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Technical Paper on Environmental Monitor and Control, Pests and Diseases in the Greenhouse

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Abstract:- A greenhouse is a glass or plastic covered area or a room dedicated for the growing of crops under a controlled environment with the intention of growing plants all year round undisturbed by prevailing weather environment. The issue of seasons that make it difficult to grow crops is disregarded or completely ignored in such a scenario. Maximum yield is realized in this instance as a result of controlled temperature, humidity, soil moisture to mention but a few parameters that are kept under check so that crops have optimal conditions for growth at any one given time. To further buttress the issue of crop yield it is critical to consider pests and diseases in the equation. Mitigation efforts to monitor and control pests and diseases assists in coming up with a quality crop that translate into a bumper harvest. In order to achieve this Internet of Things and Embedded systems together with Machine Learning techniques are used. Sensor readings of these environmental parameters together with crop image status are used to train a model that help identify patterns followed by pests and diseases thus assisting in decision-making purposes to curtail pests and diseases spread. Once a disease or pest is identified through a camera as a result of image processing, an actuator connected to a tank with chemical spray go high thus spraying all tomato plants in the greenhouse affected by red spider mite to correct the anomaly. The greenhouse is highly automated although minimal human effort cannot be overlooked. Sensor readings and crop images are stored in the cloud as big data. With this information, farmers can plan ahead, gather required chemicals and inputs in preparation for spraying pests and diseases once they surface. Stakeholders can view status of the green house via a smart phone, a laptop or a desktop so long there is a reliable internet connection.

Keywords:- *Greenhouse, Internet of Things, Machine learning, Embedded systems, Image processing.*

I. INTRODUCTION

Over the years Sub Saharan Africa's climate has changed remarkably. The areas most affected by drought in 2019 were in Southern Africa[1]. The rainfall season has not been spared either; the Zimbabwean season used to start as early as August and September, when the first rain hit the ground to set the tone for yet another season, stretching right through to April, May and sometimes June. Nowadays the season starts end of December and January when most rains signal the start of serious planting of maize seed into the ground. Usually the rains recorded in the past few years save for 2020-2021 season were inadequate for plant growth. As a result farmers that relied on natural rainfall suffered the most from the pelting heat-induced drought that dealt a big blow to most parts of Southern Africa. Many people in Southern Africa have been negatively impacted on by drought and the climate issue[2]. Against this background of uncertainty of the weather there is need to utilize a smart greenhouse where environmental parameters can be manipulated to suit growing condition of crops. At household level, community level and national level vegetables grown in greenhouses can contribute to self-sufficiency by allowing crops to be grown all year round thereby significantly curbing hunger. In order to increase crop yield the issue of pests and diseases have to be nipped in the bud so that the earlier the detection of these setbacks the better they are dealt with right away. The early detection of pest will help in the process of crop management[3].

II. LITERATURE REVIEW

Several literature sources have been read from two facets of research namely environmental monitor and control, pests and diseases with image processing papers. The two have been integrated to create a greenhouse that the researcher propose to monitor and control humidity, temperature and soil moisture as well as monitoring and controlling of pests and diseases through image processing. By combining these aspects in the greenhouse the idea being to maximize greenhouse output by creating a conducive environmental that keeps check of optimal parameters for plant growth and ridding the crop of pests and diseases that would hinder crop growth.

The greenhouse make use of temperature, humidity, soil moisture and light sensors to keep check of climatic conditions in the greenhouse[4]. The system has two setups: Visual inspection of the growth of plants, manual irrigation, turning ON/OFF temperature controllers and combination of manual supervision and partial automation. The system comprise of micro-controller, sensors, and GSM phone line such that when a parameter strays, the sensor picks up the change and the micro-controller utilize the relay to control such a parameter.

Yield loses in tomatoes are mostly a result of attack by Tuta absoluta[5]. Tuta absoluta may be as serious as causing total loss of the tomato plants if no control methods are applied. Indoxacarb is a major insecticide used to counter the effects of Tuta absoluta in the EU.

The greenhouse is remotely monitored and controlled via a mobile application based on Android platform such that a user can view and adjust environmental parameters at any time should the need arise. Mobile application was tested and found to be reliable, accurate and give real-time data (environmental parameters)[6]. The application is connected to the web server to get environmental parameters. Remote control is achieved via a mobile phone terminal in order to achieve optimal conditions suitable for plant growth.

Remote monitoring of temperature, humidity and light intensity is achieved through sensors and server software. Monitoring involve a TTL signal on the sensor being converted into a WIFI signal that is sent to the server via the internet[7].

Greenhouse monitoring and control has a number of sensors that gets some environmental parameters[8]. The microcontroller Arduino Uno comes in handy in storing as well as processing the data. A GSM module is used to alert a user on the greenhouse status through a message on the phone. Solar power is used to provide continuous power supply to the greenhouse.

A prototype that comprised of a sensor node, raspberry pi based monitors climatic parameters within a greenhouse[9].IoT analytics is integrated in the setup where sensors are placed in the greenhouse to collect different climatic data which is then channeled to the gateway. The gateway node is used to pass on data to users through the web. Depending on received data, the embedded system controls the greenhouse through a relay that turns ON/OFF lights, water sprinklers, fans to regulate the climatic parameters.

Pests are trapped using a yellow sticky paper which is distributed across the greenhouse[10]. The system counts pests to allow integrated pest management through image processing and machine learning algorithms. The image so obtained is converted into the right color according to the time of day.

Raspberry Pi 3 is used along with 8 Mega pixel camera and a sensor module.

Dual network of WIFI and 4 G Router is used to allow remote internet connectivity.

Images collected together with environmental parameters are sent via the internet.

The server processes the image and data from sensors. An image processing program running on the server gets the insect count with the data being stored on MySQL database.

The images are then converted into the right color which is either black or white. Thereafter clustering takes place through k-means for color separation of black and white insects.

IPM is a method of managing pest in a profitable manner that is socially embraced without harming the environment[11].

Pest management involves managing pests' populations to low levels such that no crop loss can be incurred. Taking note of the type of pest, knowing its biological formation and population numbers is very important to know for control purposes. Regular monitoring by detecting cases of pests prevalence is necessary to lower effects of pests through on the spot treatment. A good record keeping of pests, their damage, effective treatment, seasonal fluctuation is important to allow the farmer to take corrective action at the right time. Communication is central in allowing people to stay informed by allowing communication within groups and the public to mitigate effects of pests. Business aspect allow consumers to have healthy produce while the environment and human life is safe.

The research paper reveal a smart system that predict soil moisture through a sensor connected to a microcontroller. An actuator turns on a sprinkler once soil moisture level falls below a specified threshold. Communication process is duplex and takes place via a cellular network[12].A user interface displays the irrigation process via the internet. The irrigation can be monitored remotely. Two sensor nodes are employed; one for environmental control of soil moisture and the other for captured images in order to check on crops.

A wireless visual sensor network, some cameras planted in the greenhouse and Hugh forest machine learning algorithm are used to check pests and diseases on plant leaves[13]. A camera relays information to a sensor node that measures humidity level once pests are identified. An actuator triggers action based on humidity level read. If the humidity is too high the actuator accordingly re-adjust the humidity level thereby making it difficult for the fungus to thrive.

Strawberry management system comprise of integrated control system of micro-controller (89C51), mobile platform, picking head automatic packing machine together with sensors of temperature and humidity[14].Intelligent robot is used to manage the strawberry plant from detecting ripe fruit by color to spraying chemicals when need be to delicately reaping the fruit without damaging the soft pulp, put it in a trolley for transportation and further storage. The robot monitors temperature, humidity and water content in the greenhouse by alerting irrigation system for instance when there is need to water the plants.

Plant diseases show on plant leaves[15]. Diseases manifests through symptoms on stems, on fruit and leaves. Diseases are either caused by a virus, bacteria or fungi. Yellowing of leaves indicate that it is a virus. Bacterial diseases are difficult to identify as they need a microscope to get finer details. Fungi disease show through spots on plant leaves. When the disease is detected a user is directed to a website with chemicals that are used to treat the disease. Detection start with acquisition of image from either digital camera or mobile phone then segmentation of the image into various clusters right through to feature selection which determine the meaning of a sample image and classify image as to whether healthy or diseased. An Android system detect the diseases through convolutional neural network comprising a data set of images covering up to 14 crops.

Models detection of grape diseases as a process comprising image acquisition, image pre-processing, image segmentation, feature extraction, and finally plant disease classification[16]. Firstly the image is captured on camera. Image pre-processing removes noise through image clipping and smoothing. Image segmentation identifies a faulty region on the leaf through k-means and Otsu threshold method. R.G.B is converted into H.I.S. Disease detection favors color, texture and morphology in feature extraction. A.N.N and B.P.N.N are used as classification algorithms.

The paper looks at fungal diseases on 14 crop plants from a dataset obtained from Plant Village[17]. The plants used were fruit, vegetable, commercial and cereal crops. A computer vision system detects, recognizes and classifies fungal diseases that include powdery mildew, rot and anthracnose among others on leaves, stems and fruit. Results conducted on cereal crops using SVM classifier were more accurate on colour texture.

A study was conducted in 5 agro ecological regions in Zimbabwe[18].The study was conducted with a view to determine farmers perceptions to climate change and find out about pests distribution across the whole country. From the participatory research it was discovered that:

-22% of the farmers noted changes in temperature and drought as changing climate
-16.4% saw another angle of late rainfall.
-16% noted long dry spells.
-and yet 7.2% alluded to shorter colder season.

Heat wave, flash floods, disappearance of wetlands all pointed out to a change in climate resulting in increased insect pests, decreased natural resource base as notable climatic risks.

Majority of farmers (53%) attributed high vegetable loses to insect pests and diseases. All respondents interviewed indicated that they used a chemical insecticide as a control measure.

Precipitation and temperature variables affected aphid and whitefly distribution from the summer dataset obtained.

A conducive environment for pests was the northern parts of Zimbabwe while the southern parts had less infestations.

Based on level of infestation, aphid distribution had an overall classification accuracy of 70% and a kappa value of 0.64.

Whitefly distribution had an overall accuracy of 75% and a kappa value of 0.67.

A kappa value represented the extent to which data collected are a correct representation of variable measured so much that 0.64 and 0.67 indicate that the data was reliable.

Losses due to pests and diseases are estimated at: 10-20% for pre-harvest period; 20-30% at post-harvest and as much as 100% for perishables[19].It is indicated that main pests are coffee wilt disease, banana xanthomonas (BXW), cassava brown streak virus and citrus canker. Uganda relies on agriculture where agriculture provide 24% GDP.48% export earnings and support 80% of total households. It therefore follows that ignoring pests and diseases in Uganda the economy will be devastated.

The impact of temperature on insect population is reviewed[20]. It is reported that insects with short lives used to high temperatures increase more under continuous warm temperatures. Higher temperatures promote aphids, diamondback moth, aphidius ervi found in peas are tolerant to high temperatures. Mutondwa. M. Phophi et al reiterated that high temperatures increase pest migration.

Vegetables are prone to pests and diseases in Kenya[21]. Loses are in the range of 10% to 40%. The dominant pests are termites, cutworms, beetles, caterpillars, fruit borers, stem and leaf miners, aphids, thrips, spider mites among others negatively impact vegetable production in East Africa.

Nowadays there are more heat waves than before. Rising temperatures trigger availability of new pests[22].It is important to be pro-active in view of new pests and diseases.

III. IMPLEMENTATION

Implementation of Internet of Things in agriculture specifically in the greenhouse is the purpose of this study, focusing on smart agriculture where sensors, actuators and raspberry pi combine to make a network of devices that intelligently communicate and share data via the internet.

The monitoring part is done by the camera assisted by computer vision algorithms that scan the plant leaf to check if the plant is affected by pests and disease or not.

The controlling aspect utilize technology such that once pests and diseases are identified an actuator connected to chemical supply stored in a tank opens a valve for the right chemical to come through the spray nozzle onto the entire plants in the greenhouse.

Environmental parameters are monitored and controlled so that parameters are kept under check to allow a conducive environment to persist in the greenhouse.

A plant dataset with tomato crop images of plant leaves that are diseased and those that are not are used to train a model that given any leaf the algorithm can check leaf features like leaf texture so that the model can correctly determine leaf status.

The sensors are interfaced to raspberry pi to control displayed climatic values on a dashboard as obtaining in the greenhouse .All the big data so obtained is stored in the cloud.

Given a certain temperature and humidity, the data analytics section can determine what type of pest or disease is likely to occur basing on past records.

IV. HARDWARE COMPONENTS USED

- Raspberry pi
- Analog to Digital Convertor
- Dashboard
- Actuators
- Sensors-LM35, humidity and soil moisture.

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V. PROPOSED SYSTEM

Sensor readings from the cloud are displayed on a dashboard on a web-page. Depending on readings so obtained the relay turn ON/OFF fan, open/close vents, open close irrigation system, open/close feeder tank to spray the chemical.

Computer vision using image processing algorithm check plant status by going through the process showing four phases namely:

-Phase 1: image acquisition from camera or dataset.

-Phase 2: segmentation into clusters.

-Phase 3: feature extraction i.e. color, shape, texture.

-Phase 4: classification showing either leaf is diseased or not.

Given some occurring environmental parameters in the greenhouse one can predict the type of disease that may occur.

The farmer may therefore prepare chemicals for use and have them ready in stock.

VI. PROPOSED SYSTEM CONSTRUCTION

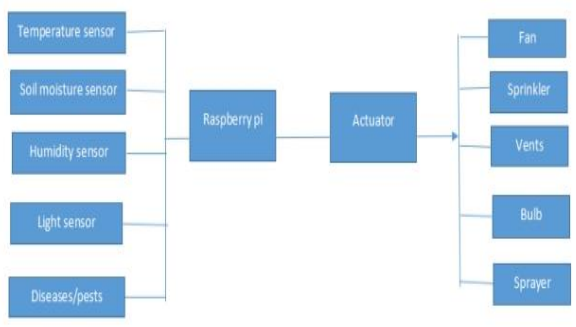

Fig. 1: Proposed system

Raspberry pi is the microcontroller working as a CPU in monitoring environmental parameters inside the greenhouse.

The microcontroller decides how and when to control the environmental parameters and pests and diseases.

The raspberry pi compare the value output against a set value so that when there is a huge mismatch an actuator turn ON/OFF a fan, open/close vents, switch ON/OFF a bulb and turn ON/OFF sprinkler.

Optimal conditions for a specific crop are maintained to ensure that the plant grows unhindered within a conducive environment.

For instance, when soil moisture is low, the sprinkler will irrigate until a threshold is met.

The microcontroller intelligently control the greenhouse weather so that the issue of seasons will not affect crops being grown. Any crop can be grown anytime anyhow so long a conducive environment is created and maintained.

VII. IMAGE PROCESSING

A camera is used to capture plant leaf images. The images will then be processed by going through a classification process.

A dataset was used to train the model that classifies the texture of a tomato plant whether diseased with red spider mite or not. A sample of the dataset was used for testing purposes with the results being noted.

When a plant leaf is classified as diseased an actuator connected to a tank with chemicals go high thereby opening a non-return valve to spray all the plants in the greenhouse. Red spider is highly contagious hence the need to spray all the plants rather than only the affected plant.

Greenhouse status is viewed on a website showing environmental parameter readings of soil moisture, humidity and temperature in real-time.

VIII. CLASSIFICATION PROCESS

Some machine learning algorithms were used to classify tomato plant leaves to determine whether diseased or healthy.

The algorithms used are: Linear Regression (LR), Linear Discriminant Analysis (LDA), k Nearest Neighbor (kNN), Classification and Regression Trees (CART), Random Forest (RF), Naïve Bayes (NB) and Support Vector Machines (SVM).

Linear regression-is a form of supervised learning used to predict a dependent variable given some independent variables. Linear regression establishes a correlationship between two variables.

Linear discriminant analysis-an algorithm which classifies two or more classes separated by some hyperplanes.When there are two classes a single hyperplane separates the two classes; with more classes so do the hyperplanes increase accordingly. The classes have to be linearly separable.

K Nearest Neighbor-is a supervised learning algorithm used to classify by considering k nearest neighbors within its vicinity. Nearest neighbors lie within close proximity to some new data points e.g. given red and yellow balls. A green ball near to red balls will be classified with red since they are close by.

Classification and Regression Trees-this algorithm uses decision trees to arrive at a solution. The algorithm can be split into classification tree and regression tree. The classification algorithm identifies class within which a target variable will most likely fit in. Regression tree on the other hand is used to forecast the value of a continuous variable e.g. the price of a house is dependent upon square metres the house is built upon, the area the property is located, is it a flat/apartment or a mansion etc.

Random Forest is an ensemble algorithm made up of many decision trees combined together resulting in a forest. The trees values obtained are averaged to give a more

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accurate model. Sampling the input vectors that are passed through each and every decision tree of the forest based on the number of votes obtained will give rise to classification.

Naive Bayes classifies according to the likelihood of an event occurring based on past knowledge of conditions relative to the event in question. An assumption is made on the basis that features are independent of each other though they may be interrelated somehow. The final classifier combines prior probability and likelihood value.

Support Vector Machines classify by mapping every data item to some feature space. A hyperplane separates the data points into two. Classification is a function of maximum margin that differentiates the two classes on the hyperplane.

IX. RESULTS AND DISCUSSIONS

Some tomato leaf images from a dataset was tested to determine leaf texture as to whether the leaf is diseased or is healthy. The leaves correctly classified according to texture. The leaves with disease were correctly classified as much as those without the disease.

The diagram below shows a healthy tomato leaf overleaf followed by one that is diseased with red spider mite.

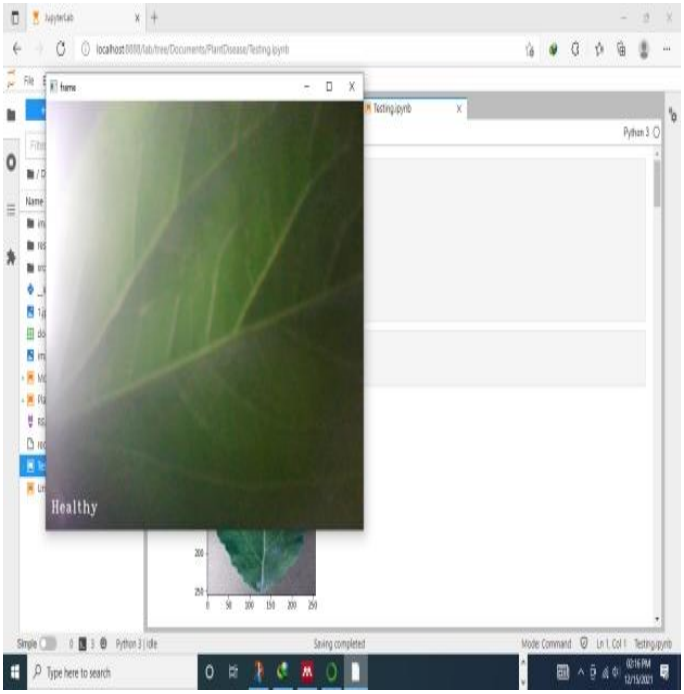

Fig. 2: Healthy Leaf Result

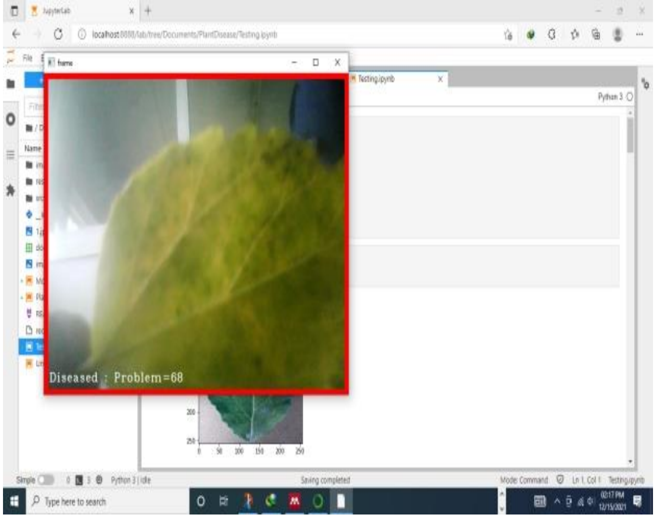

Fig. 3: Diseased Leaf Result

Algorithm performance were as follows:

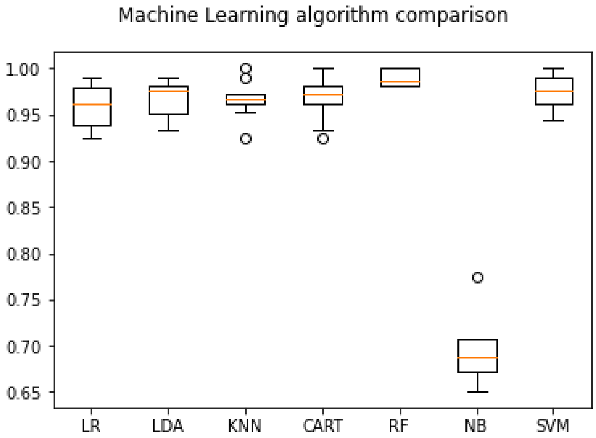

Fig. 4: Machine learning algorithm comparative analysis.

Algorithm	%
Linear Regression	91.6406
Linear Discriminant Analysis	90.7813
K Nearest Neighbor	92.0312
Classification and Regression Trees	90.6250
Random Forest	95.7031
Nave Bayes	85.7031
Support Vector Machines	91.9406

Table 1: Machine learning algorithms performance

	precision	recall	f1-score	support
0	1.00	0.93	0.96	57
1	0.98	1.00	0.99	209
accuracy			0.98	266
macro avg	0.99	0.96	0.98	266
weighted avg	0.99	0.98	0.98	266

Table 2: Evaluation metrics

Support gives an idea as to how frequent an itemset is in a given transaction. Support is low when precision, recall and f1 score is at 0. Otherwise support is high.

Accuracy define the ratio of correctly labelled subjects to the whole pool of subjects.

Precision is the ratio of the correctly positive labelled to all positive labelled.

Recall is the ratio of the correctly predicted to all observations in the whole class.

F1 score is weighted average of precision and recall.

In short support is a function of accuracy. The more the support the better the accuracy where accuracy is dependent on recall, f1 score and precision.

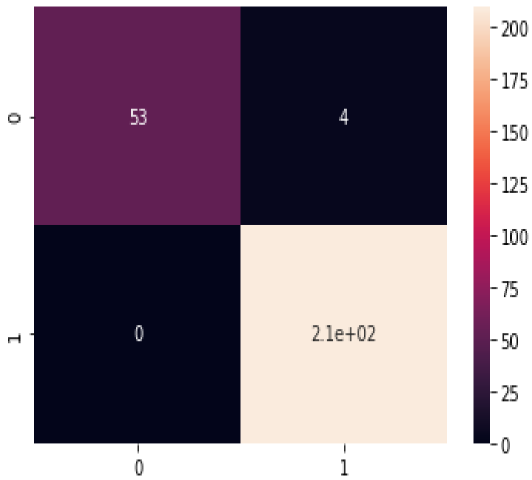

Fig. 5: Model evaluation score

To further elaborate on this an evaluation score showing precision, recall, f1 score and support are revealed where precision is almost equal to one and so is recall and f1 score.

X. CONCLUSIONS

The project implements the monitor, control of environment within the greenhouse by creating a conducive environment for crops to grow.

Temperature, soil moisture and humidity have been observed to be controllable parameters as indicated in the results section in the previous chapter. A conducive environment is therefore created for plants to grow undisturbed regardless of season prevailing at a point in time.

The emphasis is on controlling pests and diseases specifically tomato disease such as red spider mite. However, any plant whose leaves have been sampled and trained can classify as diseased or not. Hence there is no limitation on tomato plant. The results have shown detection of a disease if the leaf of the plant is affected otherwise it is not hence the plant will be healthy. Random forest algorithm has accurately classified diseased or healthy leaves.

The function of the environment and diseases have been successfully integrated into the greenhouse and the hypothesis that environmental parameters do affect pests and diseases has been proved to hold water.

XI. RECOMMENDATIONS

For the future, the research can be extended into or take the direction of pests and diseases prediction given sufficient data of environmental values within the greenhouse.

Working with a dataset of a different setting may mislead data analyst whereas working with practical values give the right insight that helps in decision-making

When sufficient data of temperature, soil moisture and humidity is availed in real-time the values so obtained can be used to pre-empt the likelihood of pests/diseases that may affect crops in the greenhouse giving farmers ample time to adequately prepare for pests and diseases, acquire requisite chemicals in advance.

In the same vein technology can be utilized to do away with manual feeding of chemicals into the tanks.

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