moisture. An additional of 3500 ml of water mixed with soil indicates maximum soil moisture or 100% soil moisture content. The sensor was programmed from the range of 0% - 100%.

The soil and ambient temperature sensors are both thermocouple nodes that are connected to the arduino module. Thermocouples are comprised of two dissimilar conductors joined at one end to form a hot junction which produces a voltage. As the junction is heated or cooled the voltage changes and is converted to return the temperature

The light-dependent resistor (LDR) gives out an analog voltage when connected to supply voltage of Vcc= 5V, which varies in magnitude in direct proportion to the input light intensity on it. This output analog voltage from LDR is then fed to the analog input pin of the arduino. The built-in Analog to Digital Converter converts the analog voltage from 0V-5V into a digital value in the range of 0-1023. Thus, when there is sufficient light in its environment or on

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its surface, the converted digital values read from the LDR through the arduino will be in the range of 800-1023.

The authors used ultrasonic sensor for water level, which measures the height of the water inside the tank.

C. Water Irrigation System

For the control of the sprinkler system, solenoid water valves were used. Instead of creating pressure by use of a pump, the pressure generated from the elevation of the water tank is utilized instead, and water flow is enabled or disabled by the solenoid water valves. The water valves operate with 12 Volts, 1 ampere and can withstand 0.02 to 0.8 Mega Pascal of water pressure. The water tank is a plastic drum having a diameter of 60.20 centimeters and a height of 82.55 centimeters. The total volume of water it can hold is 234.95 liters. The sprinkler system is responsible for watering the compost when triggered by the system to maintain the preferred soil moisture and soil temperature for the compost.

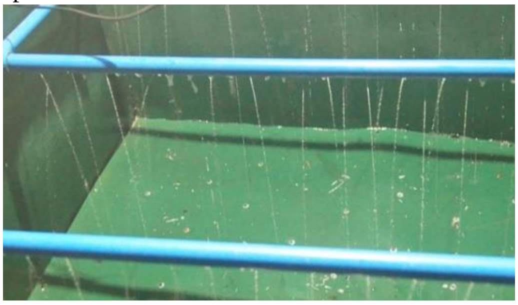

Fig. 4. Water sprinkler system. The design ensures well distributed water over the area of the vermicompost.

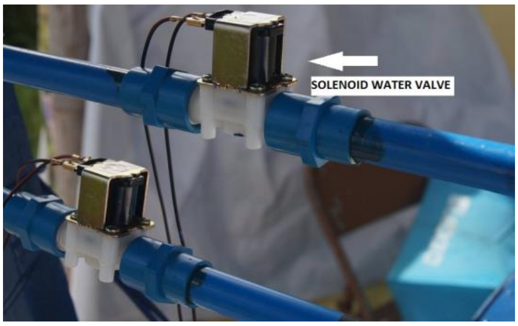

Fig. 5. Solenoid water valve. Compatible with the used of arduino microcontroller, cheaper than submersible water pump and synergizes with water pump

D. Worm Migration System

Two worm bins were prepared for faster worm migration. The first bin was prepared for the first vermicomposting. Each bin has a volume of 0.4 m^3 with an ideal harvest of 0.083 m^3 to 0.1 m3 vermicast.

The second worm bin was made ready for worm migration for the next vermicomposing. Earthworms vacate the place if they find no food to consume. In this case, when they have consumed the decomposed materials from the first bin, worms will get attracted to the next worm bin because of the presence of the decomposed. It was observed that worms took 20 days to consume the decomposed. The Arduino 2 will trigger the gate to open after 20 days, and to assure the transferring of worms between the bins, a lamp will light-up during worm migration. ANC does not like lights, for this reason, the lamp helps in worm migration. The lamp will be turn off once the gate is closed. The evacuated worm bin 1, consists of produced vermicast which is ready for harvest.

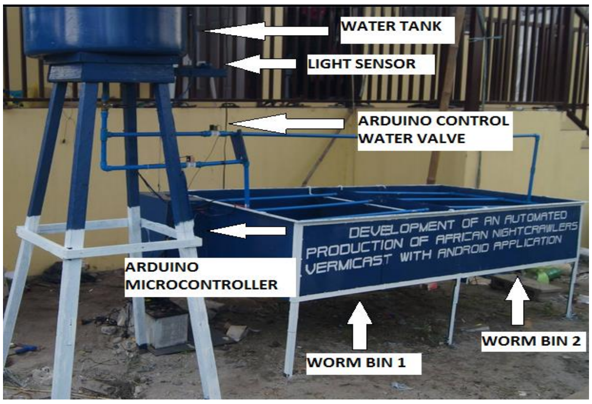

Fig. 6. Automated vermicast system. The study has 4 subsystems: water irrigation, migration, sensor network, and communication subsystem

The required motor used for the project needs a forward and reverse mode of rotation. The motor used for this project has a speed of 2-3 revolution per minute, 12V, 6A and brush commutation. The motor was designed for high torque and low speed applications.

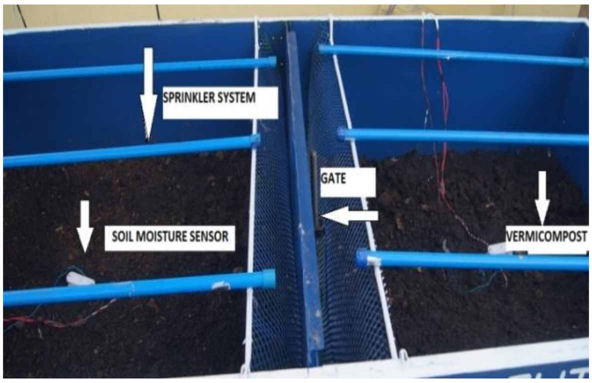

Fig. 7. Worm bins with gate controlled. Two worm bins were designed for worm migration to eliminate the process of manual separation of worms with the produced vermicast.

E. Bluetooth and Android

The Bluetooth connection is provided by the Bluetooth module connected to the arduino 1. It is a BC417, single chip radio and baseband IC for Bluetooth 2.4 GHz systems including enhanced data rates (EDR) to 3 Mbps. Bluetooth V2.0 is used by the module, using a short-wavelength ultrahigh frequency (UHF) band from 2.4 to 2.485 GHz, and has a physical range of 10 to 100 meters. This version of Bluetooth is used in the project in conjunction with the android app so that the user will have a monitoring application displaying the parameters the project is processing besides the Liquid Crystal D display when the user is near the project itself.

Data received by arduino1 is sent via bluetooth to the android phone. This was done by using the android application APK file to view the data from arduino through android phone.

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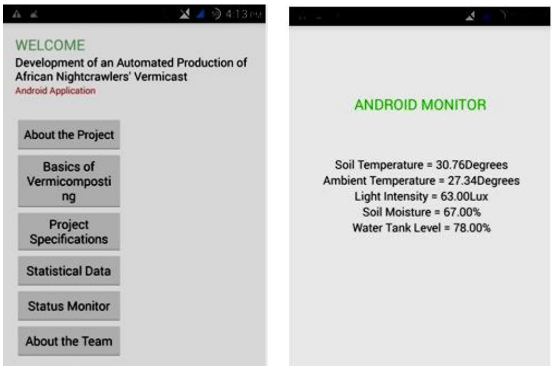

Fig. 8. Developed android pplication (left) & Android Monitoring(right).. The arduino 1 sends data to be view using Liquid Dsiplay (LCD) and android application

III. TEST AND ANALYSIS OF RESULTS

The development of the system includes several test performance to undertake. Experiments and test measurements were performed on hardware and selection of best pre-decomposed substrate. These tests were performed based on the following hierarchy:

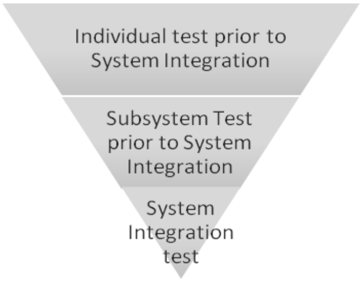

Fig. 9. Test hierarchy of the project. Inverted pyramid modeling the structured mode of test performed.

Selection of best pre-decomposed substrate

Prior to performance of each tests, selection of the best pre-decomposed must first be considered. These two pre-decomposed are chopped banana stalk and sugar bagasse. Test results on soil moisture and soil temperature of these materials as pre-decomposed substrate were measured and data were taken every hour for 3 days. The mean soil moisture of sugar bagasse was 60% while the chopped banana stalk has 60.83% from 24 observations. Statistical treatment used was two-tailed t-test to determine if there exists difference between materials. The critical region was found at t(46, 0.05) =2.013 with t Stat value of -.702. Therefore, the mean soil moisture of materials has no difference.

Fig. 10 Selection of best decomposed for the study. (left) Chopped banana stalk and (right) sugar bagasse were tested to determine the best decomposed to use. Each material were tested based on the result values from the sensor network.

Test on soil temperature of both materials shows that pre-decomposed substrate with sugar bagasse has a mean soil temperature of 25.68 ^{0}C while substrate with chopped banana stalk has 25.08 ^{0}C. There is a closeness of soil temperature value for both materials. Statistical treatment using one-tail t test shows that t-stat value of 1.441 is not in critical region with t(27,0.05)=1.703. Therefore, the soil moisture between pre-decomposed substrate has no difference. The authors selected sugar bagasse as pre-decomposed substrate since it does not require longer process to prepare as compared with the banana stalk that needs to be finely chopped.

Individual Test Prior to System Integration

Prior to system integration, each sensor was tested for its usability and required functionality. The tree diagram in represents hardware parts that were individually tested.

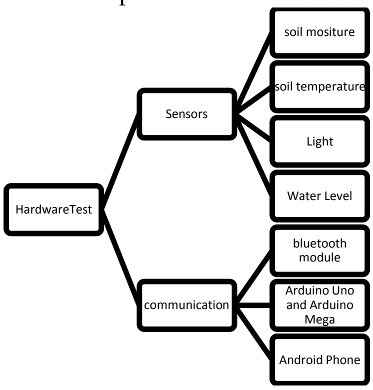

Fig. 11. Individual hardware test. Each used sensors and hardware were test based on its functionality

Subsystem Test prior to System Integration

Integrating the sensors with other sensors completes the subsystem for sensor networks. These allow the coordination between subsystem. The key component of this test is the coordination of each subsystem with its sensors and needed hardware.

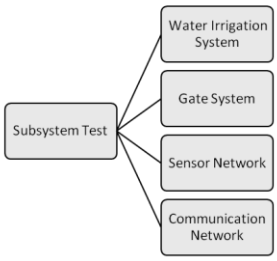

Fig. 12. Test on each subsystem. Each subsystem consists of different sensors and hardware that requires compatibility and functionality test.

System Integration test

Five cases are introduced for system integration test to determine the response of the system. Also, five sensors were used to determine the soil moisture and soil temperature in the worm bin, light intensity, tank water level, and ambient temperature. These values were processed by arduino 1 and displays it through LCD at the worm bin and via Bluetooth to an android phone.

Case No.	Case Description
Case 1	Normal Condition

Case 2	Abnormal Condition
Case 3	Water level in critical condition
Case 4	Migration condition
Case 5	Power Interruption

The system is in normal condition for Case 1, soil moisture is within permissible range of 60%-80% soil moisture value. The system LED water level indicator is off and arduino 2 is not triggered. In Case 2, under abnormal condition, soil moisture level of the worm bin is outside the accepted range, which is below 60%. Arduino 1 will send triggering signal to the sprinkler system to water the active worm bin. The sprinkler stops when the soil moisture reaches again the permissible soil moisture content of at least 60%. Water level indicator is off and arduino 2 is not triggered. In Case 3, the tank's water level is below 50% of its full volume. The system's LED water level indicator is "on". For migration condition, under case 4, Android 2 is triggered by android 1. It then triggers the motor of the gate and lights- up the lamp. Case 5 occurs when there is a power interruption. Uninterruptible power supply (UPS) will then be triggered to provide necessary voltage for continuous process of the system.

IV. UNCERTAINTY AND PREDICTIVE ANALYSIS

The measurement of preciseness from soil moisture and soil temperature was considered between the two system to for comparative analysis. Forty five (45) sample data were taken. The authors express the level of preciseness in terms of Uncertainty Analysis in three modes: range, absolute average deviation, and relative uncertainty. The automated system gives mean soil moisture of 61.22 % with $\pm$4 % range versus the manual system with mean soil moisture of 60% with $\pm$ 20 %.

Measurement of preciseness through absolute average of deviation |Δw| is:

$$|\Delta w| = i\frac{1}{N-1}\sum_i |SM\ i| \qquad (1)$$

The parameter SM is the soil moisture content of the vermicompost. The automatic system displays |Δw| soil moisture of 61.22 $\pm$ 0.641 while the manual system has |Δw| soil moisture of 60 $\pm$0.891. The relative uncertainty or the measure of preciseness of soil moisture is 2.91 % for automated system while 15.82% for manual system.

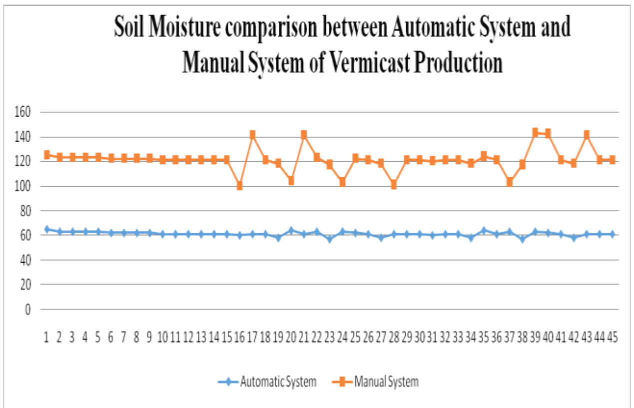

Fig. 13. Soil Moisture content using Automated and Manual System. Soil Moisture values from 45 data were compared between two systems.

The design and development of the automated system's soil moisture provides consistency of soil moisture content to the active worm bin as compared to the manual system of irrigation as seen in figure 13.

Mean Soil temperature of the automated system gives an advantageous value as compared with the manual system.

Table 1 Mean Soil Temperature Uncertainty Analysis between Automatic Vermicomposting and Manual System

Uncertainty Analysis	Mean Soil Temperature (Automatic)	MeanSoil Temperature (Manual)
Range	26.92^{0}C $\pm$2.685%	25.68 ^{0}C $\pm$ 3.5 %
Absolute Average Deviation	26.92^{0}C$\pm$ 0.607%	25.68^{0}C$\pm$ 0.673%
Relative Uncertainty	5.348203 %	10.40815%

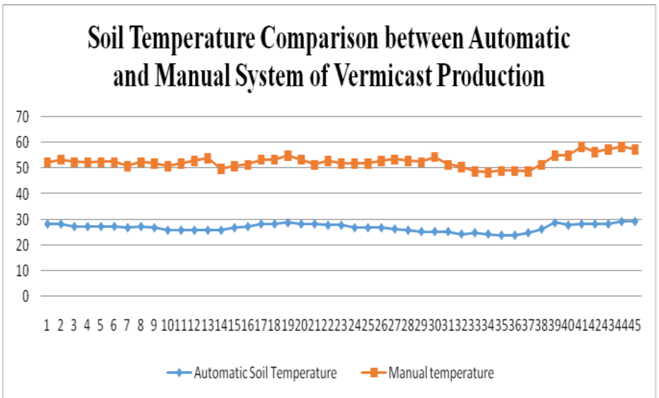

Fig. 14. Soil temperature of automated the manual system from 45 sample data.

It is evident that the measurement of preciseness of data is much more improved in automated system. More so, the accepted temperature had been within the accepted level.

Predictive Analysis

The predictive analysis was considered to determine moisture level for any instantaneous value temperature using curve fitting. Curve Fitting is the process of constructing a curve or mathematical function that has the best fit to a series of data points possibly subject to constraints. This is helpful if soil moisture sensor becomes faulty. Reading from soil temperature may be used to determine the soil moisture of the worm bin.

Mathematical model for the soil moisture and soil temperature:

$$y = 0.02\ x^2 - 0.98x + 73 \qquad (2)$$

The parameter y is the soil moisture and x is the soil temperature as seen in Figure 15.

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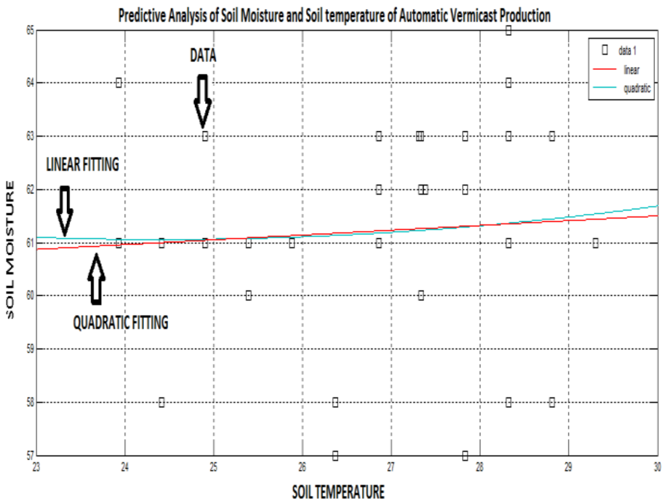

Fig. 15. Data curve fitting. Soil Moisture and soil temperature data curve fits in a quadratic form.

IV. IMPROVED PROCESS OF AUTOMATED VERMICAST PRODUCTION FROM MANUAL SYSTEM

The nine (9) manual procedures of vermicast production were reduced to four (4) processes. Nets are nolonger used to manually separate the worms from the vermicast during harvest period. Manual preparation of worm bed per layer has been improved by worm migration. Manual checking of the soil moisture has been reduced as well as the three times a day water irrigation of vermicompost. The network sensor automatically triggers the sprinkler system when soil moisture content goes below the allowable 60% soil moisture.

The vermicast produced by the automated system was tested at the Soil Laboratory of Department of Agriculture in Region III of the country.

Result of Assay of sample of Vermicast from Automated System:

pH	5.36
Nitrogen, %	1.97
Phosphorous, %	0.80
Potassium, %	0.18
Moisture-Content, %	53.20

V. CONCLUSION

The paper contributions to agriculture with the integration of electronics technology greatly helps farmer to save time and effort. The automated system provides consistency of soil moisture content of the vermicompost. The two arduino microncontrollers were considered to avoid time delays if only one microcontroller will be used. For this project, 20 days were used and still produced acceptable nutrient for a fertilizer. Worm migration takes when the gate between two worm bins is open. It is open for 2 days to ensure total worm migration from the first worm bin towards the second worm bin. Either sugar bagasse or chopped banana stalk may be consider to use as pre-decomposed substrate, since they show similar response in terms of soil moisture and soil temperature. However, the results of vermicast production weighed 33 kilograms from a decomposed with 2 kilograms of chopped banana stalk as compared with dried sugar bagasse, the vermicast weighed 38 kilograms. Therefore, sugar bagasse was used for automated system to ensure fast production of vermicast. Data coming from sensor network are sent to an android phone via Bluetooth for monitoring and are displayed on the LCD of the worm bin.

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