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Early stage detection of Downey and Powdery Mildew grape disease using atmospheric parameters through sensor nodes

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ABSTRACT

Grape diseases are major factors causing severe diminution in its fruit development. Unfavorable climatic conditions are one of the principal dangers for grape disease development. Downy Mildew, Powdery Mildew, Anthracnose, Stem borer, Black Rot, Leaf Blight are widespread grape leaf vermin and diseases, which cause stern monetary losses to the grape industry. Devices ready to quantify the climate conditions in real-time for disease onset are hence crucial to perform timely diagnosis and precise detection of grape leaf diseases. This will ensure the healthy growth of grape plants, further controlling the spread of diseases. This paper discusses the requirements for building a consistent grape disease detection framework that would encourage headways in agribusiness. The primary aim of this work is to adapt an Internet of Things (IoT) based approach to predict the occurrence of Downey and Powdery Mildew grape diseases at an early stage. The sensor values received are transmitted to the Central Server with the help of the IoT device NodeMCU. At the server side, an analysis is made based on weather conditions. Further notification to the farmer is sent if weather properties are conducive for disease onset. The exclusivity of the system lies in using a rain gauge sensor along with the temperature sensor to predict the occurrence of grape diseases. This system realizes an overall accuracy of 94.4% for Downey Mildew and 96% for Powdery Mildew. Experimental results suggest the projected model can proficiently recognize Downey and Powdery Mildew grape diseases.

1. Introduction

The grape industry is one of the significant organic product industries in India. Nearly 2,46,133 tons of fresh grapes worth $334.79 million were exported by India in 2018–19 (Indian Grape Forum, 2019). Maharashtra (third largest state in India) comprising over 81% of the yield for grape production in India. However, grape plants are vulnerable to different types of diseases due to the ongoing climate conditions such as rain and humidity. Ranchers struggle with various issues in keeping grape quality and trade responsibilities in diverse business sectors. Subsequently, detection and prevention of grape leaf diseases at an early stage are required by vineyard peasants and research experts.

Downey Mildew (induced by Plasmoparaviticola), and Grape Powdery Mildew (induced by Uncinulanecator (Schw.) Burr.), are two significant diseases of grape in numerous parts of the world (GuanlinLi and Wang, 2011). These diseases affect both leaves and grapefruits. Downey is particularly severe under severe precipitation, high relative moistness, and significant stretches of dampness on leaves and fruits (Indu et al., 2010); whereas high humidity and moist weather favours the development of Powdery disease (Mundankar et al., 2008). Crop protection products (fungicides) are applied to minimize these diseases. Fungicides are expensive for farmers and can cause ecological contamination (Weissteiner et al., 2014), (Zhang et al., 2011) (Zhao and Pei, 2012). Thus, only applied when there are vibrant signals about the existence of the disease.

Many recent approaches for disease identification depends primarily on visual or image recognition. Nonetheless, this is a tedious and onerous task. Precision horticulture (McBratney et al., 2005) aims to improve the yield per unit of cropland using Information and Communication Technologies (ICT) equipment and advancements. Utilization of ICT devices and identification frameworks have been created to notify the farmers about the unexpected advent of diseases. Grape diseases can disseminate swiftly in various climates due to temperature and humidity (Eitzinger et al., 2013) under India climatic conditions. Other countries such as the U.S. and Australia have various systems in place that use both hourly and daily meteorological conditions to anticipate the onset of a variety of different crop diseases but not for grapes. The disease model developed by (Thomas et al., 1994) computes the day-to-day average temperature

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along with the hours of moisture and propose treatment solutions for ascospore infections. They discuss the model testing in California climatic conditions. There is a need for devices to quantify the climate conditions in real-time such that onset of grape disease can be predicted. In recent years, modern mechanisms from the Internet of Things (IoT) have been utilized to acquire real-time onsite observations (Pesonen et al., 2014) and it is crucial to build disease models referenced to these IoT devices.

The principal objective of this work is to acclimate a disease warning model in the field of viticulture via an innovative framework using sensors to measure real-time meteorological conditions within the vineyard. Measured data is sent to a central server using the cloud and an alert message is sent to the farmer, when the favorable conditions arise, for the occurrence of Downey and Powdery on grapes or leaves. Distinctively, the contributions of this effort are:

(a) Effective determination of Downey and Powdery mildew via leaf wetness, humidity and temperature.
(b) Pro-creation of regular warnings, contingent on the level of development and kind of disease, sent directly to farmers; and.
(c) Application of the models for use on IoT hubs sent legitimately.

The rest of the paper is organized as follows: Section 2 presents the background. Section 3 details methodology used to detect Downey and Powdery Mildew grape disease, in vineyards. Section 4 shows experimental results of this system followed by insights on performance. Section 5 concludes the work and proposes commendation of future work.

2. Background

Downey Mildew (PlasmoparaViticola) is a major grape disease in India (Emmett et al., 1992). Farmers need to use judgment on whether to use fungicides for Downey Mildew (Magarey et al., 1991) noting that both cost and residue levels on crops increase with fungicide use. Clearly, farmers need to restrict the occasions to shower, so that the cost diminishes along with ecological contamination; however they likewise need to limit the danger of crop failure because of the disease. Decades ago only a few methodologies were utilized to anticipate Grape Downy Mildew disease. Various statistical models were evolved (Hill, 2000) (Maurin, 1983) (Tran Manh Sung et al., 1990)(Blaise and Gessler, 1992) (Orlandini et al., 1993) that performed without explaining all functioning details. Robotic models often depends on the assessment of numerous parameters and require a good knowledge of mechanisms and impact of various ecological factors on these mechanisms. In 1992, an Austrian analyst built up the Metos programmed climate station and related software, to foresee the occurrence of Downy Mildew. The abroad could not precisely determine diseases in India. The Metos software model (G. Pessl, 2000) was personalized for South African environment in 1995. Consequences have revealed that supplementary splashes were required in the protection showering program, rather than proposals of the Metos-2 model, for the equivalent or even further developed control of Downey mildew. Metos-2 model didn't caution of any Downey mildew contaminations. In 2006 to make it more exact and easy to use DonsigeSkimmelVroeg-Waarskuwings model (DSVW) (Afrikaans for “Downey Mildew Early Warning Model”) was developed (Haasbroek and Vermeulen, 2005). Two significant changes were made in comparison to Metos-2, the leaf wetness was supplanted with a numerical, non-linear regression and the Metos-2 model's “Yes/No” admonitions for Downey Mildew diseases were supplanted with four classes of potential dangers. The determined leaf wetness of the DSVW model, which used estimated relative dampness and air temperature as info esteems, had a critical coefficient of assurance of 0.70, compared to estimated leaf wetness.The DSVW model yield at present gives a graphical depiction of the past climate factors (as long as 3 weeks), and an alert of (3 unique tones - high, medium and low possibility) of probable favorable condition for both essential and optional disease occurrence.

Powdery Mildew is another monetarily significant disease. In India, this disease reoccurs in grape plantations with humid climate (e.g. high relative dampness) favoring growth of the disease (Oberti et al., 2014). Presently, in the hotter and drier grapevine-developing territories, powdery mildew is meticulously constrained by agrochemicals, applied consistently in grape plantations (Stummer et al., 2003) (Calonnec et al., 2004) (Crisp et al. (2006a)) (Crisp et al. (2006b)) (Iriti et al., 2011).

Sensor mechanization for grape yield malady has been comprehensively analyzed by (Sankaran et al., 2010), who describe current technologies for developing a ground-based sensor framework which aid in supervising disease in plants under field conditions. The authors also reviewed that the spectroscopic and imaging innovation could be incorporated with a self-governing agricultural automobile for reliable and real time disease detection recognition to accomplish predominant plant disease monitoring and control. Various researchers have projected solutions for identifying the condition of a vineyard by utilizing sensors. Sensors permit us to recognize the particular necessities of every territory, which improves the supervision of the grape plantation and addresses the potential issues precisely. The majority of recent literature centers on remote monitoring of vineyards grapevines by utilizing

Table 1
Summary of literature review.

Reference	System Description	Findings
Blaise and Gessler (1992)	Statistical	They can anticipate complex frameworks, but they do this without explaining all functioning in details.
Pessl, 2000	Uses a variety of wireless sensors and devices to monitor field conditions	Cannot precisely determine diseases in India
Haasbroek and Vermeulen, 2005	Gives an alert of probable favorable condition and also a graphical depiction	Works for South African Environment
Sankaran et al., 2010	Review of various plant disease detection techniques.	Sensor Mechanization, spectroscopic and imaging Can be incorporated for reliable and real time disease detection recognition to accomplish predominant plant disease monitoring and control
Luvisi et al., 2012	Assess the impact of explicitly planned High and Low Frequency transponders.	Distress the development of the shoots examined
Rossi et al., 2014	A real-time monitoring framework and online system.	Provide up-to-date information for managing the vineyard in the form of alerts and decision supports
Matese et al., 2009	Incorporates a climate station and a few remote hubs situated that transmits the information to a remote central server.	This system gathers only miniature meteorological factors without bearing about infection counteraction.
VintiOS	Props the choices of grapevine cultivators and vintners on the grapevine growth.	Product shows the location of the homestead and permits the farmers to deal with all the information identified with it.
Monet	Incorporate precision sensors equipped for seizing the most precise weather parameters.	Monitors the wellbeing of a grape plantation, including the danger of rising diseases, climate data

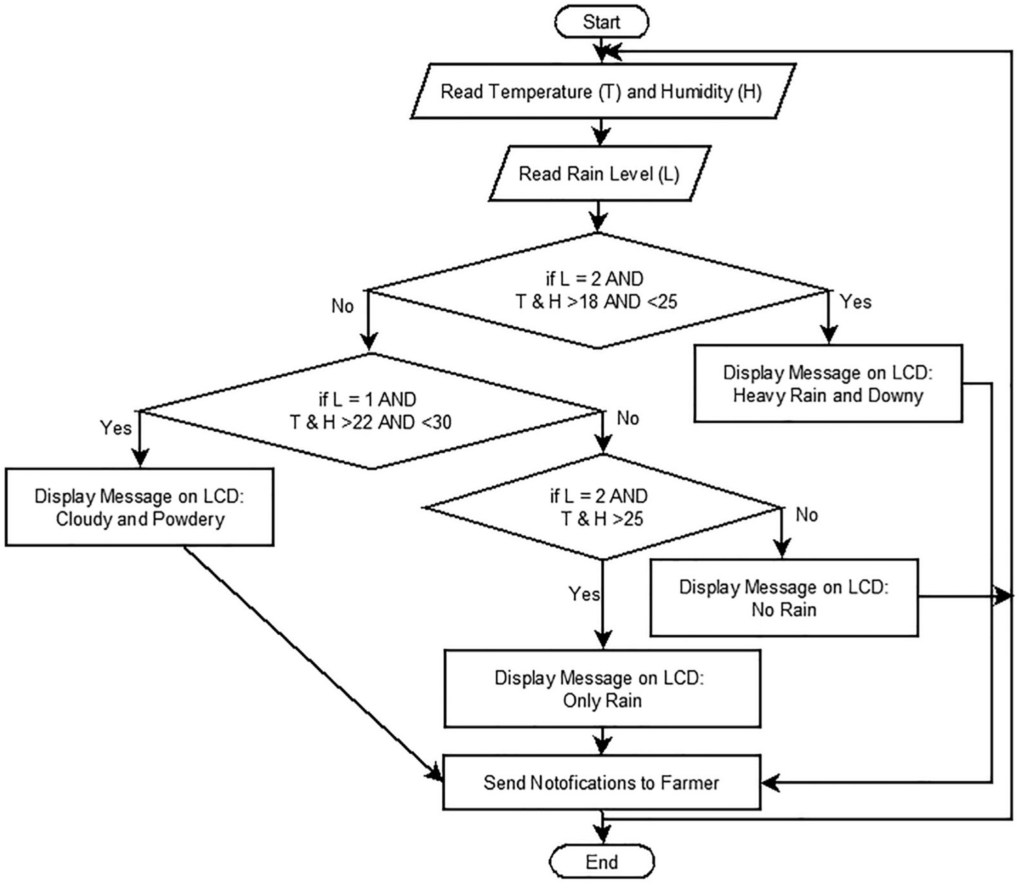

Fig. 1. Flow chart of the proposed Algorithm 3.2.

thermal imaging (aeronautical and ground-based) and hyperspectral methods (Pôças et al., 2015) (Sepúlveda-Reyes et al., 2016) (Rey-Caramés et al., 2015) (Turner et al., 2011) (Karakizi et al., 2016). These approaches include the procurement of spectral information using expensive technologies, for example, satellites, airplanes, or Unmanned Aerial Vehicles. Agrochemical information can be utilized to develop the grape plant growth process and to ensure tractability and precise grapevine health perceptions. The impact of explicitly planned High and Low Frequency transponders when embedded in grape vineyards is documented in (Luvisi et al., 2012). In spite of the fact that the tractable data is helpful, the authors describe that the embedding methods distress the development of the shoots examined.

Vite.net, introduced in (Rossi et al., 2014) is an encompassing methodology which incorporates a real-time monitoring framework and online system to deal with the grape plantation. Nonetheless, the authors depend on third –party hardware, so details on the sensor hubs are precluded. A wireless sensor network for precision viticulture (Matese et al., 2009) is useful for observing grape plantations progressively. The framework incorporates a climate station and a few remote hubs situated in the grape plantation. A modem introduced on the hubs transmits the information to a remote central server. This system gathers only miniature meteorological factors. (Zhang et al., 2015) proposed a system for agriculture monitoring using factors like temperature, soil dampness, and computes system dependent on the field information. The system incorporated WSN with decision support system and computerized many undertakings including climate monitoring. It gives an instrument to ranchers, framework clients, and viticulture ventures, to further develop the grape plantation proficiency. Various organizations now offer improved monitoring solutions for grape plantations. SGSMap developed an agribusiness system that sustains the choices of grapevine cultivators and vintners on grapevine growth (VintiOS, 2020). The product shows both the location and all information identified with it. (Monet, 2020), outlines a comparative instrument, which monitors the wellbeing of a grape plantation, that includes the danger of rising disease outbreak, climate data. Other exclusive arrangements have been proposed by SmartVineyard (SmartVineyard, 2020) which incorporate precision sensors equipped for seizing precise weather parameters (e.g. hourly, daily). The sensor is intended for grapes and can be placed among leaves to convey this important information to viticulturists.

On studying all the frameworks referenced and summarized (See Table 1.), Our proposed system intends five primary focal points that have not been discussed simultaneously in the literature. To begin with, it gives a total hardware and software framework, so similarity issues are limited. Secondly, this system tries not to gather information from or through third-party cloud-based platforms Third, because of the utilization of standard android Nodes, the arrangement cost of the framework is genuinely reasonable, while giving a decent coverage. Fourth, it focuses on early stage detection in grape production. Lastly, this approach has been devised in a secluded manner for ease in adding new alerts, sensors, and actuators to the framework.

Hence, the objective for this work lies in developing an adaptable system for the management of grape diseases that occurs at much early stages for crop disease using wireless sensors nodes.

3. Proposed work

3.1. Functionality of the proposed system

The proposed system empowers the ranchers with a simple device for grape disease manifestation and prevention to preserve the grape vineyard. The framework was considered to assist in monitoring the development of grape plantation and ultimately expand the quality of grapes via exhibiting the data about weather conditions and in adding selection for fungicide use. Thus, the proposed system stands in for two essential necessities:

a. It tracks important factors that influence growth of grapes within vineyard while offering data through the Internet by utilizing a wide scope of sensors.
b. It helps in grape disease prevention through prescient models, procuring alerts to the farmers from the vineyard.

The implementation of algorithms 3.1 and 3.2 automates the identification of Downey and Powdery mildew grape diseases and sends notification for these diseases to the farmers. Algorithms are executed on a central server which monitors the status of the disease occurrence using the climatic parameters gathered from the sensor hubs. A notification is sent to the farmer when leaf wetness and the temperature range sensed by the sensors surpasses the threshold value necessary for disease onset. The flow diagram for our approach demonstrates its inward operations and multifaceted nature(Fig. 1).

Algorithm to Check Rain Level

```
Function chkRainLevel()
Declarations:
nLevel as Integer
Begin
// Per Hour 0.10 Inches: Light Rain Fall, 0.1 to 0.30 -> Moderate, >0.3 Heavy Rainfall
nLevel = ReadWaterLevel()
if(nLevel< 0.10)
        return(2)
else if(nLevel>=0.10 &&nLevel<=0.30)
        return(1)
else if(nLevel> 0.30)
        return(0)
End
```

Algorithm identify Occurrence of Downey and Powdery

```
Function Main()
Declarations:
        nRange as Integer
        fTemperature, fHumidity, fMoisturePercentage as Float
Begin
        ##Sense_Values:
        fTemperature = readTemperature()
        fHumidity = readHumidity()
        nRange=chkRainLevel()

       if(nRange==0 &&  fTemperature>=18 &&fTemperature<=25) then
        showOnLCD3(fTemperature,"Heavy Rain","Downey")
        SendMessageDisease(fTemperature,"Heavy Rain","Downey")
       else if(nRange==1 &&fTemperature>=22 &&fTemperature<=30 )
        showOnLCD3(fTemperature,"Cloudy","Powdery");
SendMessageDisease((Temperature,"Cloudy and Rain Warn","Powdery");
        else if(nRange==0 &&  fTemperature>25)
                showOnLCD("Only Heavy Rain",String(fTemperature))
        else if(nRange==1 &&  fTemperature>30 )
        showOnLCD("Cloudy & Rain Warn",String(fTemperature))
        else
                showOnLCD("No Rain",String(tfTemperature))
End if
        ##Write Data on Cloud
        send Values To NodeMCU(tfTemperature,nRange)
End
```

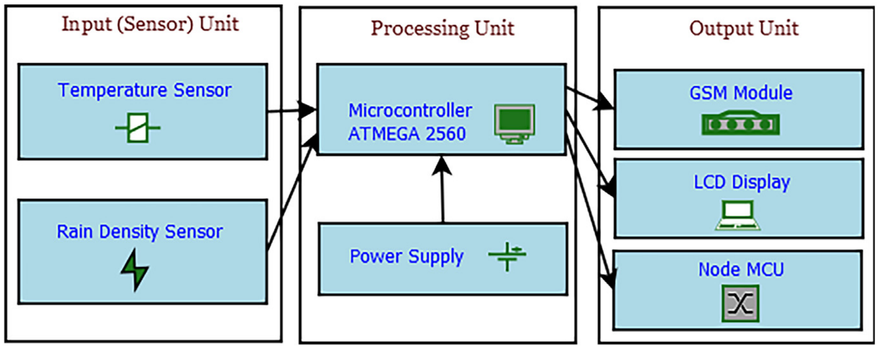

Fig. 2. System architecture.

Table 2
Specification of proposed solution.

Sr. No	Component Description	Specification
1	Power Supply: Battery	40A, 14.8 V - 16.8 V
2	Temperature Sensor	DHT11
3	Rain Density Sensor	Nil
4	GSM Module	SIM800L GSM/GPRS, 4 V
5	LCD	16 * 2 Display
6	Node MCU	ESP8266, 16 Digital Pins, Analog −1 Pin
7	RTC Clock	DS3231 RTC

3.2. System architecture

3.2.1. Overview

The architecture of the proposed system (See Fig. 2) depicts the predominant components and linkage that occurs. Temperature and Rain Sensor nodes are used to gather sensor information and send them to the central server via IoT device platform NodeMCU(NodeMCU ESP8266, 2020).

NodeMCU is liable for transmitting the records accrued from the sensor nodes to the Central Server.

3.2.2. Sensors

Temperature Sensor and Rain Sensor measure essential environmental parameters viz. temperature, humidity and rainfall. Each sensor is managed by a NodeMCU (a low cost firmware and development board particularly designed for Internet of Things (IoT) based applications (NodeMCU ESP8266, 2020)). NodeMCU is programmed by the IDE of Arduino Microcontroller ATMEGA 2560 utilizing sensor libraries offered by Arduino commune. Specification of the proposed solution can be observed in Table 2.

3.2.3. GSM module and LCD display

Notification are sent to the farmers by the means of Short Messaging Service (SMS) about the grape disease occurrence. SIM800L GSM/GPRS, 4 V, is the modem selected for the transmission of messages, and LCD Display allows the farmers to visualize the temperature and humidity values on the field.

4. Results and discussions

This section discusses about the experimental setup deployed in the field and actual results captured from the field at real time. Captured data from IoT sensors were analyzed using the algorithm stated to test for the occurrences of Downey and Powdery Mildew. After analysis the proposed system is compared with the existing system which reveals that the proposed system is worth detecting the occurrence of both diseases.

4.1. Experimental setup

The deployment of the field apparatus was carried out in a vineyard located in Materwadi (Tal- Pimpalgaon) and Sakura(Tal- Pimpalgaon) as can be viewed in Fig. 3. The sensor nodes were placed 1 m above the ground to monitor the weather parameters, based on the regulation of World Meteorological Organization (WMO) (1996).

Fig. 3. Experimental device setup in farm for monitoring weather.

Table 3
Number of sensor recordings in each farm.

Sr·No	Source of Data	Total Samples	Testing Samples (20%)
1	Prashant Agro Farm, Materwadi, Pimpalgaon, Nashik	1080	215
2	Boraste Agro Farms, Sakura, Pimpalgaon, Nashik	1080	215
	Total	2160	430

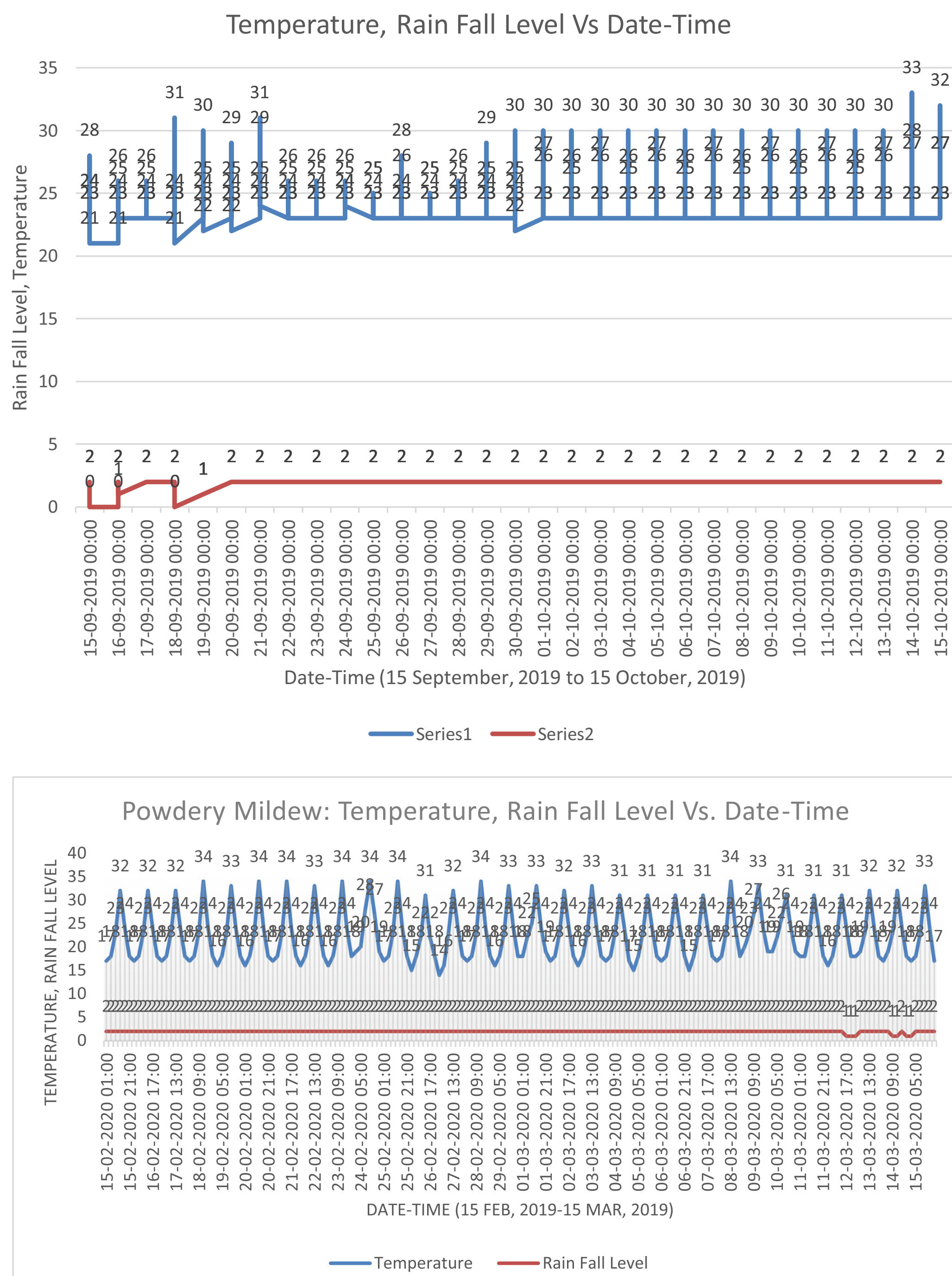

Fig. 4. Daily temperature values collected by the Hub.
(a) (15th Sept 2019 to 15th Oct 2019)
(b) (15thFeb 2020 to 15th March 2020)

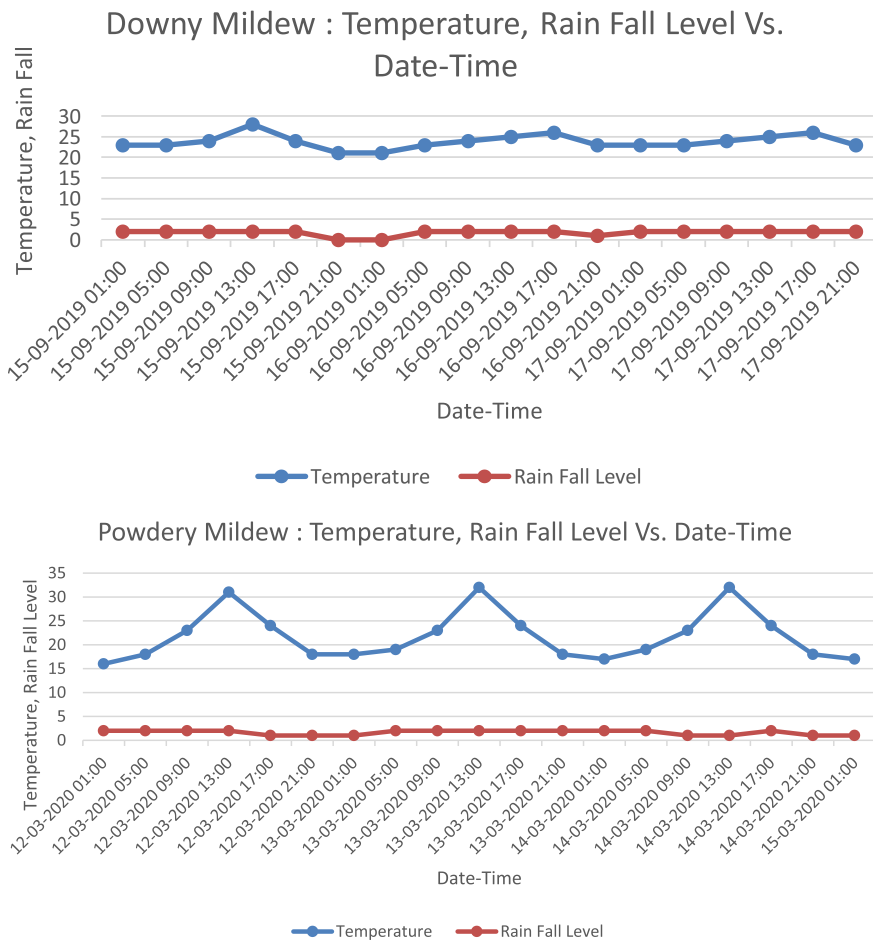

Fig. 5. (a)Downy Mildew Favorable Condition (15thSept to 17thSept 2019).(Rossi et al., 2014). (b) Powdery Mildew Favorable Condition (12thMarch to 15th March 2020)

4.2. Simulation

The proposed model has been evaluated based on the data gathered in real -time by the IoT based device placed in the farm. This section presents the evaluation of the devised model.

Table 3, shows the data collection values for experimental purpose. The recordings of sensor values were collected during 1stSeptember 2019 to 31stAugust 2020, 1080 recordings in each farm under consideration i.e. 6 values per day.

Fig. 4.depicts a graph of the information sensed by sensors (temperature and rainfall) and sent to the server by NodeMCU from 15thSeptember 2019 to 15thOctober 2019 at Prashant Agro Farm. It also shows the temperature values sensed in the period of 15th Feb 2020 to 15th March 2020. It demonstrates the estimations after every four hours. This is also depicted in Table 3 i.e. testing samples estimations are 215 per farm.

Fig. 5 shows the temperature acquired by the hub on 15th September -17th September 2019 and 12thMarch to 15th March 2020 respectively (from Prashant Agro Farm). The encircled value in Fig. 5a indicates the favorable condition for Downey Mildew showing temperature value 21 °C and heavy rainfall in accordance to the algorithm 3.2. Similarly, in Fig. 5b. The encircled value indicates the favorable condition for Powdery Mildew showing temperature value 23 °C and cloudy atmosphere in accordance to the algorithm 3.2.

A small dissimilarity can modify the turn of events and necessities of the plant even though initially the information may appear to be analogous. For example, favorable conditions for Downey Mildew arose approximately at night 9.00 p.m. on 15th Sept 2019 as heavy rain was sensed by the rain gauge sensor, Fig. 5. (a). These conditions occurred because of the downpour, and a decrease in the temperature. Similar experimentation was carried out to demonstrate occurrence of Powdery Mildew from 12thMarch 2020 to 15thMarch 2020.

4.3. Alerts

The temperature and rain level values are checked after every four hours. Fig. 6, depicts the Experimental device set on the field to display and gather the agroparameters value and also the message of disease occurrence. If the parameters convene the threshold values, a notification is sent to the farmer. Fig. 6 also illustrates an instance of a warning sent by SMS about the occurrence of Downey and Powdery Mildew disease.

4.4. Performance measure

The performance of the developed merchandise is assessed by computing accuracy Eq. (1), recall Eq. (2), and precision Eq. (3) based on Confusion Matrix as shown in Tables 4.1 and 4.2 for Downey and Powdery respectively. The Accuracy, Recall and Precision are derived from True Positive (TP), True Negative(TN), False Positive (FP), False Negative(FN). These are calculated as follows:

$$Accuracy = \frac{TP + TN}{Total} \tag{1}$$

$$Recall = \frac{TP}{TP + FN} \quad (2)$$

$$Precision = \frac{TP}{TP + FP} \quad (3)$$

Precision, Recall and Accuracy are calculated as demonstrated in Tables 5.1 and 5.2 for Downey and Powdery respectively based on the Confusion Matrix illustrated in Tables 4.1 and 4.2.

From the above results we can observe that 94.4% of recordings were correctly identified in case of Downey Mildew disease occurrence and 96% for Powdery Mildew. Thus, the accuracy achieved has helped the farmers to reduce the use of fungicides on grape plants. This increases the quality of grapes.

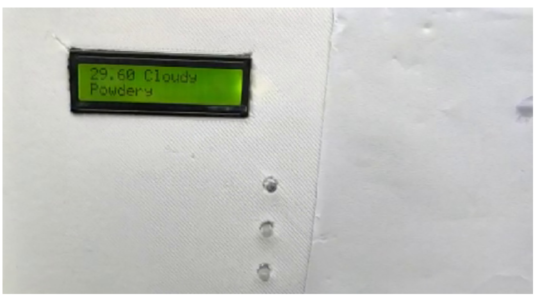

Fig. 6. Occurrence Notification for Powdery Mildew showing temperature value 29.60 and Cloudy atmosphere on the experimental device.

Table 4.1
Confusion Matrix of the proposed system for Downey Mildew.

$n = 430$	Predicted (No)	Predicted Yes	Total
Actual (No)	TN = 106	FP = 14	**120**
Actual (Yes)	FN = 10	TP = 300	**310**
	116	**314**	**430**

Table 4.2
Confusion matrix of the proposed system for Powdery Mildew.

n = 430	Predicted (No)	Predicted Yes	Total
Actual (No)	TN = 115	FP = 11	126
Actual (Yes)	FN = 6	TP = 298	304
	121	309	430

Table 5.1
Performance measures Downey Mildew.

Measure	Estimation	%
Accuracy	0.944186047	**94.4**
Recall	0.967741935	**96.8**
Precision	0.955414013	**95.5**

Table 5.2
Performance measures Powdery Mildew.

Measure	Estimation	%
Accuracy	0.960465116	**96**
Recall	0.980263	**98**
Precision	0.9126984	**91.3**

4.5. Comparison with other systems

Depending upon the proposed system, the grape diseases can be effectively identified at a much early stage. The novelty of the proposed system lies in using the Rain sensor along with temperature and humidity sensor. The accuracy of disease notification is therefore considerably increased then if a rain gauge was omitted. Thus, the projected device demonstrates higher performance in recognizing grape diseases.

In this proposed system, temperature and rainfall level have been used as features to identify the favorable conditions for grape disease growth. The performance of the projected framework has been contrasted with existing detailed strategies and is conferred in Table 6, proposed (Patil and Thorat, 2016), (Das et al., 2009) (Kharde and Kulkarni, 2016). The systems used for comparison have used IoT, WSN and Image Processing approach. All the systems have been analyzed on our augmented data set and achieved accuracy of approximately 90%. However, the accuracy proposed in our system is increased due to the use of rain sensor along with humidity and temperature sensor. From the comparison, it is clear that the proposed algorithm is capable of identifying Downey and Powdery Mildew grape disease with high accuracy better than other systems investigated.

5. Conclusion

This paper presents a framework dependent on wireless sensor hubs that considers remote monitoring of grape plantations. Particularly, the proposed system suggests an executive approach to control Downey and Powdery Mildew (devastating grape diseases for vine producers). Based on literature surveys, we develop an adaptable system for the management of grape diseases at much early stage using wireless sensor nodes. When a particular threshold level is achieved, the proposed framework generates an alert to the farmer so they may take preventive measures by scouting and potentially using a fungicide. Consequently, the framework avoids the use of pesticides and herbicides when not required, thereby reducing the impact on the surroundings and minimizing the cost to farmers.

The system was deployed initially in Prashant Agro Farm (Materwadi, PimalgaonBaswant) and also Boraste farm(Sakura, PimapalgaonBaswant) in September 2019. The arrangement included two types of sensor hubs dependent on ESP8266 microcontrollers. Type-1 nodes monitor environmental information and Type-2, precipitation level. A battery was used to satisfy the power supply of the grapevine in an economical manner. The data gathered by the developed system is introduced through an easy to understand LCD interface for representation. The information can also be accessed online through the cloud and can be operated from any PC, tablet or smartphone with the sole prerequisite of having a browser and an Internet link. Additionally, the framework offers state-of-art information to deal with the grape plantation in the form of cautions by means of messages to the farmers. As regards to the tests performed, it was confirmed that the framework executed well in a real-world situation and also gave accurate information gathered on the climate, the nodes, and the alarms related with the advancement of Downey and Powdery Mildew grape disease.

To summarize, all outcomes from the proposed system affirm that it offers excellent information to the grapevine producers to automate the detection of Downey and Powdery Mildew through monitoring weather related variables while providing a cost-effective system for the ranchers to address real-time climate issues surrounding disease manifestation in grape plantations.

CRediT authorship contribution statement

Kainjan Sanghavi: Conceptualization, Methodology, Writing – original draft, Visualization, Investigation. **Mahesh Sanghavi:** Data curation,

Table 6
Comparison of proposed system with existing systems.

Parameters / Authors	Early Detection of Grapes Diseases Using Machine Learning and IoT (Patil and Thorat, 2016)	WSN Monitoring of Weather and Crop Parameters for Possible Disease Risk (Das et al., 2009)	Unique Technique for Grape Leaf Disease Detection(Kharde and Kulkarni, 2016)	Proposed Scheme
Diseases Covered	Downey Powdery Bacteria LeafSpot Anthracnose	Downey Powdery	Downey Powdery Black Rot	Downey Powdery
Early Stage Detection	Yes	Yes	No	Yes
Notification	No	No	Yes	Yes
Technique Used	IOT	WSN	IP	IoT
Accuracy	Downey 90.9% Powdery 90.9%	Downey 87% Powdery 84%	Downey 90.47% Powdery 92.85%	Downey 94.4% Powdery 96%
Cloud based	No	Yes	No	Yes
Year	2016	2014	2016	2020

Writing – original draft. **Archana M. Rajurkar:** Writing – original draft, Supervision.

Declaration of Competing Interest

Please check the following as appropriate:

o All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version.
o This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.
o The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript.

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