Educational Administration: Theory and Practice
2024, 30(9), 877-888
ISSN: 2148-2403
https://kuey.net/

Research Article

Agriculture Soil Testing And Nutrient Spraying Machine- An Inference With Esp-32 Wroom Microcontroller

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Citation: Anjana P. Mevada, et.al (2024), Comparative Studies Of Phytochemicals Of *Acacia Tortilis* Of Industrial And Non-Industrial Area Of Palanpur Taluka, Banaskantha, Gujarat, *Educational Administration: Theory and Practice*, 30(9) 877-888
Doi: 10.53555/kuey.v30i9.9657

ARTICLE INFO	**ABSTRACT**

The HPLC analysis and quantification of Quercetin in methanolic extracts of *Acacia tortilis* reveal the presence of this bioactive compound in significant concentrations. Utilizing Quercetin as a standard, the chromatographic results exhibit a distinct retention time (Rt) of 4.1 minutes and a peak area of 41540169, indicative of its abundance in Acacia species. A standard curve established for Quercetin demonstrates excellent linearity within the range of 200-1000 mg/spot, with a high correlation coefficient (r-value) of 0.9924, ensuring precise quantification. *Acacia tortilis* emerges as a notable reservoir of Quercetin, with the highest concentration detected in its leaf extract at 1045.8 µg/ml, followed by the pod extract at 494.41 µg/ml. Comparative analysis with *Leptadenia reticulata* validates the specificity of the HPLC method, emphasizing consistency in Quercetin retention times across different plant extracts. In addition to Quercetin, the presence of other flavonoids, including p-coumaric acid and Rutin, is quantified, enriching the flavonoid profile of *Acacia tortilis*. Reference to previous studies underscores the broader relevance of these findings within phytochemistry.

Keywords: HPLC analysis, Quercetin quantification, *Acacia tortilis*, flavonoid profile, methanolic.

Precision agriculture is a management philosophy or approach to farm operations, rather than a defined prescriptive system. It identifies factors limiting crop yield that can be controlled, and determines intrinsic spatial variability. It essentially enables more precise farm management through modern technology. Variations in crop or soil properties within a field are noted, mapped, and management actions are taken based on ongoing assessment of spatial variability within that field by adopting site-specific management systems using remote sensing, Global Positioning Systems, and geographical information systems. Precision agriculture requires specialized tools and resources to recognize inherent spatial variability associated with soil characteristics, crop growth, and to prescribe the most appropriate site-specific management strategy. It offers potential for significantly improved production efficiency.
Soil testing is of prime importance for improving yield, as soil fertility is the main factor influencing plant growth. The major macronutrients, such Nitrogen, Phosphorus, and Potassium, play a crucial role in providing nutrients that plants need. Fertilizers also enhance soil fertility and its ability to retain water. Both organic and inorganic fertilizers fall under the category of fertilizers.
Modern methods of soil testing involve taking soil samples from the field and testing them in the laboratory. However, this process requires more manpower, and the testing time is also extended, taking up to 15 to 20 days to get results. These methods cause delays in sowing, harvesting, and subsequent crop cycles. As a result, many farmers do not test the soil before sowing seeds, leading to an excess amount of nutrients stored in the soil, which can be toxic and eutrophication.
Historically, farmers couldn’t detect soil nutrients, manual nutrient spraying was time consuming and uneven. Our proposal addresses this, using NPK sensors for automatic nutrient testing and IoT- controlled sprayers for precise nutrient application, viewed through a mobile application.
The International Fertilizer Association (IFA) notes significant soil deficiencies (85 percentage of nitrogen, 73 percentage of phosphorus, 55 percentage of potassium).Fertilizers deepen roots, enhance water storage,

strengthen plant structures, and when combined effectively, yield high productivity. Precision farming maintains soil nutrients,pH, humidity, and temperature.
Several studies have evaluated the performance of various Agriculture soil testing and nutrient spraying machine designs.Saurabh Kadam *et al.*[42] in the journal "FABRICATION OF AUTOMATIC AGRICULTURAL FERTILIZERS SPRAYING MACHINE" concluded that this has been.Still, the sprayer machines available for the farm in the country are imported. Engine-driven sprayers are fast but the cost is high. Existing manually operated sprayers are inefficient so modification is required. If this concept is presented appropriately for the Indian market, it will assist in reducing the 15% modality rate observed in Indian formers, which is related to pollution. As for the 15% modality rate related to agricultural spraying operations seen in Indian farmers, it will help in reducing it.
Gaodi *et al.*[19]in the journal "DEVELOPMENT OF MULTIPURPOSE SPRAYER- A REVIEW" concluded that this study, Two types of sprays are commonly used in Indian agriculture: hand-operated and fuel-operated pumps. The main limitation of hand-operated spray pumps is that users cannot operate them continuously for more than 5-6 hours before fatigue sets in, whereas fuel-operated spray pumps require fuel which is expensive and not always readily available in rural areas. In such situations, alternative energy sources should be considered. This paper aims to develop a new mechanical system that would overcome these challenges and help farmers. Given the economic circumstances of farmers and the cost of labor, this equipment could provide value. The equipment is intended to perform three key agricultural operations in the fields: spraying pesticides, spraying herbicides, and applying urea fertilizer. Furthermore, current urea application methods result in high waste; our focus is on addressing that issue.
Narete et al.[46] concluded in their journal article "Design and Fabrication of Solar Operated Sprayer for Agriculture Purpose" that spraying pesticides is an important agricultural task for protecting crops from insects.Farmers mainly use hand or fuel-operated spray pumps for this job. Conventional sprayers can cause user fatigue due to their excessively bulky and heavy construction. Through this design, we can eliminate the back mounting of sprayers as it is not good for farmers' health from an ergonomic point of view during spraying, thereby reducing user fatigue levels. Thus, the solar-powered agricultural pesticide sprayer was fabricated according to the design parameters.
Kartik et al.[47] concluded in their journal article "SOIL NUTRIENTS ANALYSIS TECHNIQUES AND CROP/ FERTILIZERS PREDICTION- A REVIEW" that this study benefits both farmers and academics. The traditionally time- and cost-intensive chemical analysis method has given rise to numerous novel approaches to measuring soil characteristics thanks to technological improvements. The principle of maximum optical absorption of visible light by material in a particular frequency region due to the movement of electrons is applied to obtain information about critical soil nutrients i.e., NPK. The cost-effectiveness of determining soil properties is increasing due to advancements in MEMS technology. Digital image analysis with CNN is a noteworthy way to monitor already grown plants and predict the appropriate amount of fertilizer. Thus, the proportion of NPK nutrients contained in the soil may be more easily and affordably determined thanks to this study. AI technology has advanced by integrating with computer-aided precision agriculture services to obtain potent data mining capabilities. However, there are still certain problems, for example, numerous neural network training parameters are altered but there are no theoretical or practical frameworks to improve these models.
Hema Pallevada *et al.*[39]in the journal "REAL-TIME SOIL NUTRIENT DETECTION AND ANALYSIS" concluded that this study ,Farmers believe that higher fertilizer usage necessarily leads to greater productivity. However, this is not correct. The soil only utilizes the exact amount it needs and leaves the rest. Overutilization results in leaching and decreases the natural soil fertility, causing many problems. A potential solution is to allow farmers to test their lands and use fertilizer according to the soil's needs at an affordable cost. This report describes the design of a cost-efficient soil nutrient detection system using pre-prepared capsules. Farmers can now independently test their soil at a very low cost and then decide the type and quantity of fertilizer to use, ultimately leading to increased crop yields. The proposed system could be improved by adding the capability to test red soils. The system could also be improved by adding support for different crops suited to all soil types and nutrient availability levels in the soil.
Nitish Das *et al.*[16] in the journal "AGRICULTURAL FERTILIZERS AND PESTICIDES SPRAYERS"-a review concluded that in this study, Farmers are attracted to organic farming methods. Through mechanization of spraying devices and fertilizer/pesticide distribution, inputs can be applied evenly across fields, reducing waste and losses. This prevents the wasteful application of inputs and lowers production costs. Mechanization provides higher productivity with fewer inputs.In India, industrial sectors have developed more significantly compared to agricultural sectors. Conventionally, spraying is done manually by laborers carrying backpack sprayers and applying fertilizers by hand. This requires greater effort, especially for small landholders. To increase output from farms, mechanization is needed, as it provides higher productivity with lower inputs. Mechanizing allows farmers to reduce labor efforts while uniformly applying fertilizers and pesticides across entire fields. There remains a need for increased mechanization in India's agricultural industries.
Kenneth Solomonal *et al.*[3] in the journal "DROP SIZE DISTRIBUTIONS FOR IRRIGATION SPRAY NOZZLES" concluded that in this study, Drop size distributions for irrigation spray nozzles were characterized using a calibrated stain technique. A simple regression model was proposed to predict parameters of the upper

limit of the lower narrow range (ULLN) as functions of nozzle style, size and pressure for flooding and smooth flat plate spray nozzles.

The objectives of this work were to: review the literature regarding drop size distributions from irrigation spray nozzles, and summarize this information accessibly. The specific results presented here will be particularly informative for those working with irrigation spray nozzles. The analytical techniques described, of course, can be applied to any other available drop size data. The authors are currently involved in a similar project analyzing drop size data from various irrigation sprinkler sources. The regression model approach used here could potentially be improved with alternative functional forms.
In response to these challenges, engineers developed the engine-operated fertilizer spreader. This machine, powered by an efficient engine design, covers areas quickly and ensures even fertilizer distribution. Its fuel efficiency makes it cost effective while its sturdy construction requires minimal maintenance. The spreader is adaptable to farms of various sizes, significantly reducing the need for labor.

MATERIALS AND METHODS

The agriculture soil testing and nutrient spraying machine has the following components.
- Steel frame
- 3 tanks (35L capacity)
- 12V Diaphragm Pump
- Pipes
- Wiper motor
- Sprayer
- 12V Batteries
- 12V Power Relay
- ESP 32 WROOM micro controller
- NPK sensor
- Power Window Motor
- IC Converter
- Digger

STEEL FRAME

A steel frame is a structural component commonly used in various machines and equipment to provide support, stability, and strength. Steel is a preferred material for frames in many applications due to its high strength, durability, and resistance to deformation. The steel frame is the important framework of the machine as it holds all the other components of the machine. The other components such as tank, motor, pump, pipes, wheels etc., are attached to the steel frame. The steel frame is made up of aluminium metal, specifically an aluminium frame, offers many advantages, including its lightweight nature, corrosion resistance, and versatility in various applications.

Specifications:

TABLE 1.1 SPECIFICATIONS OF STEEL FRAME

Outer Sheet	0.8 mm
Inner pipe material	1.2 mm

35 L TANK

The tanks are fitted on the steel frame. Three tanks are fitted one next to the other. Each tank is of 35L capacity. Individual tanks are placed for nitrogen, phosphorus, and potassium. Tank is made up of plastic material. The tank is made of high-density polyethylene (HDPE) or other suitable plastic materials. HDPE is commonly used due to its resistance to corrosion, durability, and compatibility with various chemical solutions, including fertilizers and nutrients.

DIAPHRAGM PUMP

A diaphragm pump is a type of positive displacement pump used to move fluids by means of a flexible diaphragm, which expands and contracts to create pressure variations that draw in and expel the fluid. Positive displacement pumps are commonly utilized across numerous industrial sectors due to their capacity to transfer various fluid types and deliver dependable and effective performance.The diaphragm pump which is connected to the tank is used to suck nutrients from the tank. These pumps are fitted individually for each tank. These pumps are used to flow the nutrients from the tank. This pump sucks nutrients from the tank and makes it flow through the sprayer.

Specifications:

TABLE 1.2 SPECIFICATIONS OF DIAPHRAGM PUMP

Pump Capacity	4.5 lit/min

PIPES

A pipe is a tubular, hollow, or cylindrical conduit or channel that is used to transport fluids, gasses, or granular materials from one location to another. Pipes come in various materials, shapes, and sizes, and they serve a wide range of purposes in various industries and applications. Polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC), polyethylene (PE), and cross-linked polyethylene (PEX) are plastic materials commonly used for piping applications.They are lightweight, corrosion-resistant, and often used in plumbing and irrigation.

TABLE 1.3 SPECIFICATIONS OF PIPES

Material	Polyurethane

WIPER MOTOR

A wiper motor is a key component in automotive and other applications where it is used to control the motion of windshield wipers. Its primary purpose is to move the wiper arms back and forth across the windshield to remove rain, snow, or debris. The wiper motor is used for the rotational movement and turning of the wheels. When electrical power is supplied to the motor, it starts to rotate. The motor's rotational motion is converted into reciprocating (back and forth) motion by the linkage mechanism. It is also used for all the rotational movements. It is used to rotate rods and wheels.The wiper motor is connected to the worm gear mechanism that transmits force to facilitate rotational movement.

Specifications:

TABLE 1.4 SPECIFICATIONS OF WIPER MOTOR

Motor	60 rpm
Voltage	12 V
Torque	50 kg/cm

SPRAYER

The "5 Holes Speaker Nozzle" is a component used in certain sprayers. It combines sprayer technology with a nozzle that has five holes for dispersing liquid. The "speaker" description may indicate a design ensuring even liquid distribution like speakers disperse sound. This nozzle could benefit gardening, agriculture or cleaning needing precise, uniform liquid dispersion. The battery power offers convenience and portability operating without a continuous power source. In summary, the "Battery Sprayer 5 Holes Speaker Nozzle" innovates sprayer design for efficiency and user experience in various spraying tasks.

Specifications:

TABLE 1.5 SPECIFICATIONS OF SPRAYER

Type of sprayer	Pump sprayer
Material composition	Durable plastic
Pressure	30 psi

12V BATTERIES

A 12V battery is a type of rechargeable battery that provides electrical power at a voltage of approximately 12 volts. These batteries are commonly used in a wide range of applications, from automotive use to powering various devices and systems.The batteries are provided to supply power to the motor and other sources for the operation of the machine components.As the power of the battery decreases, the speed and efficiency of the machine also decreases. This battery can be added upto 24V and more efficiency can be obtained.

Specifications:

TABLE 1.6 SPECIFICATIONS OF 12V BATTERIES

Battery Type	Lead-Acid Battery
Capacity	12 AH

12V POWER RELAY

A power relay is an electrical component used to control the flow of electrical power within an electrical circuit. It is an electromagnetic switch that can handle high currents or voltages, making it an essential part of various electrical and electronic systems. The power relay is used to control the high voltage, high current load in motors, solenoid valves and AC loads. It interfaces with ESP32-WROOM micro controller, IoT and microcontroller. Each movement of the machine such as forward, backward, turning etc., are operated by the relay module using the IoT components.

ESP32-WROOM CONTROLLER

The ESP32-WROOM is a versatile Wi-Fi module developed by Espressif Systems. It features a dual-core processor for efficient multitasking and integrated support for 802.11 b/g/n Wi-Fi and Bluetooth 4.2/BLE connectivity. An integrated antenna is also included. Its GPIO pins, low power consumption, and compatibility with development platforms like Arduino IDE and ESP-IDF make it well-suited for a wide range of Internet of Things and embedded systems applications.The module supports interfaces such as SPI, I2C, UART, PWM, and ADC, providing flexibility for connecting various sensors and peripherals. Security features like secure boot and flash encryption enhance its reliability, and it allows for Over-The-Air (OTA) updates for remote firmware updates. With widespread use in IoT applications, the ESP32-WROOM module is known for its programmability, energy efficiency, and ease of integration into diverse projects.

NPK SENSOR

NPK sensors serve as specialized detection tools in agriculture and horticulture settings. They are utilized to quantify concentrations of critical soil nutrients, namely nitrogen, phosphorus, and potassium. These macronutrients represent vital components for plant growth and development, with their soil levels markedly influencing crop health and output. NPK sensors deliver real-time data surrounding nutrient amounts, empowering farmers and cultivators to make educated choices pertaining to fertilization and nutrient administration. The device is employed to ascertain the quantity of elements like nitrogen, phosphorus, and potassium present in the soil when the probe is immersed in the medium.These nutrients are the major nutrients that should be present in the soil for better growth of the plants. The NPK sensor senses the nutrients which are connected to the IoT module and then connected to the mobile application to view the nutrient content.

POWER WINDOW MOTOR

The power window motor was originally designed for automotive power windows. However, in recent years robotics engineers and builders have increasingly utilized this motor type in robot designs, especially for combat robots given its performance capabilities and competitive pricing. The default motor configuration may not be ideally suited for external attachment of parts. We recommend considering models of the power window motor that include a coupling mechanism to facilitate integration. Additionally, take note that the motor housing is asymmetric, with options for left or right-sided output shafts. Be certain to select the appropriate variant to suit your design prior to purchase.

Specifications:

TABLE 1.7 SPECIFICATIONS OF POWER WINDOW MOTOR

Speed (rpm)	30
Torque (kg/cm)	25

IC CONVERTER

The IC converter is used to convert the RS485 module to RS232. This is done so because the sensor communication is RS485 but the IoT module communication is RS232. So, to convert the communication signals of the sensor this IC converter is used. The sensor is connected in the IC converter and the values of the nutrients in the soil are sensed.

DIGGER

A digger, also known as an excavator, is a heavy construction machine used for digging, moving, and lifting large quantities of materials, such as soil, rocks, debris, and other materials at construction sites, mines, and other earthmoving operations.Excavators are versatile equipment utilized in construction and excavation. They are available in a variety of sizes and configurations tailored to meet specialized needs. It is a common practice in various industries and applications. Diggers such as excavators, are heavy machinery designed to dig, scoop, and move earth efficiently, When it comes to placing sensors in the ground.

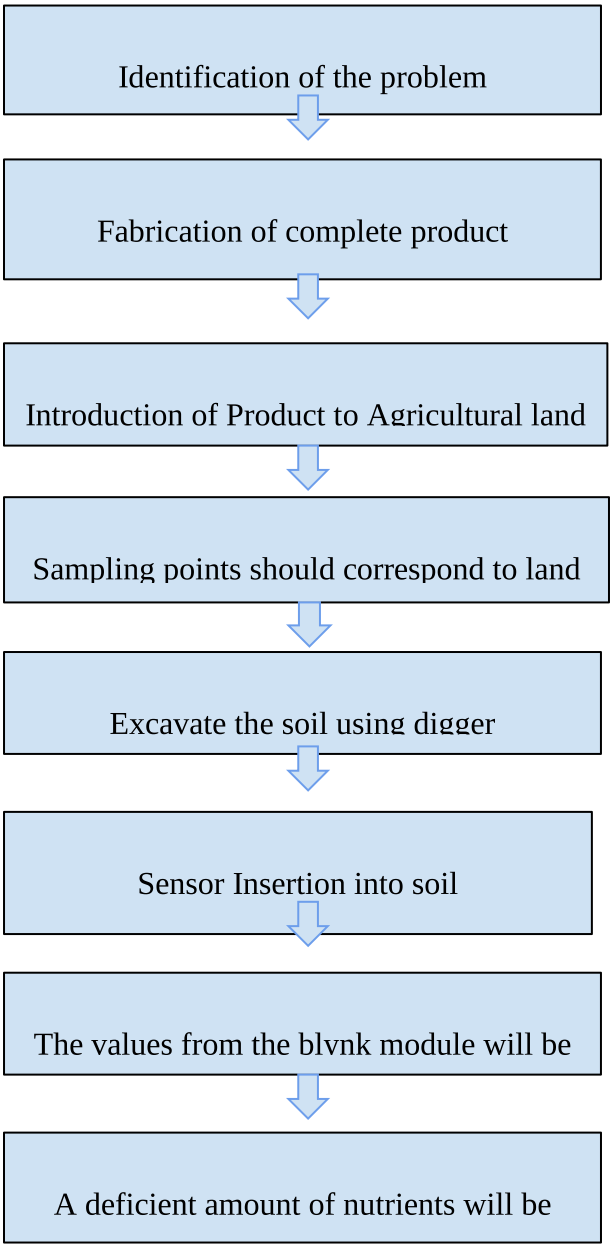

Fig 1.1 Methodology

RESULT AND DISCUSSION

We conducted soil testing on our experimental plot. As advised by Dr.S.Thiyageswari is a professor in the Department of Soil Science and Agricultural Chemistry at Tamil Nadu At the Agriculture University in Coimbatore, India, samples were collected from 10-12 points per hectare of the test plot of land. The selected plot measured 54 feet in length by 36 feet in width, totaling 1,944 square feet or approximately 0.44 cents.
To test our machine, we fixed 5 sample points within the plot to analyze macronutrient content. At each point, we dug down approximately 6-8 centimeters using a small digging tool. Then we inserted our NPK sensor into the dug soil to obtain readings from that location.
More testing will be required across varying conditions to thoroughly evaluate machine performance. Additional notes on results will be recorded after data analysis is complete.
mg/kg - represents 1 milligram of nutrient in the 1 kilogram of soil.

No of Sample	Nitrogen (mg/kg)	Phosphorous (mg/kg)	Potassium (mg/kg)
S 1	17	82	99
S 2	27	95	93
S 3	14	83	94
S 4	29	94	96
S 5	18	96	93
Average	21	80	79

Field Calculation:

Nutrient	Low	Medium	High
Organic carbon	< 0.5 %	0.5 - 7.5%	> 0.75%
Available nitrogen (N)	< 240Kg/ha	240- 480kg/ha	> 480Kg/ha
Available Phosphorus (P)	< 11.0 Kg/ha	11 – 22 Kg/ha	> 22 Kg/ha
Available potassium (K)	< 110Kg/ha	110-280Kg/ha	> 280Kg/ha

Source:https://agritech.tnau.ac.in/agriculture/agri_soil_soilratingchart.html

1.Nitrogen(N)
Average(N) = 21 mg/kg
1 ha = 10000 m^2
Depth = 8cm = 0.08m
Volume of soil,V = 10000m^2 x 0.08m
V = 800 m^3
Bulk density for Sandy Loamy Soil
= 1.2 g/cm^3
= 1200 kg/m^3
m(mass of soil) = 800m^3 x 1200 kg/m^3
= 9600000 kg
N content in soil = 21 mg/kg
Total N content in kg/ha
= 960000 kg x 21 mg/kg
= 20160000 mg
= 21840000/100000
= 201.6 kg / ha.
At less than 201.6 kg/ha, the nitrogen content of the soil appears to be low.

2.Phosphorus(P)
Average(P) = 80 mg/kg
1 ha = 10000 m^2
Depth = 8cm = 0.08m
Volume of soil,V = 10000m^2 x 0.08m
V = 800 m^3
Bulk density for Sandy Loamy Soil
= 1.2 g/cm^3
= 1200 kg/m^3
m(mass of soil) = 800m^3 x 1200 kg/m^3
= 960000 kg
N content in soil = 80 mg/kg
Total N content in kg/ha
= 960000 kg x 80 mg/kg
= 76800000 mg
= 76800000/100000
= 768 kg / ha.
At greater than 768 kg/ha, the phosphorus content of the soil appears to be high.

3.Potassium(K)
Average(K) = 79 mg/kg
1 ha = 10000 m^2
Depth = 8cm = 0.08m
Volume of soil,V = 10000m^2 x 0.08m
V = 800 m^3
Bulk density for Sandy Loamy Soil
= 1.2 g/cm^3
= 1200 kg/m^3
m(mass of soil) = 800m^3 x 1200 kg/m^3
= 960000 kg
N content in soil = 79 mg/kg

Total N content in kg/ha
= 960000 kg x 79 mg/kg
= 75840000 mg
= 75840000/100000
= 758.4 kg / ha.
At greater than 758.4 kg/ha, the potassium content of the soil appears to be high.

Comparison of Data Values Obtained from a Device with TNAU Data:
Acquired data from the device:

Nitrogen(kg/ha)	Phosphorus(kg/ha)	Potassium(kg/ha)
201.6(Low)	768(High)	758.4(High)

Soil test result data obtained from TNAU:

Available N	192 kg ha^{-1}	Low
Available P (Olsen's)	752 kg ha^{-1}	High
Available K	745 kg ha^{-1}	High

The values obtained from the device and TNAU were in **close proximity to one another.** Based on both reports, it can be concluded that the nitrogen level was low, the phosphorus level was high, and the potassium level was high.

Time Management:
Our technology has advanced beyond all traditional approaches. Resource allocation is exclusively dedicated to this initiative. As we understand the requirements, some sample points must be analyzed at specific depths. We have already determined the time needed to excavate soil to a depth of 6-8 cm and insert NPK sensors, which typically takes 5-6 minutes per data collection operation. As recommended, approximately 15-20 sampling locations should be examined per hectare to sufficiently map soil nutrients.

Time Calculation:
Time Estimates for Soil Sampling of a One Acre Plot One acre plot equals 43560 square feet in area.Sample collection will involve taking measurements at 20 individual sample points across the acre.Based on prior experience, it takes approximately to complete the sampling process at each point.
The total estimated time to collect samples from all 20 points on the one acre plot Estimated time= 20 x 6 mins Estimated time = 120 mins
An IoT-based automated soil assessment and nutrient supplementation system was presented. The system aims to enhance efficiency, sustainability and data-driven decision making in agriculture through real-time soil monitoring and mobile control.
The overall goal is to address challenges with manual soil testing and nutrient application using an automated IoT approach. Sensors, motors, wheels and an embedded system seek to streamline processes and reduce human intervention. However, more evaluation of accuracy, efficiency and cost versus manual methods is needed for a comprehensive assessment.

Initial soil testing of an experimental plot found average macronutrient levels of nitrogen at 21 mg/kg, phosphorus at 80 mg/kg, and potassium at 79 mg/kg. These values from five sample points within a 1,944 square foot area suggest nutrient variation and emphasize precision importance in supplementation.

Time savings for soil sampling was also demonstrated, with an estimated 120 minute reduction to sample 20 points on one acre compared to traditional methods. Further considerations include accurate sampling depths and varying condition impacts.
Agriculture Soil testing and nutrient spraying machine figure is given in figure 2.

CONCLUSION

The use of IoT allows for data collection and analysis to help farmers make more informed nutrient application decisions. By analyzing weather, soil moisture, and other environmental data, farmers can optimize timing and frequency of application for more precise and efficient results. Integrating an ESP32 microcontroller and IoT into a soil testing and spraying machine significantly advances precision farming practices. Enabling targeted, efficient application allows maximizing crop yields while reducing environmental impacts. IoT also enables further advances like machine learning and AI to further enhance efficiency and effectiveness.

Demand for agricultural products has grown with population, requiring improved output efficiency. While new machinery developments continually occur, technology has not significantly altered farm operations. Automation has greatly increased production, preparation, and other agricultural capabilities. This also reduces labor impacts on agriculture. With a futuristic vision, this approach's potential breadth increases.

Besides conventional 15-20 day soil sampling and laboratory testing, this method allows easy, immediate nutrient testing. It automatically sprays deficient nutrients, reducing testing time to half a day compared to earlier methods. It displays on-screen nutrient content and sprays below-requirement nutrients. This project focuses on soil nutrient content.

Initial soil testing of an experimental plot revealed average macronutrient levels of nitrogen at 21 mg/kg, phosphorus at 80 mg/kg, and potassium at 79 mg/kg. These values were derived from five sample points within a 1,944 square foot area, suggesting potential nutrient variation across the plot and emphasizing the importance of precision in supplementation.Time savings for soil sampling was also demonstrated, with an estimated reduction from 120 minutes to sample 20 points on one acre compared to traditional methods. Further considerations include accurate sampling depths and varying condition impacts. The 0.95 m/s revolution speed calculation provides operational insight but requiring more discussion on significance to soil sampling and nutrient application performance.

Detailed nitrogen, phosphorus and potassium content analysis revealed valuable insights, such as low nitrogen below 240 kg/ha but relatively high phosphorus and potassium exceeding benchmarks. These findings indicate targeted nutrient adjustment opportunities to optimize soil health.

In conclusion, the presented IoT-driven automated soil assessment and nutrient supplementation system represents significant progress in advancing agricultural practices. Real-time soil monitoring and mobile control addresses limitations of manual testing and nutrient application. Initial tests revealed promising results in terms of nutrient variations and time efficiency. However, a comprehensive evaluation of accuracy, efficiency, and cost-effectiveness compared to conventional methods is imperative for broader adoption. Integrated components including wheels, motors, sensors, and an embedded system show potential to minimize human intervention. Operational insights from revolution speed calculation hint at system performance warranting further discussion. Detailed nutrient analysis identifies targeted adjustment opportunities for optimizing soil health. Ongoing research and comparative studies will be crucial as the system evolves to validate efficacy and ensure integration into diverse agricultural landscapes.

FIGURE 1.2 : FINAL PROTOTYPE

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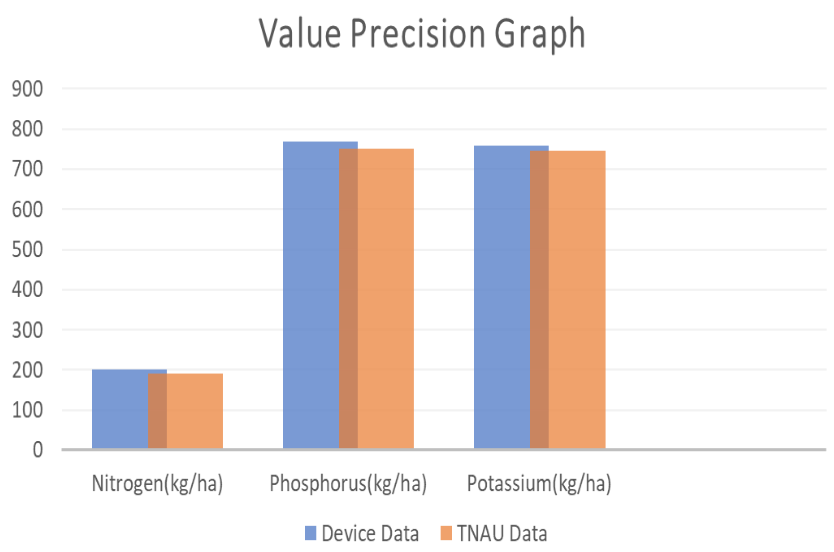
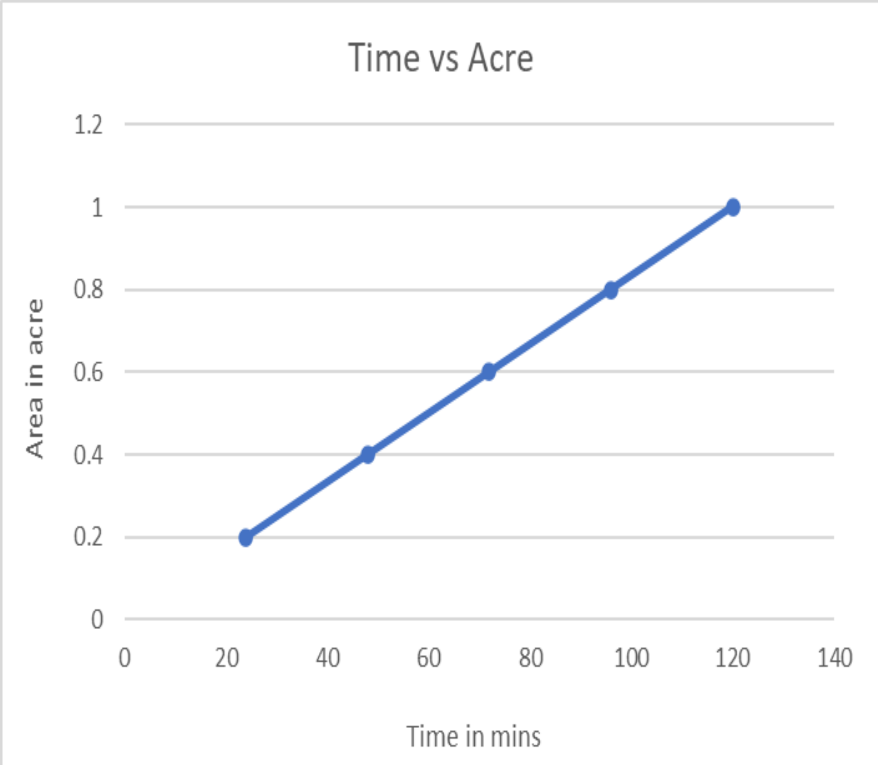


Comparison of Device Data with TNAU Data:



Time Estimates for Soil Sampling