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Dear Claudio Arcos:

We are pleased to inform you that your work "IoT applied to improve production controls in the Ecuadorian floriculture sector" has been accepted for oral presentation and publication at the IV International Conference on Research and Innovation - CI3 2023, to be held from August 30 to September 1 of this year.

All papers accepted at the conference will be published in the CI3 2023 Proceedings and indexed in the SCOPUS bibliographic database."

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You must confirm your participation in the conference and submit the final version of your paper by August 27, 2023, with the following attached documents:

- Complete article in MS-WORD or Latex format (1 file).
- Complete article in PDF format (1 file).
- Scan the proof of payment of the conference registration, including paper ID in the Easychair platform, 1st author name and affiliation (1 file).
- For the presentation of the speaker on the day of his presentation, a document (Word or pdf) is required with the paper title, full name, academic degree and mini biography (5 lines) of the speaker (1 file).
- The 4 documents must be sent to info@ci3.tech, with a copy to ci3@ister.edu.ec.

Finally, we ask that you consider papers published in earlier versions of CI3 for citation in your accepted publication. The papers published in past editions can be consulted at the following link:

https://na01.safelinks.protection.outlook.com/?url=https%3A%2F%2Fister.edu.ec%2Fcongreso%2Ftechnical-papers%2F&data=05%7C01%7C%7C8e6ac6fbcd3741b3b3f308db96d68606%7C84df9e7fe9f640afb435aaaaaaaaaaaa%7C1%7C0%7C638269620337664844%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C3000%7C%7C%7C&sdata=cGPuc%2BdNnJgz8zCTzIkCdWQ1icTq6Luz0sVjX3nlMf8%3D&reserved=0.

Do not hesitate to contact us if you need more information (info@ci3.tech).

We look forward to hearing your presentation at CI3 2023!

Regards,

Ph.D. Marcelo Zambrano V.
GENERAL CHAIR
CI3 2023

IoT applied to improve production controls in the Ecuadorian floriculture sector

Claudio Arcos, Ph.D.[1][0000-0002-0438-8933] and Pablo Calvache, M.Sc. [2][0009-0007-7518-4392] and Ricardo Calderón, Eng. [3][0009-0001-2354-4065]

[1] Associate Researcher in San Francisco Global Foundation and ISMAC Technological Institute, Quito, Ecuador
claudioarcos@sanfranciscoglobal.org

[2] Graduated Vice-rector and full-time teacher at ISMAC Technological Institute, Quito, Ecuador
pablo.calvache@tecnologicoismac.edu.ec

[3] Associate Researcher in World Roses Center Farm, Tabacundo, Ecuador
cio@worldrosescenter.com

Abstract. Using the IoT concept, a sensor network is deployed in a 30,000-square-meter crop of roses covered under a greenhouse, the same one that is located at 2,900 meters above sea level. For a year and a half, humidity, dew point, temperature and VPD data are collected, reaching a database of more than 49 million data that are used to contrast and analyze the data collected in the same period, related to diseases and pests present in the production of roses. The results show that there are levels of correlation that allow determining mechanisms for measuring environmental conditions in production to improve the efficiency and effectiveness in the decision-making process for better crop management.

Keywords: IoT, digital transformation, precision agriculture

1   Introduction

Between the years 2018 and 2022, Ecuador exported 20.46% of a total of USD$15,850'580,000.00 of the fresh cut roses product, thus becoming the second most exporting country of this product during that period, below the Netherlands and above Columbia [1].

In this context, rose crops in Ecuador must implement control technologies in productive management to meet local and international demands in various areas. The phytosanitary field is one of the areas whose management, adequate or not, positively or negatively affects access to international markets, compliance with local controls, quality improvement and waste reduction.

The fact is that damage to the rose plant can occur in different ways. The main damage is caused by pests such as thrips and mites or diseases such as botrytis, powdery mildew and downy.

In this sense, the concept of precision agriculture is transcendental to implement mechanisms that favor the control and management of potential effects on plants. In this context, it is important to first understand what IoT is as a mechanism to promote precision agriculture in rose production, and secondly what are the main diseases and pests that affect the cultivation of roses.

1.1   IoT as a mechanism to promote precision agriculture in rose production

At present, the domain of agriculture results from the application of methods that, by using technological instruments, allow the improvement of traditional cultivation methods in the areas that are possible [2].

The fact is that knowledge-intensive solutions such as the use of sensors, drones, automated irrigation systems, real-time monitoring, timed disinfection, etc., make it possible to enhance the organization's resource and capacity management and favor productivity, efficiency, control of pests and diseases, quality of the final product and competitive access to markets, mainly.

For this reason, farmers are constantly looking for mechanisms to manage the risks of climate change. In this context, the Internet of Things, known as IoT, is a technological evolution that provides access to data, information and services of the activities in which it is applied, through intelligent networks that deliver data in real time [3].

The IoT applied to agriculture can improve several processes, because with better information it is possible to deploy actions to sustain the quality of the product during the production process and thus satisfy customer requirements [4].

In the flower sector, with the application of sensors within the IoT concept, it is possible to know what is happening with the production processes in terms of their incidence environment. In other words, in order to maintain optimal growth and development conditions for rose plants inside a greenhouse, it is necessary to control and manage, among other things, the temperature, humidity, vapor pressure deficit and the dew point within the crop environment [5].

The use of IoT technology can simplify this management by obtaining data from said measurements in real time and, with the analysis of these data, favor decision-making for the good of the production process, as well as the management and control of pests and diseases.

The diffusion of these technologies for the improvement of competitiveness in the flower sector of Ecuador is essential. This is because it has been shown that the presence of innovation activities depends on the execution of various skills within the organization, and its innovative approach is stimulated by mastering a portfolio of technological skills from which they are carried out. R&D activities and, if digital transformation and absorption are not promoted, innovation will not happen [6].

1.2   Diseases and pests that affect the cultivation of roses

Mainly: the development of cultural practices, adequate air circulation, correct protection of the growing area and irrigation, help prevent and control diseases and pests [7], This, plus the productive capacities of the peasants, which include their traditional and

ancestral knowledge on sowing and harvesting mechanisms and practices, have contributed to the development of the flower sector in Ecuador [8].

Additionally, there are organic and chemical treatments to manage pests and diseases, mainly pests such as thrips and mites or diseases such as botrytis, powdery mildew and downy [9] [10] [11].

As for pests, thrips are small insects that feed on the petals and cause cosmetic damage to the flower. For their part, the mites that affect roses are sap suckers, therefore, they feed on the sap of the leaves, causing them to turn yellow and dry.

Among the most common diseases are: botrytis, which is a fungal disease that generates brown spots mainly on the petals. Powdery mildew is also a fungal disease that consists of the appearance of a white coating mainly on the leaves and stems, the same that is similar to dust on the leaves, buds and stems. For its part, downy is another fungal disease characterized by the appearance of reddish or orange pustules on the underside of the leaves [12].

The different affectations can cause decomposition of the flower, premature wilting, weakness of the plant, disorder of the growth cycle, deformations, premature fall of the leaves, affectation of the photosynthesis process; all of this decreases the quality of the flowers, reduces their life time in the vase, and therefore decreases the competitiveness of the final product, with the consequent loss of the export market.

The control of environmental conditions inside the greenhouse facilitates decision-making regarding agricultural activities as well as the application of fungicides to protect the health of plants. The fact is that both pests and diseases are the result of poor production management in the face of changing environmental conditions that favor the appearance of pests and diseases, mainly temperature, humidity, vapor pressure deficit and the dew point.

2 Materials and methods

2.1 Database and variables

For the development of the study, five sensors were installed on June 25, 2021, the same ones that were distributed in 30,000 square meters of a rose farm located in Tabacundo - Ecuador, at 2,900 meters above sea level.

The sensors used are dataloggers that record and store the data in their internal memory, and transmit it in real time through the internet or it can be downloaded via Bluetooth. For the present study, the data was obtained by the transmission via the internet to a PC.

The characteristics of the sensors are:

- Wireless access to data.
- The recorded data can be downloaded but cannot be edited.
- It has user-configurable alerts.
- Unlimited number of users that can monitor the same sensor.

- Connection to a portal to monitor in real time through a mobile application that allows the storage and download of data in CSV format.
- Measures temperature ranges from -40ºC to +60ºC.
- Measures relative humidity ranges from 0% to 100% (prolonged exposure to >80% can create a lag of up to +3% in readings, this effect gradually reverses after returning to <80% conditions).
- Temperature accuracy (0ºC to 60ºC): +-0.3ºC typical, +-0.5ºC maximum.
- Temperature Accuracy (full range): +-0.7ºC typical, +-1.2ºC maximum.
- Humidity Accuracy (@25ºC, 20% to 80%): +-3% typical, +-4.5% maximum.
- Humidity Accuracy (@25ºC, 0% to 100%): +-4.5% typical, +-7.5% maximum.
- Signal range: 100 m in line of sight. It is greater with the use of an amplifying antenna that increases the coverage radius to connect the sensor signal to a router.
- Battery: CR2477 x 1.3V (duration of one year approximately).
- Dimensions: 40 x 40 x 16.5mm.
- Weight: 40 gr.
- Compatibility: iOS 8+, Android 4.3+, Bluetooth 4.0+

Each sensor obtains data on temperature, humidity, vapor pressure deficit, and dew point. Sensors are IoT technology that record, store, and transmit data over the Internet in real time to one or more terminals with Android or iOS systems. The network architecture is shown below (see Fig. 1).
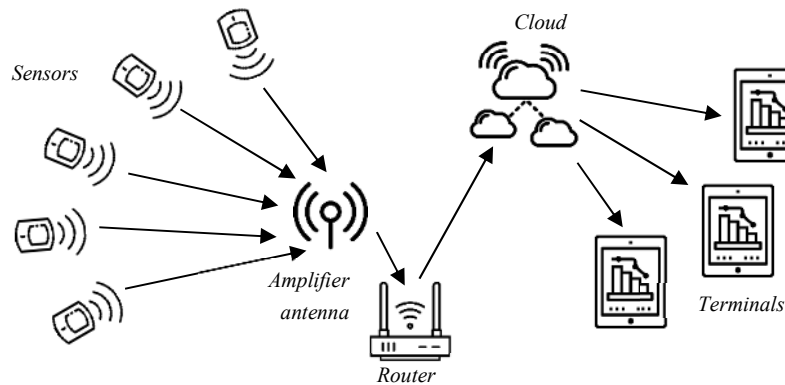
Fig. 1. Network architecture. Source: direct investigation.

Once the sensors were distributed, an amplifying antenna was fixed in the center of the five sensors at a distance of approximately 100 meters from each sensor to the antenna. The antenna was connected to a router with internet access via a network cable. The router receives and transmits the data in real time to any terminal that has installed access to the information transmitted by the five sensors.

The data is permanently displayed in the sensors' own software, which allows all the data to be downloaded in CSV format. The databases constitute structured repositories with observations managed by storage systems and software packages of the sensors. In this sense, to obtain the data under study, observations collected from June 25, 2021 at 12:40 p.m. to January 19, 2023 at 5:40 p.m. were considered.

The database consists of minute-by-minute observations of four readings: temperature, relative humidity, vapor pressure deficit (VPD) and dew point, within the crop environment, obtaining the following observations and data:

- Block 1 database: 825,421 observations and 9,905,064 data
- Block 2 database: 825,407 observations and 9,904,884 data
- Block 3 database: 825,411 observations and 9,904,932 data
- Block 4 database: 825,411 observations and 9,904,932 data
- Block 5 database: 825,414 observations and 9,904,968 data

In order to compare the measurements of the five sensors with the state of the plants, the postharvest database of the company participating in the study was used. Said database stores daily information on harvest about production for exporting and discarded production. Discarded production is the number of stems discarded by pests and/or diseases caused in the rose, which go through the composting process because they do not comply with quality parameters for export. Within the discarded production, the different causes analyzed in this study are recorded, such as: in pests: mites and thrips; in diseases: botrytis, downy and powdery mildew. In the same way, the period of time considered for the analysis of the post-harvest database is from June 25, 2021 to January 19, 2023, obtaining the following observations and data:

- Postharvest database: 289,270 observations and 5,785,400 data

Since in Ecuador there are critical points in the productive systems, such as the precariousness of governance and management capacity [13], it is essential to consider that the determining factors of innovation in organizations include the adoption of digital transformation tools, understanding this action as the acquisition or absorption of innovation.

Therefore, demonstrating the application of a system based on IoT to improve production from the implementation of innovation solutions stimulates the mastery of technological skills as determinants of innovation [6].

In this sense, it is understood that the IoT applied acts as a catalyst for innovation, for which the question for this research is: how to improve efficiency in the Ecuadorian floriculture sector using IoT?

3   Results

Prior to the statistical analysis of the databases, these were refined and organized, disaggregating the date and time data as individual variables, to facilitate the grouping of data in intervals by hours, days, weeks, quarters, and years; and the days June 25, 2021

and January 19, 2023 were discarded as they did not have the total number of observations on those days.

To treat the database, a very important criterion for the study was incorporated, such as solar luminosity, so that the observations were grouped considering the sunrise from 6:00 a.m., and the sunset at 6:00 p.m., as well as the highest point (zenith) 12:00 pm. Therefore, a weighted average of four indicators per day was obtained considering the daily luminosity and a simple average was applied for grouping the days per week.

In reference to the postharvest database, the data was broken down by dates in format (mm/dd/yy), to facilitate their grouping by days and weeks. The production data were disaggregated to obtain the discarded production due to pests and diseases, and the data from each of the five sensors were grouped to obtain the discarded production and its causes. Sundays and holidays were not considered for not having postharvest records.

For the analysis, the databases were grouped and the observations were structured in years divided into weeks with the readings of the sensors and the causes of national production obtained from the postharvest record.

Once the data of the sensor variables and the causes of discarded production have been organized by years and weeks, the normality test is calculated. The normality test is performed because it is necessary to examine whether the data follows a normal distribution or not. For the normality test we use the Kolmogórov-Smirnov test, which is performed at a 95% confidence level. According to the result of this test, the statistical model should be selected, either for parametric or non-parametric data, and the following hypotheses are proposed:

H1: The data set does not follow the normal distribution

H0: The data set follows the normal distribution

If the result of the Kolmogórov-Smirnov test is less than 0.05, then the H0 hypothesis is rejected, that is, the data set does not follow a normal distribution.

The database was processed with the SPSS software, and the results show that the pest and disease variables obtain significance values less than 0.05 (see Fig. 2, 3, 4, 5, 6), therefore the null hypothesis H0 is rejected and the alternative hypothesis H1 is accepted. Consequently, a statistical model for non-parametric data was then applied, it was Spearman Rho correlation coefficient, that is a nonparametric test used when the data does not follow a normal distribution.

Kolmogórov-Smirnov[a]			
	Stat.	df	Sig.
Humidity	,079	83	,200*
Dew point	,113	83	,011
Temperature	,058	83	,200*
VPD	,110	83	,015
Botrytis	,305	83	<,001
Powdery mildew	,306	83	<,001
Downy mildew	,308	83	<,001
Thrips	,191	83	<,001
Mites	,197	83	<,001

* This is a lower limit of the true meaning.
a. Lilliefors significance correction

Fig. 2. Normality test with data from sensor #1. Source: direct investigation.

Kolmogórov-Smirnov[a]			
	Stat.	df	Sig.
Humidity	,064	83	,200*
Dew point	,124	83	,003
Temperature	,063	83	,200*
VPD	,096	83	,056
Botrytis	,271	83	<,001
Powdery mildew	,308	83	<,001
Downy mildew	,353	83	<,001
Thrips	,259	83	<,001
Mites	,220	83	<,001

* This is a lower limit of the true meaning.
a. Lilliefors significance correction

Fig. 3. Normality test with data from sensor #2. Source: direct investigation.

Kolmogórov-Smirnov a			
	Stat.	df	Sig.
Humidity	,068	83	,200*
Dew point	,118	83	,006
Temperature	,063	83	,200*
VPD	,111	83	,013
Botrytis	,323	83	<,001
Powdery mildew	,302	83	<,001
Downy mildew	,273	83	<,001
Thrips	,283	83	<,001
Mites	,213	83	<,001

* This is a lower limit of the true meaning.
a. Lilliefors significance correction

Fig. 4. Normality test with data from sensor #3. Source: direct investigation.

Kolmogórov-Smirnov a			
	Stat.	df	Sig.
Humidity	,122	51	,057
Dew point	,139	51	,016
Temperature	,209	51	<,001
VPD	,132	51	,026
Botrytis	,280	51	<,001
Powdery mildew	,260	51	<,001
Downy mildew	,402	51	<,001
Thrips	,346	51	<,001
Mites	,183	51	<,001

* This is a lower limit of the true meaning.
a. Lilliefors significance correction

Fig. 5. Normality test with data from sensor #4. Source: direct investigation.

Kolmogórov-Smirnov a			
	Stat.	df	Sig.
Humidity	,085	82	,200*
Dew point	,117	82	,008
Temperature	,092	82	,085
VPD	,102	82	,033
Botrytis	,291	82	<,001
Powdery mildew	,305	82	<,001
Downy mildew	,299	82	<,001
Thrips	,309	82	<,001
Mites	,204	82	<,001

* This is a lower limit of the true meaning.
a. Lilliefors significance correction

Fig. 6. Normality test with data from sensor sensor #5. Source: direct investigation.

Once the Spearman correlation coefficient statistical method was applied to the database, the respective correlation coefficient levels were obtained. The interpretation of Spearman's correlation coefficient ranges between -1 and +1, indicating negative or positive associations respectively; 0 zero means that there is no correlation. The results can be seen in figures 7, 8, 9, 10 and 11.

Humidity					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	0,122	0,204	0,041	-0,054	0,165
Dew point					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	0,081	0,245	-0,021	-0,09	0,097
Temperature					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	-0,003	0,072	-0,085	-0,034	-0,108
VPD					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	-0,086	-0,078	-0,057	-0,064	-0,15

Fig. 7. Correlation of pests and diseases with data from sensor #1. Source: direct investigation.

Humidity					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	0,533	0,093	-0,028	-0,434	0,382
Dew point					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	0,664	0,3	-0,144	-0,45	0,554
Temperature					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	0,251	0,317	-0,174	-0,038	0,267
VPD					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	-0,284	0,107	-0,024	0,318	-0,165

Fig. 8. Correlation of pests and diseases with data from sensor #2. Source: direct investigation.

Humidity					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	0,573	0,442	-0,014	-0,236	0,377
Dew point					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	0,698	0,62	-0,187	-0,128	0,477
Temperature					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	0,335	0,391	-0,296	0,118	0,292
VPD					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	-0,222	0,09	-0,123	0,229	-0,066

Fig. 9. Correlation of pests and diseases with data from sensor #3. Source: direct investigation.

Humidity					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	0,452	-0,009	-0,248	-0,142	0,22
Dew point					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	0,689	0,295	-0,233	-0,03	0,384
Temperature					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	0,455	0,393	-0,018	0,168	0,236
VPD					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	-0,071	0,18	0,181	0,178	-0,02

Fig. 10. Correlation of pests and diseases with data from sensor #4. Source: direct investigation.

Humidity					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	0,524	0,299	0,106	-0,298	0,405
Dew point					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	0,713	0,373	-0,081	-0,079	0,425
Temperature					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	0,449	0,227	-0,276	0,234	0,144
VPD					
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho=	-0,116	-0,054	-0,219	0,348	-0,195

Fig. 11. Correlation of pests and diseases with data from sensor #4. Source: direct investigation.

According to the statistical analysis of the data and its correlation, the following can be noted:

Humidity. It is verified that there is a positive correlation between the relative humidity variable with the presence of botrytis. The relationship is directly proportional with values of Rho min= 0.122 in sensor #1 and Rho max= 0.573 in sensor #3.

It is verified that there is a positive correlation between the relative humidity variable with the presence of powdery mildew. The relationship is directly proportional with values of Rho min= 0.093 in sensor #2 and Rho max= 0.442 in sensor #3. In this relationship, sensor #4 is the only one with a negative correlation with Rho= -0.009, so the possibility of an investigation by rose variety is opened considering the types of roses existing in the analysis radius measured by this sensor.

There is not enough significance to prove a correlation between the variable relative humidity with downy. The values shown are negative Rho max= -0.248 in sensor #4 and positive Rho max= 0.106 in sensor #5.

It is verified that there is a negative correlation between the relative humidity variable with the presence of thrips. The relationship is inversely proportional with values of Rho min= -0.054 in sensor #1 and Rho max= -0.434 in sensor #2.

It is verified that there is a positive correlation between the relative humidity variable with the presence of mites. The relationship is directly proportional with values of Rho min= 0.165 in sensor #1 and Rho max= 0.405 in sensor #5.

Dew Point. It is verified that there is a positive correlation between the dew point variable with the presence of botrytis. The relationship is directly proportional with values of Rho min= 0.081 in sensor #1 and Rho max= 0.713 in sensor #5.

It is verified that there is a positive correlation between the dew point variable with the presence of powdery mildew. The relationship is directly proportional with values of Rho min= 0.245 in sensor #1 and Rho max= 0.620 in sensor #3.

It is verified that there is a negative correlation between the variable dew point with the presence of downy. The relationship is inversely proportional with values of Rho min= -0.021 in sensor #1 and Rho max= -0.233 in sensor #4.

It is verified that there is a negative correlation between the dew point variable with the presence of thrips. The relationship is inversely proportional with values of Rho min= -0.030 in sensor #4 and Rho max= -0.450 in sensor #2.

It is verified that there is a positive correlation between the dew point variable with the presence of mites. The relationship is directly proportional with values of Rho min= 0.097 in sensor #1 and Rho max= 0.554 in sensor #2.

Temperature. It is verified that there is a positive correlation between the temperature variable with the presence of botrytis. The relationship is directly proportional with values of Rho min= 0.251 in sensor #2 and Rho max= 0.449 in sensor #5. In this relationship, sensor #1 is the only one with a negative correlation with Rho= -0.003, so the possibility of an investigation by rose variety is opened considering the types of roses existing in the analysis radius measured by this sensor.

It is verified that there is a positive correlation between the temperature variable with the presence of powdery mildew. The relationship is directly proportional with values of Rho min= 0.072 in sensor #1 and Rho max= 0.391 in sensor #3.

It is verified that there is a negative correlation between the variable temperature with the presence of downy. The relationship is inversely proportional with values of Rho min= -0.085 in sensor #1 and Rho max= -0.296 in sensor #3.

There is not enough significance to prove a correlation between the variable temperature with thrips. The values shown are negative Rho max= -0.038 in sensor #2 and positive Rho max= 0.234 in sensor #5.

It is verified that there is a positive correlation between the temperature variable with the presence of mites. The relationship is directly proportional with values of Rho min= 0.236 in sensor #4 and Rho max= 0.292 in sensor #3. In this relationship, sensor #1 is the only one with a negative correlation with Rho= -0.108, so the possibility of an investigation by rose variety is opened considering the types of roses existing in the analysis radius measured by this sensor.

VPD. It is verified that there is a negative correlation between the VPD variable with the presence of botrytis. The relationship is inversely proportional with values of Rho min= -0.086 in sensor #1 and Rho max= -0.284 in sensor #2.

There is not enough significance to prove a correlation between the variable VPD with powdery mildew. The values shown are negative Rho max= -0.078 in sensor #1 and positive Rho max= 0.078 in sensor #2.

There is not enough significance to prove a correlation between the variable VPD with downy. The values shown are negative Rho max= -0.219 in sensor #5 and positive Rho max= 0.181 in sensor #4.

It is verified that there is a positive correlation between the VPD variable with the presence of thrips. The relationship is directly proportional with values of Rho min= 0.178 in sensor #4 and Rho max= 0.348 in sensor #5. In this relationship, sensor #1 is the only one with a negative correlation with Rho= -0.064, so the possibility of an investigation by rose variety is opened considering the types of roses existing in the analysis radius measured by this sensor.

It is verified that there is a negative correlation between the VPD variable with the presence of mites. The relationship is inversely proportional with values of Rho min= -0.020 in sensor #4 and Rho max= -0.195 in sensor #5.

4   Discussion

The use of IoT technology helps to obtain data in real time so a farm is able to take decisions also in real time looking to improve the production process, as well as the management and control of pests and diseases.

Controlling affectations that cause damage of the flower can help to get a better competitive level with the consequent increase of the possibilities for exporting.

As a result of the present study, the control of environmental conditions inside the greenhouse can help decision-making regarding agricultural activities as well as the application of fungicides to protect the health of plants. In this sense, this research proposes a data sheet that combines both, pests and diseases, to show when the farm should be alert about the changing environmental conditions that favor the appearance of pests and diseases, considering temperature, humidity, vapor pressure deficit and the dew point, to deploy actions to prevent the damage of the roses.

Figure 12 shows a set of indicators that consider the conditions of temperature, humidity, dew point and VPD, which when combined, resulted in the 20% of highest presence and incidence of diseases and pests. These indicators represent the possibility of improving production control through the IoT applied to the production of roses, and mean a guide for daily work on a farm that decides to implement digital transformation tools such as IoT and data analytics.

Estimated conditions for the incidence of botrytis				
Range	*Humidity*	*Dew point*	*Temperature*	*VPD*
MIN:	49.20	6.95	16.57	0.54
MAX:	77.50	14.77	22.02	1.66
Estimated conditions for the incidence of powdery mildew				
Range	*Humidity*	*Dew point*	*Temperature*	*VPD*
MIN:	57.72	9.80	16.03	0.59
MAX:	77.50	12.89	23.60	1.95
Estimated conditions for the incidence of downy mildew				
Range	*Humidity*	*Dew point*	*Temperature*	*VPD*
MIN:	55.57	7.11	13.82	0.36
MAX:	79.40	12.95	20.16	1.39
Estimated conditions for the incidence of thrips				
Range	*Humidity*	*Dew point*	*Temperature*	*VPD*
MIN:	48.90	8.36	16.56	0.66
MAX:	71.69	12.83	21.30	1.86
Estimated conditions for the incidence of mites				
Range	*Humidity*	*Dew point*	*Temperature*	*VPD*
MIN:	49.20	6.95	14.73	0.45
MAX:	79.10	14.02	21.27	1.71

Fig. 12. Data sheet of estimated conditions for the prevention of pests and diseases in the production of roses. Source: direct investigation.

5   Conclusions

In all cases it was evidenced that the incidence of pests and diseases has different levels of correlation with the environmental conditions inside the greenhouses. This information is useful to establish a data sheet with a set of indicators that allow the producer to know when it must be carried out preventive and even corrective actions due to the effect of knowledge about environmental conditions in real time.

The present study demonstrates the importance of the IoT applied to control production in the floriculture production sector, however, this study does not cover the economic impact and administrative management due to the fact of handling data on environmental conditions that could affect the crop. Nevertheless, the data sheet of estimated conditions for the prevention of pests and diseases in the production of roses is an important advance for this agricultural sector, the same one that should be measured in a new study.

The possibility of deepening the current study and developing decision-making methods based on statistical information built from the IoT applied to the flower sector remains open.

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