BOTSWANA INTERNATIONAL UNIVERSITY OF SCIENCE & TECHNOLOGY

Research proposal for funding (Maximum 15 pages 1.5 spacing, 12 Times New Roman)

PART I: GENERAL INFORMATION

Project title: **Determining the efficiency of hydroponics against conventional farming systems in Botswana.**	
Desired Starting Date: 01/07/2020	Desired Completion Date: 30/06/2022

	Year 1	Year 2	….	Year	TOTAL
Overall Budget Distribution, BWP:	P2 467 000.00	P 627 000.00			P 3 094 000.00

Details of the project leader

Full name:	Nonofo Ditshego
Title:	Dr
Research Group	Electronic Design and Applications (EDA)
Dept./Faculty:	ECT/FET
Address:	Private Bag 16, Palapye
Telephone No.:	490 1673
Fax No.:	4900102
E-mail:	ditshegon@biust.ac.bw

Details of the project deputy leader

Full name:	Gaolathe Rantong
Title:	Dr
Research Group	Plant Biology Researcher (Molecular, Cell, Development and Biotech)
Dept./Faculty:	FS/ Department of Biological and Biotechnological Science
Address:	Private Bag 16, Palapye
Telephone No.:	490 1572
Fax No.:	4900102
E-mail:	rantongg@biust.ac.bw

Executive summary

Recent years have seen researchers testing and developing ways to improve crop production efficiency. Due to the ever increasing need for food, associated with increasing populations, there needs to be constant improvements in food production systems. Challenges in soil-based systems of crop production such as loss of prime land to urbanisation, climate change, natural disasters, compromised land fertility and environmental effects from indiscriminate use of herbicides and pesticides, has led to the development and use of new systems such as hydroponics. These systems are important for countries like Botswana who face challenges in agricultural production and food security. Hydroponic systems are becoming more popular, more advanced and are taking advantage of technological advancements. This project assesses effectiveness of hydroponic systems against soil based systems under the climatic conditions of Botswana. In addition, the effectiveness of closed settings such as greenhouses will be evaluated in comparison to the conventional open settings that are commonly practiced in Botswana. The project aims to develop a SMART system to monitor and control parameters related to crop production under closed hydroponic and soil based systems. It will explore utilising internet of things (IoT) to improve crop productivity under Botswana conditions. Parameters that will be examined to assess the yield and quality of crops include emergence percentage, emergence time, height of plants, length of leaves, plant biomass, photosynthesis rate, respiration rate, transpiration rate, stomatal conductance, nutritional composition of crops and others. Effects of variables such as nutrient solution levels, nutrients quality, pH, atmospheric conditions, light intensity and quality, dissolved oxygen levels, moisture, temperature, and relative humidity and others will also be investigated with the help of IoT.

PART II Background and Motivation

1. Introduction

Botswana is mostly a semi-desert to arid country in which most crop production is heavily affected by a shortage of water, high temperatures, poor soils, pests and crop diseases [1–4]. These conditions affect both arable (e.g., maize) and horticultural (e.g., spinach) crops. Most of the arable crops grown in Botswana are moderately drought tolerant and can grow based on natural rain. However, the yield is usually heavily compromised and they are usually grown within only 3-5 months of the year [1]. This duration is the only window in the year in which environmental conditions (especially rainfall and temperature) allow for these crops to be produced. Besides, most of the plant developmental processes (such as flowering) of theses crops are limited and synchronized to this 3-5 month period. The short production window and limitations associated with our natural climate (and climate change) limits their yearly yield [2]. Trends in arable crop production indicate that traditional production (dependant on rainfall) has seen continuous declines in yield over the years while commercial production (using irrigation) has observed increases (Botswana Agricultural Census 2015) [1–5].

Horticultural crops in Botswana require regular irrigation. Some may be grown during the warm months while others prefer cold conditions of winter. They (especially vegetables) require a lot of water and usually require addition of fertilisers and pesticides. Lack of irrigation and disease (and pest) control heavily diminishes the quantity and quality of produce [1–5].

With water shortage being a problem in Botswana (even irrigation water), it is usually the limiting factor that determines how much arable and horticultural produce a farmer can output. Constant irrigation is also costly and thus elevates local crop produce prices. Different crop production settings may require different inputs. Open settings (e.g. open field or netshade) for example, require more water, herbicides and pesticides in comparison to closed settings. Open settings are also reliant upon natural environmental conditions that may be unpredictable. They therefore are impossible to regulate. Closed settings (e.g. greenhouse) require assembly of structures that may be costly. Due to regulation of crop production conditions, inputs such as electricity and monitoring systems are also necessary. However, under this system crop production can be optimised and crops may be produced throughout the year [1–5].

In Botswana, most crop production occurs in open settings such as open fields and netshades In open settings, the plants are directly exposed to the natural environmental conditions, except for regular irrigation to supplement water and occasional addition of nutrients through fertilisers. Arable crops are almost exclusively produced in open fields, while a large amount of vegetables are also produced in net shades in addition to open fields. Netshades reduce heat and water loss though evaporation and transpiration. They also protect crops from insects and larger animals such as birds [1–5].

In Botswana, even the advanced crop production systems such as hydroponics are more commonly practised in open settings in Botswana. Under these systems, even though factors like nutrients, water, pH etc may be regulated, light intensity, and temperature may be reduced but are not regulated. These attributes are controlled in closed systems, however, the closed system require greenhouses, plant growth rooms or growth chambers, which may be costly to an ordinary farmer. Under Botswana conditions, there is need to evaluate the production efficiencies of hydroponic and conventional soil-based systems. This would help identify the most effective system based on crop productivity and cost effectiveness. In addition, the crop production efficiencies of these systems need to be studied under both open and closed settings. Aspects to be determined include water use efficiency, production cost efficiency, and crop product quality [1–5].

1.1 . Automation of farm system

Wireless Sensor Networks (WSN) will allow a network of devices to collect and monitor field data conditions through wireless links. A farmer can easily monitor his field's condition with WSN's like hydroponic system pH, temperature, fertilizers, humidity, and water levels with various sensors that are spatially dispersed. WSN's are used for monitoring the growth conditions, and microcontrollers are used to control and automate the growth processes by manipulating key factors such as temperature, light/dark hours, irrigation, nutrient status and pH levels [6–17]. With WSN's a farmer can easily access information about these conditions of his field remotely. When this WSN are interconnected together through the internet and regularly communicating and interacting with one another through the Internet of Things (IoT), farmers can substantially optimise growth conditions in order to increase their production [6–17].

This project investigates the development of many ways in which IOT can be used in crop field monitoring and the challenges. IoT allows a large-scale interconnection of devices such as computing devices (for instance, WSN's), mechanical and digital machines that work together without the human-computer interaction; it is an extension of the internet. Through a connection over the internet, these devices can be remotely monitored and controlled and are frequently in interaction and communicating with each other. IoT means to go further with its application in the energy sector (smart grid concept), industrial internet, automobiles, logistics, smart cities, agriculture, and healthcare. It is projected that by 2020 the number of devices connected in IoT across all technologies will be 20 billion. To put up with ever rising population growth food demand, agriculture also needs to embrace new technologies (smart farming) such as IoT. With this new technology, farmers can cut costs, increase production efficiency by optimising the inputs of valuable resources such as water and fertiliser. IoT has beneficial applications including moisture content sensing/monitoring in plants, humidity content/ Temperature sensing, determining the fertilizer profiles for each crop, water usage control (smart irrigation), environment pH level sensing, drones to monitor overall conditions of fields, livestock health monitoring, livestock tracking and monitoring of climate conditions [6–17].

These applications will enhance crop production by correcting imbalances through early warning system sensed variables.

1.2 . Knowledge gap

Most of crop production in Botswana occurs in open systems, however, there are no studies that compare production efficiency of the open systems to close systems under local conditions. In addition, studies that compare advanced crop production systems such as hydroponics to conventional soil-based systems are also lacking. Therefore, this study would provide much needed data that may inform crop production choices in terms of systems and settings. Furthermore, there are current knowledge gaps in the field of IoT in relation to crop production. To address this knowledge gap (including experience in the field in areas such as advanced communication between nodes, advanced programming), there will be a need to benchmark with other more experienced countries such as Israel.

1.3 . Motivation and Significance

Botswana imports 80% of its food and is dependent on surpluses from our neighbouring countries. All models of climate change indicate that this situation is unsustainable from now on as the countries themselves are forecast to experience shortages in the future. Precision farming techniques, such as hydroponics and precision drip irrigation which is desirable because it has the ability to increase current food production capabilities significantly. There exists an opportunity to design a prototype on a precision farming system that is suitable for our climate and circumstances here in Botswana.

1.4 . Problem statement

Over the years, there has been a significant increase in demand in agricultural production, especially in the crop section. Due to low supply from our farmers, many of our crops are imported from neighbouring countries such as South Africa and Zimbabwe. Local farmers cannot meet these needs because of many reasons, one of which is the arid and semi-arid nature of Botswana agricultural landscapes. These conditions include poor soil nutrition, unsuitable pH, high temperatures, low precipitation, and relative humidity, pests, weeds, and diseases. There needs to be updated ways to produce crops more efficiently and over a larger portion of the year. These crop production systems need to be efficient in terms of both yield production an cost of production. Under current systems, farmers fail to efficiently monitor their fields as it is both time and labour exhausting. This poses a problem as it leads to low crop yield. Crop fields are usually large, this hence calls for more labour and time, thus more costs for the farmers. This, in turn, leads farmers to neglect their fields, which causes low yield as a result. More innovative ways for farmers to monitor their crop production needs to be developed.

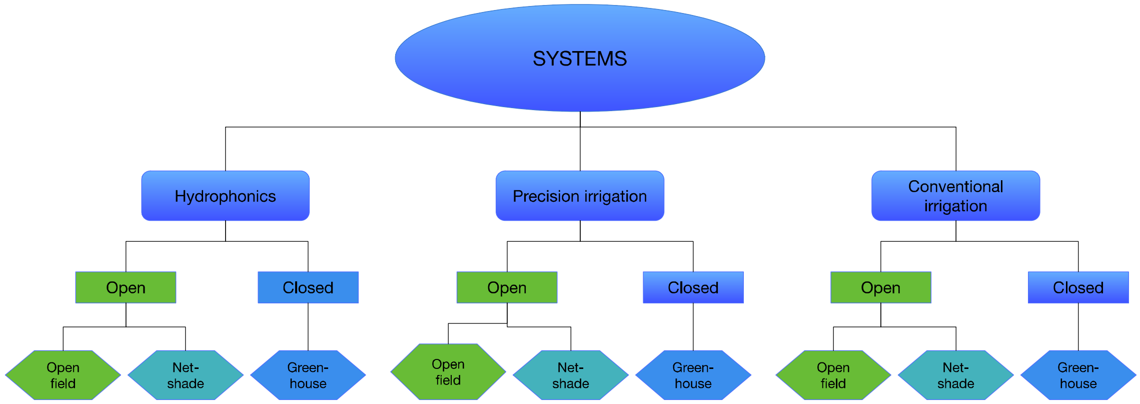
Objectives

1. To investigate the efficiency of different crop production systems under Botswana conditions.
2. To develop a SMART system to monitor and control these crop production systems.

PART III Project description

Experimental design

The experimental design will need to be divided into two settings; open setting and closed setting (see schematic diagram below). Under the open environment, we can use open fields and netshades. In the hydroponics system, the hydroponics setup may be placed in (i) an open field and (ii) in a netshades and/or (iii) reinforced transparent roofing shades. The closed hydroponics system will be in a greenhouse. Under the conventional approach, we will also have open and closed settings. These settings, under the conventional method, will be irrigated and supplemented with the standard amount of fertilizers, pesticides, and herbicides.



Parameters

The parameters to be measured will include the following;

a. Crop production attributes; e.g. percentage emergence, emergence time, rate of photosynthesis, respiration, transpiration, stomatal conductance, product biomass (yield), nutritional content, plant height, leaf length and other yield associated plant characteristics.
b. System parameters to be monitored and optimised for the different crops (through the use of a SMART system) will include nutrient solution levels, nutrients quality, pH, atmosphere conditions, light intensity, light duration (light/dark hours) and quality, dissolved oxygen levels, moisture, temperature, relative humidity, and others.
c. Cost efficiency in each system; the costs will be standardized to per kg of product

Crops used

A typical vegetable crop (e.g., spinach) will be ideal to use in testing these systems (We could use more). The crop monitoring system's main objective is to monitor/control conditions of the field and send feedback to the farmer, so they take the corrective measures (even after being done automatically). This will be done wirelessly hence solving the farmer time and money. The system will use microcontrollers allowing for IoT. Wi-Fi will be used to relay the data between the output devices and the microcontroller. The system will be monitoring four main conditions of the field; health of the crop, moisture, pH, and humidity. After recording these parameters, the system can decide the action based on the corrective measures installed, such as irrigation and fertilizer deployment. The microcontrollers will also be linked up to a motion sensor for antitheft purposes. In case they are removed or fallen out of place, the motion sensor will detect, and the farmer will be alerted.

In addition, through monitoring crop parameters, the system can also use crop conditions to identify needs to modify the growth environment to maximize yield. It may also be used to design improved growth protocols for different crops.

2.1 . Budget BWP3 094 000.00

Item	Estimated Cost
1. Growth space requirements • Land clearing 1 Ha (total space for open fields, net shades and a greenhouse) • Fencing of experimental space • Netshade construction	P50 000.00 P20 000.00 P120 000.00

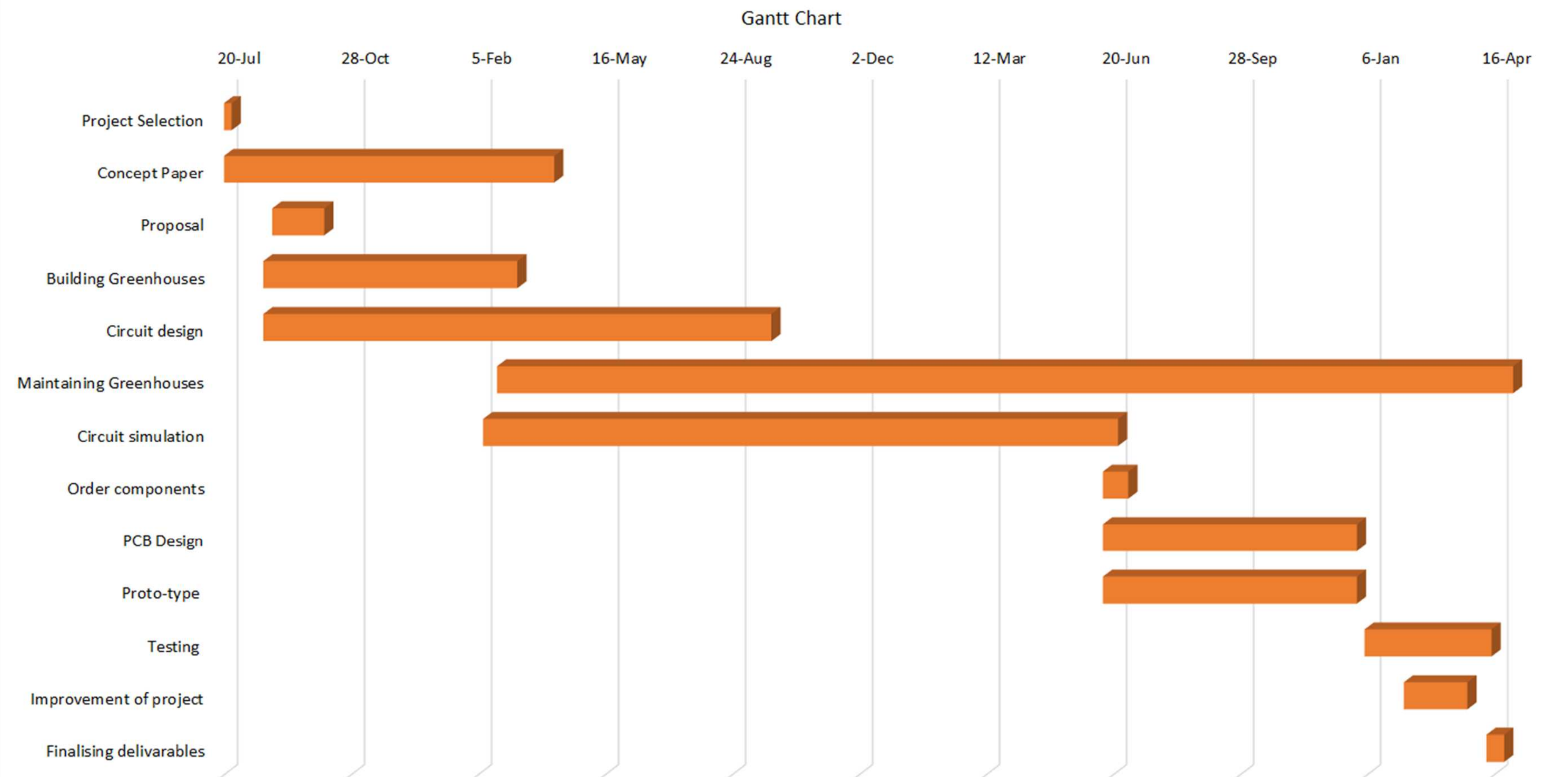
1.1.	Labor • Research Assistants (2) • Plant maintenance personel (2) • Labour costs for setting up and building the hydroponics system	 P336 000.00 P168 000.00 P100 000.00
1.1.	Equipment and Software • Greenhouse/growth rooms • Water containers, and irrigation systems for open settings • Development Kits and Software • Sensors (soil pH, moisture, temperature, and humidity) • Laptop computer	 P1 000 000.00
1.2.	Consumables • Seeds, ferlisers, herbicides, pesticides etc • Hydroponics consumables for the closed setting, rails, saws, drills, fittings, connectors, submersible pump, air pumps, drain system, seeds, fertilizers, pots, clay pebbles (hydroton), recirculation tanks, plumbing materials etc. • Hydroponics consumables for the open setting including rails, saws, drills, fittings, connectors, submersible pump, air pumps, draining system, seeds, fertilizers, pots, clay pebbles (hydroton), recirculation, tanks, plumbing materials etc.	 P100 000.00 P300 000. 00 P300 000.00
1.4.	Sample analysis • Nutritional content analysis	 P100 000.00
1.4.	Travelling Expenses • 2 Local Conferences (Flight, Accommodation, and Meals) • Data collection and bench marking travel	 P250 000.00 P200 000.00
1.5.	Printing Books, Photocopying, and Stationary	P50 000.00
	TOTAL	P3 094 000.00

Budget breakdown by year

Year 1 costs will include land clearing (P50 000.00), fencing (P20 000.00), construction of netshades (P120 000.00), labour for Research Assistants (P168 000.00), labour for plant maintenance personnel (P84 000.00), labour for building the hydroponic systems (P100 000.00), purchasing equipment and software (P1 000 000.00), Consumables (P650 000.00), sample analysis (P50 000.00), travel for data collection and bench marking (P200 000.00) and printing (or stationary) associated costs (P25 000.00). The total sum for year 1 is P2467 000.00.

Year 2 costs will include labour for Research Assistants (P168 000.00), labour for plant maintenance personnel (P84 000.00), consumables (P50 000.00), sample analysis (P50 000.00), local conference expenses (P250 000.00) and printing (or stationary) associated costs (P25 000.00). The total sum for year 2 is P627 000.00.

2.2 . Timelines (Gantt chart)



	Finalising delivarables	Improvement of project	Testing	Proto-type	PCB Design	Order components	Circuit simulation	Maintaining Greenhouses	Circuit design	Building Greenhouses	Proposal	Concept Paper	Project Selection
Start Date	10-Apr	4-Feb	4-Jan	12-Jun	12-Jun	12-Jun	9-Feb	20-Feb	20-Aug	20-Aug	27-Aug	15-Jul	20-Jul
Days to Complete	14	50	100	200	200	20	500	800	400	200	41	265	6

2.3 . Project Management (Team and roles)

Dr. N. Ditshego,	**Leader**
Dr G. Rantong,	**Deputy Leader**
Dr N. Ditshego, Prof. A. Zungeru, Dr. M. Mangwala, Dr. O. Matsebe, Prof. Yahya, Prof. Ravi Samikannu	**Supervisors, developing electronic side of the project**
Keene Osupile, and others to be engaged.	**Students working on the electronic side of the project**
Dr G. Rantong, Prof. Casper, Dr. P. Eliasson, Amare Gessesse,	**Supervisors working on the chemical, agricultural, biological side of the project.**

2.4 . Innovation/novelty

A cost and yield efficient combination of system and setting of crop production based on Botswana conditions. An in-depth analysis based on crop production systems that will be used to inform farming decisions for specific crops. A real-time crop monitoring system that will allow ease of farming to local farmers, thus increasing and optimizing their productivity rate and enabling us to be self-sufficient in terms of crop production supply. Besides, improved crop growth protocols will be determined for different crops and under specific conditions.

2.5 . Output

Our crop production system recommendations will be used to inform farming decision and maximise efficiency of production in terms of yield, crop quality and costs. In addition, the smart farming prototype produced will have easy-to-use interfaces that will enable the end-user to perform a wide range of tasks from the comfort of their home. The end-user will get up-to-date information about their agricultural lands and will be able to configure various environmental parameters (via the sensors), regulate the water flow, will have updated information on various fertilizers and the quality of various crops. Importantly, they need not worry about the underlying complexity of the hardware devices and their programming functionalities. They will have all the facilities available in the form of interfaces on their smartphones.

2.6 . Outcomes

- A detailed report on the different crop production systems indicating yield, crop quality and production costs
- Recommendations of optimal parameters specific to particular crops under local conditions. These crop growth protocols for different crops will be developed and availed to farmers and agriculture officers.
- Recommendations of production system for specific crops studied in the project
- The final version of our automated smart farming testbed readily available to the farmers, agriculture officers, and concerned authorities.
- Agriculture-as-a-service (AAAS) platform.

A real-time crop monitoring system that will allow ease of farming to local farmers, thus increasing and optimizing their productivity rate and enabling us to be self-sufficient in terms of crop production supply.

3. References

[1] Sharma et al. (2018). Hydroponics as an advanced technique for vegetable production: An overview, Journal of Soil and Water Conservation, 17, 364-371.

[2] Lavanya et al. (YEAR) Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115.

[3] Jovicich, E., Cantliffe, D.J. and Stoffella, P.J. 2003. Spanish pepper trellis system and high plant density can increase fruit yield, fruit quality and reduce labour in a hydroponic, passive-ventilated greenhouse. Acta Horticulturae 614: 255-262. Lenzi, A., Baldi, A. and Tesi, R. 2011.

[4] Maboko, M.M., Plooy, C.P. and Bertling, I. 2011. Comparative performance of tomato cultivars cultivated in two hydroponic production systems. South African Journal of Plant and Soil. 28(2): 97-102.

[5] Resh, H.M. 2013. Hydroponic Food Production: a Definitive Guidebook for the Advanced Home Gardener and the Commercial Hydroponic Grower. CRC Press, Boca Raton, FL.

[6] SOIL MOISTURE SENSOR. (2018). Retrieved from smart-prototyping.com: https://www.smart-prototyping.com/Soil-Hygrometer-Detection-Module-Soil-Moisture-Sensor-For-Arduino.html

[7] Temperature-and-humidity-DHT-sensors. (n.d.). Retrieved from arduino.cc: https://create.arduino.cc/projecthub/MisterBotBreak/how-to-use-temperature-and-humidity-dht-sensors-9e5975

[8] A, S. T., & Prasad, J. (n.d.). International Journal of Recent Trends in Engineering and Research, 254-255.

[9] Akash, A. B. (July 2017). International Journal of Innovative Research in Science, Vol. 6, Issue 7.

[10] Gabriela et al. (2018). Internet of things (IoT) applied to an urban garden. IEEE 6th International Conference on Future Internet of Things and Cloud.

[11] Mahendran et al. (2017). International Journal of Current Engineering and Scientific Research.

[12] Nuttakarn, K., Yosuke, K., Masahiro, I., Taketoshi, Y., & Shinichi, S. (n.d.). Internet of Things for Greenhouse Monitoring System Using.

[13] O.Pandithurai, S.Aishwarya, B.Aparna, & K.Kavitha. (2017). Agro-Tech: A Digital Model for Monitoring Soil and Crops Using Internet of Things (IoT). Third International Conference on Science Technology Engineering & Management (ICONSTEM), 343-345.

[14] Primo and Otto –(YEAR): https://www.techprevue.com/primo-otto-arduino-developer-board/

[15] Rubala, I., & Anitha, D. (2017). Journal of Engineering Science and Computing Volume 7 Issue No.3, 5218-5220.

[16] Vaishali, P., Sharmila, Anamika, K., & Ankit, R. (2019). Automation in Agriculture and IoT.

[17] Wankhade et al. (2016). International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering. Journal volume and page numbers v.