JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

PGM: Plant Growth Monitoring using Machine Learning Algorithms

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Abstract: - We propose a novel approach that utilize machine learning algorithm for plant growth monitoring that enables real-time analysis and optimization, fostering sustainable agriculture practices. Machine learning algorithms can analyze data with high precision, detecting subtle changes in plant growth that might be missed by human observation or basic sensors. This leads to more accurate monitoring and better-informed decisions. Machine learning models can continuously learn and improve over time as they are fed with more data. Convolutional Neural Networks (CNN) are employed for image analysis. Plant dimension such as height and width measurements are captured. This leads to increasingly accurate predictions and insights into plant growth dynamics. Overall, the integration of machine learning technology into plant growth monitoring offers significant improvements in efficiency, accuracy, and decision-making, ultimately leading to better plant health and increased agricultural productivity.

Index terms: - Automated monitoring, Crop monitoring, Leaf area index, Precision agriculture, Smart agriculture.

I. Introduction

India's agriculture has its own history. If we check the statistics of worlds' country, we can say that India ranks second in farm output. 13.7% of the GDP (Gross Domestic Product) was accounted for agriculture and allied sectors in 2013; about 50% of the workforce depends on farming. The contribution of agriculture to India's GDP is steadily decreasing with the countries less attention over farmers. Still agriculture is the broadest sector and plays a significant role in the overall social fabric of India.

Some of the crops of specific season are not able to get required climatic conditions due to uncertain change in our environment due to greenhouse effect. Some of the Industries are polluting rivers by ejecting harmful chemicals in it. Some horticultural plants don't grow due to insufficient watering and some due to insufficient temperature and etc. Green house is one and only solution against uncertain climate change or global warming. Green house helps our farmers to create an artificial environment for maintaining required temperature, humidity and light. Today Greenhouse systems are available in market as user desires it to work like. But the problem is user has to observe it continuously to check whether it is working properly or not.

The system has a network of soil moisture sensor and a temperature sensor placed in the root zone of the plants. A microcontroller handles sensor information; triggers pump and transmit data to the Arduino. An algorithm was developed with threshold values of temperature and soil moisture that was programmed into a microcontroller to control water quantity. This unit is powered by photovoltaic panels and has a communication with the Arduino.

1.1 Motivation

The motivation behind this innovation lies in its potential to revolutionize agriculture by optimizing resource utilization, reducing environmental impact, and increasing crop yields. With precise monitoring and analysis, farmers can make informed decisions, such as adjusting irrigation schedules or applying fertilizers, leading to healthier plants and higher productivity.

1.2 Contributions

Plant growth monitoring using IoT and machine learning has revolutionized agriculture by providing real-time insights into plant health and environmental conditions. IoT sensors placed in the soil measure parameters such as moisture levels, temperature, and nutrient content, while sensors above ground monitor factors like light intensity and humidity. These data are then transmitted to a centralized system for analysis. Machine learning algorithms analyze the data to detect patterns, predict plant growth, and diagnose any potential issues such as diseases or nutrient deficiencies.

1.3 Organization of Paper

This report is divided primarily into six sections, and each component gives a thorough or succinct summary of the project. The five divisions listed are: Introduction - This section gives you an overview of the project, a description of the principal issue being addressed, the project's objectives, the methods we'll be using to carry them out, and information on the remaining sections of the report. Related Work - This section includes prior research on this issue and its drawbacks. System Requirement SRS - Information on the project's functional and non-functional needs is provided in the specification section. System Design - This provides insight into the potential results. Results- What advantages do the technique or framework being created have over the one that is currently in use, and information about. System Implementation-This section discussions about system implementation are typically found in the methodology or implementation sections. These sections provide detailed insights into how the proposed system or research work is practically carried out and put into operation. Result and analysis section is a critical component that presents the outcomes of the research or project work. This section is where the data collected during experimentation or implementation is detailed, and the findings are analyzed and interpreted.

II Related Work

Timely and accurate prediction of rice yield information is closely related to the people's livelihood, which has been attached great importance by all levels of government [1]. Satellite remote sensing provides the possibility for large-scale crop yield estimation, but they are usually limited by spatial and spectral resolution. Unmanned Aerial Vehicles (UAV) remote sensing with hyperspectral sensors can obtain high spatial temporal resolution and hyperspectral images on demand. Generally, time-series Vegetation Indices (VIs) are used for estimating grain yield.

Crop yield prediction has been a significant area of research in [2] agricultural sciences. Various techniques have been employed to forecast crop yields, ranging from statistical models to machine learning algorithms. Traditional methods include linear regression, time series analysis, and expert-based systems. More recently, researchers have explored the application of advanced machine learning techniques such as neural networks, support vector machines, and Bayesian networks

India being an agriculture country, its economy predominantly depends on agriculture yield growth and agroindustry products [3]. Data Mining is an emerging research field in crop yield analysis. Yield prediction is a very important issue in agricultural.

Agriculture is the principal source of livelihood for more than 40 percent of the population of this state. According to Food and Agricultural [4] Organization (FAO)researchers, between 2010 and 2050 the world population will increase by one third. The demand for crop production will increase by 60% higher than the current production. Hence prediction plays a major role to find out the demand of crop production for maximizing the yield. For that in this paper we propose a prediction method for the major crops of Tamil Nadu using K-means and Modified K Nearest Neighbor (KNN). MATLAB and WEKA are used as the tool for clustering and classification respectively. The number result shows that our method is better than traditional data mining approach.

Food production in India is largely dependent on cereal crops including rice, wheat and various pulses [5]. The sustainability and productivity of rice growing areas is dependent on suitable climatic conditions. Variability in seasonal climate conditions can have detrimental effect, with incidents of drought reducing production. Developing better techniques to predict crop productivity in different climatic conditions can assist farmer and other stakeholders in better decision making in terms of agronomy and crop choice.

However, most prediction models are statistical-based thus are not suitable for regional application, and remote sensing-based models lacked predictability [6]. We presented a framework that assimilated leaf area index (LAI) derived from Moderate Resolution Imaging Spectro radiometer (MODIS) into World Food Studies (WOFOST) crop growth model, and forecast meteorological data from THORPEX Interactive Grand Global Ensemble (TIGGE) was used as weather data input for the future periods.

In the context of Industry 4.0, which focuses on the integration of advanced technologies and automation in various industries, a distributed soil-less food production system can leverage these concepts for future enhancements. Such a system combines [7] precision agriculture, hydroponics, vertical farming, and IoT (Internet of Things) technologies to create a sustainable and efficient method of growing food.

Early methods for crop yield prediction relied on statistical models, weather-based models, and historical data analysis. These methods often faced limitations in accurately capturing complex relationships between various factors influencing crop yields [8].

In summary, the related work in crop yield prediction using data mining techniques has seen significant advancements, encompassing a wide array of methods ranging from traditional statistical approaches to sophisticated machine learning algorithms. [9] By harnessing the power of data, researchers aim to revolutionize agricultural practices, mitigate risks, and ensure sustainable food production for the future.

Moreover, [10] ensemble learning techniques such as gradient boosting and stacking have been utilized to combine predictions from multiple models, further improving the accuracy and generalization performance of crop yield prediction models. Additionally, advancements in data preprocessing techniques, feature selection, and model evaluation methods have contributed to enhancing the reliability and effectiveness of crop yield prediction using data mining approaches.

The related to the challenges and issues faced by farmers in implementing smart farming technologies. The questionnaire should also include questions related to the [11] benefits and advantages of smart farming technologies.

This methodology which can help farmers, researchers, and policymakers to better understand the potential benefits and limitations of IoT technologies in agriculture. [12] This methodology which can help farmers, researchers, and policymakers to better understand the potential benefits and limitations of IoT technologies in agriculture.

One approach to addressing this issue is by using a Field Programmable Gate Array (FPGA) platform and the Internet of Things (IoT) communication methodology [13] The use of an FPGA platform and IoT communication could potentially improve the accuracy and efficiency of data analysis and modeling in an agricultural labor market equilibrium study.

In related work, the use of deep convolutional neural networks (CNNs) for ImageNet classification has been extensively studied. The seminal work of Kievsky et al. (2012) demonstrated the effectiveness of CNNs in large-scale image recognition tasks by achieving a significant improvement in classification accuracy on the ImageNet dataset [14].

Keep in mind that this is a general outline based on common practices in the field of precision agriculture and remote sensing. To get a precise summary of the [15] specific method you mentioned, I recommend looking for the latest research papers or articles in the field or consulting a relevant expert or source in the area of precision agriculture and soil moisture mapping.

In the realm of agricultural technology, several [16] systems have been developed to assist farmers in making informed decisions about crop selection. One notable approach is the demand-based crop recommender system, which considers market demand as a crucial factor in suggesting suitable crops to farmers.

In the related work of agricultural data analysis, researchers [17] have employed various data mining techniques to extract valuable insights from agricultural datasets. One prevalent approach is the use of machine learning algorithms to predict crop yields based on factors such as weather patterns, soil quality, and crop types.

In another research effort, Li et al. proposed a similar approach leveraging Hadoop and random forest for crop yield prediction. They introduced optimization techniques to enhance the performance of the random forest algorithm within the Hadoop framework, achieving better prediction accuracy compared [18] to traditional methods. Their study highlighted the potential of distributed computing and machine learning in addressing challenges associated with crop yield prediction.

Recent studies have also explored techniques such as multi-instance learning and metric learning to handle fine-grained datasets with limited annotated samples, further enhancing the generalization and robustness of deep learning models in this domain [19]. Despite these advancements, challenges such as data scarcity, class imbalance, and domain shift remain open research problems, driving ongoing efforts to push the boundaries of fine-grained image analysis with deep learning.

In recent years, precision agriculture has gained significant attention due to its potential to enhance agricultural productivity while minimizing resource waste. One critical aspect of precision agriculture [20] is accurate soil moisture mapping, which enables farmers to optimize irrigation strategies and improve crop yields. Remote sensing technologies offer a means to obtain timely and comprehensive data on soil moisture levels across large agricultural landscapes. However, the efficient sharing and processing of these remote sensing observations pose challenges that can be effectively addressed through cloud computing solutions.

One key aspect of such systems involves the use of advanced imaging techniques to capture high-resolution 3D images of plants. This can be achieved through technologies such as structured light, stereo vision, or depth sensors like LiDAR [21]. These images are then processed using computer vision algorithms to extract precise measurements of various plant parameters such as height, volume, leaf area, and biomass.

III Proposed Work

3.1 Problem Statement

In the case of traditional irrigation system water saving is not considered. Since, the water is irrigated directly in the land, plants under go high stress from variation in soil moisture, therefore plant appearance is reduced. The absence of automatic controlling of the system results in improper water control system. The major reason for these limitations is the growth of population which is increasing at a faster rate.

At present there is emerging global water crisis where managing scarcity of water has become a serious job. This growth can be seen in countries which have shortage of water resources and are economically poor. So, this is the serious problem in agriculture area. So, we want to design a Smart Irrigation System using Arduino microcontroller and Modules that operate automatically by humidity, type of plant and sensing the moisture content of the soil and turn ON/OFF the pump without the intervention of farmer and hence save water.

This system is a combination of hardware and software components. The hardware part consists of different sensors like soil moisture sensor, photocell sensor, etc. whereas the software part consists of an android based application connected to the Arduino board and other hardware components. The application consists of signals and a database in which readings are displayed from sensors and are inserted using the hardware. The improvement in irrigation system using wireless network is a solution to achieve water conservation as well as improvement in irrigation process. This research tries to automate the process of irrigation on the farmland by monitoring the soil water level of the soil relative to the plant being cultivated and the adaptively sprinkling water to simulate the effect of rainfall.

3.2 Dataset Descriptions

This opens a wide possibility to drive plant growth process in the most useful direction. Totally, we obtained 44112 measurements of the leaf area projection. It should be noted that estimation of the leaf area was done by measuring its maximum projection which, in general, may not be equal to the real leaf area. However, these measurements also can give us additional information about the hidden dynamics of the plant growth. For example, we can observe diurnal fluctuations in the relative leaves positions in caused by biological processes. This additional information can be included into the predictive model making it more precise. As we do not use the classical statistical methods, we can directly use our data as an input to our NN without error.

Figure 1: **In this process, we capture the dimensions of the plant through height and width measurements.**

In Figure 1 shows capturing plant dimensions through height and width measurements plays a crucial role in various applications, providing valuable information for plant monitoring, research, and management. Whether performed manually or automated, these measurements contribute to a better understanding of plant growth, health, and performance in diverse environments.

3.3 Proposed Architecture

Proposed architecture is shown in figure 2.

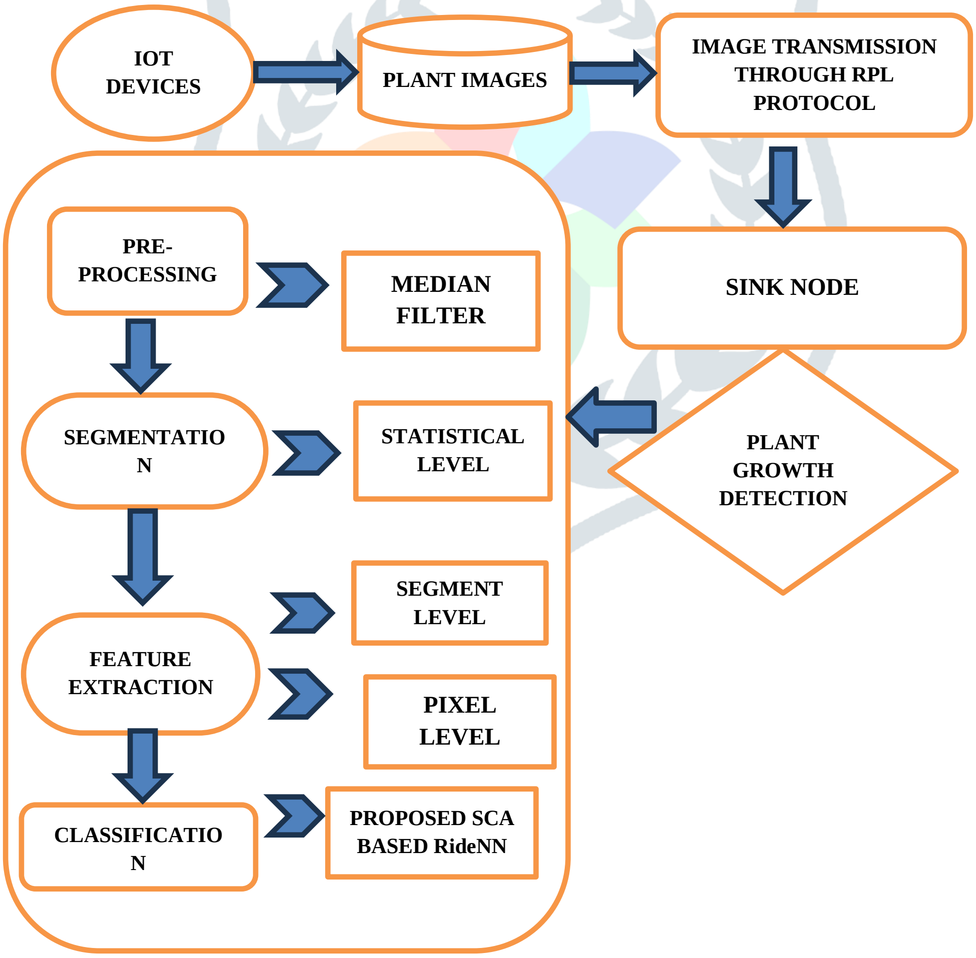


Figure 2: Proposed Architecture

3.3.1 Data Acquisition: The system collects multi-modal data from the agricultural field using ground-based IoT sensors and aerial drones equipped with high-resolution cameras. IoT sensors capture environmental parameters such as soil moisture, humidity, temperature, and light intensity, providing crucial insights into the growing conditions of the wheat crop. Simultaneously, aerial drones capture images of the crop canopy, allowing for detailed visual analysis of individual plants and leaves.

3.3.2 Data Preprocessing: Raw data collected from IoT sensors and drones undergoes preprocessing to clean, standardize, and augment it for analysis. This preprocessing step involves data cleaning to remove outliers and inconsistencies, normalization to standardize feature scales, and augmentation to enhance the diversity of the dataset. Additionally, data fusion techniques may be employed to integrate information from different sources into a unified dataset.

3.3.3 Feature Extraction: Relevant features are extracted from the preprocessed data to capture key characteristics indicative of wheat leaf health. Feature extraction techniques may include spectral analysis to analyze the reflectance properties of leaves across different wavelengths, texture analysis to quantify patterns and structures, and morphological analysis to characterize leaf shape and size. These extracted features serve as input to the machine learning models for disease detection.

3.3.4 Model Training: Supervised machine learning models, particularly deep learning models such as convolutional neural networks (CNNs), are trained on the extracted features to classify wheat leaves into different health categories. Transfer learning techniques may be employed to leverage pre-trained models and fine-tune them for the specific task of disease detection. The models are trained using labeled data, where each sample is annotated with its corresponding disease condition (e.g., healthy, Stripe Rust, Septoria).

3.3.5 Model Evaluation: The trained models are evaluated using separate test datasets to assess their performance. Performance metrics such as accuracy, precision, recall, F1-score, and area under the receiver operating characteristic curve (AUC-ROC) are computed to quantify the model's effectiveness in distinguishing between healthy and diseased wheat leaves. Cross-validation techniques may be employed to ensure robustness and generalization of the models.

IV Results and Discussion

4.1 Experimental Setup

YOLOv5 algorithm for plant growth monitoring involves training the model on a dataset of images containing various stages of plant growth. Once trained, the model can be deployed to analyze images or videos captured by cameras installed in the plant. The algorithm can detect and track plant growth over time, allowing for automated monitoring of plant health and development.

The performance of the YOLOv5 algorithm in this context depends on several factors, including the quality and diversity of the training data, the accuracy of the annotations, and the computational resources available for training and inference. Generally, YOLOv5 is known for its fast inference speed and high accuracy in object detection tasks, making it well-suited for real-time applications like plant growth monitoring.

4. 2 Performance Analysis

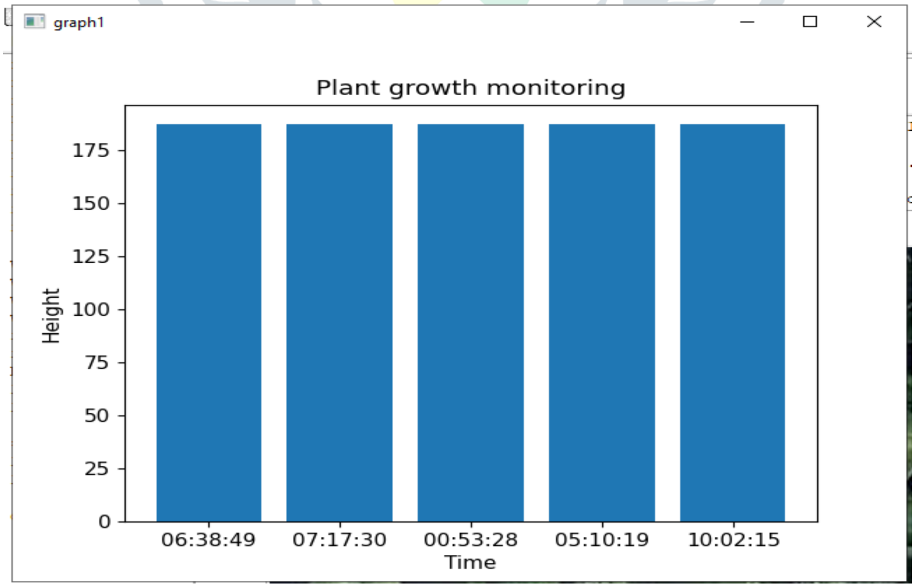
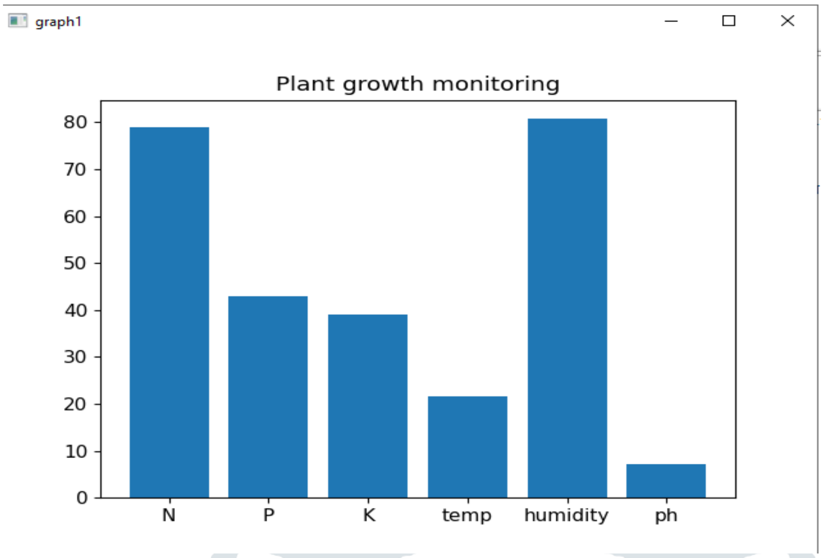


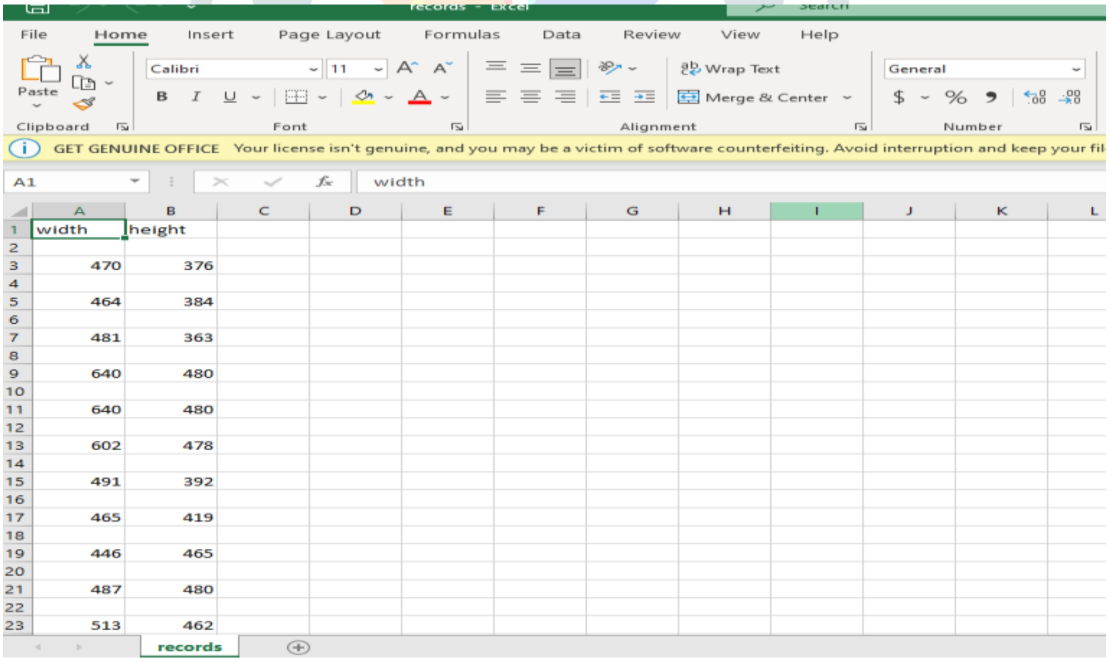
Figure 3: Plants that were grown in section with base+p feeding.



N=Nitrogen
P=Phosphorous
K=Potassium

Figure 4: Average leaves area of plants in each growing section with Corresponding feeding solution.

Fig. 3 shows an example of the leaf area calculations for each tomato planted by the nutrient solution Base + P. We also calculated the average leaves area for each section (each feeding solution). Fig. 4 shows the average leaves area for plantain each section, from which we can conclude which additive to the base solution is best. The elements are N(**Nitrogen**), P(**Phosphorous**), K(**Potassium**), Temperature, Humidity, Ph. These nutrients essential for plant growth and these nutrients add to the plant after observing growth of plant. It is highly important that we can numerically estimate effect of different factors on plant growth dynamics by using simple cameras.



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A1 width

	A	B
1	width	height
2		
3	470	376
4		
5	464	384
6		
7	481	363
8		
9	640	480
10		
11	640	480
12		
13	602	478
14		
15	491	392
16		
17	465	419
18		
19	446	465
20		
21	487	480
22		
23	513	462

Figure 5: **The height and width measurements of the captured plant image are stored in an Excel spreadsheet.**

Height and width measurements of captured plant images in an Excel spreadsheet shown in fig. 5 can effectively store and manage facilitating further analysis and decision-making processes.

V. CONCLUSIONS

Image processing is the utilization of a lot of procedures and calculations to a computerized image to investigate, improve, or streamline image attributes. In this way, one of the most significant difficulties is the absence of appropriate monitoring and control systems for proficient cultivating. The principle target of this proposed work is to build up a plant monitoring System utilizing image processing. Yolo calculation gives a better outcome as the contrast with different calculations. As the principal focal point of this application is easy to understand, this application id planned so that it supports the Multi-Lingual idea. Ranchers and research facilities may easily safeguard their plants with the use of this program, which will also contribute to the expansion of creativity.

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