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Smart agricultural environments using knowledge representation with the use of IoT: Bibliometric Review

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Abstract: This review aims to show how to collaborate to reduce malnutrition through cultivation in small urban areas for the production of healthy foods through technologies. Therefore, this paper is focused on knowledge representation for smart farms. In addition, mention the trends of the technologies covered, allowing us to infer how the state of the art in the area will develop in the near future. The survey was done through a bibliometric review conducted according to (PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyzes), the protocol of preferred report items for systematic reviews and meta-analyzes. The results showed that the most covered topics when talking about Intelligent Systems for agricultural environments using knowledge representation are expert systems with the use of rules, because it is the best known way of representing knowledge currently used in small systems using production systems to encode condition-action rules.

Keywords: knowledge representation, arduino, Iot, intelligent systems, smart agricultural environments.

Adherence to the BJEDIS' scope: This work is closely related to the scope of BJEDIS as it presents a text mining that allows foreseeing trends of use knowledge representation in Iot system to smart farm.

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1. INTRODUCTION

According to [1] by 2050, 70% of the world's population will live in urban areas and a significant factor associated with food insecurity in urban areas is the lack of access to healthy food. Food insecurity is the limitation or uncertainty of the availability of nutritionally adequate and safe food or the limited or uncertain capacity to purchase food in socially acceptable ways [2]. This insecurity is present in several groups, including small farmers, salaried workers, refugees, groups that are not provided for in the urban population in general [3]. Some neighborhoods in urban areas, particularly those that comprise a significant percentage of diverse ethnic and cultural groups, have less access to healthy foods, such as: fresh fruits and vegetables [4]. In addition, poor urban neighborhoods also have a disproportionately high number of snack bars, which have historically served highly processed and less nutritious food [5]. However, a problem that contributes as one of the main reasons presented for food insecurity is the access or distribution of food produced. Global efforts are being made by several organizations, trying to guarantee access to healthy foods for the relief of hunger [6]. One of the strategies used to reduce malnutrition is for people to use cultivation in small urban areas to produce healthy food.

Urban agriculture can be defined as the cultivation, processing and supply of food products through the cultivation of food in and around cities to feed local people [7]. Urban agriculture has become a worldwide phenomenon and, with mobile and data-centric technologies, is one of the keys to a sustainable future [8].

Among the challenges faced by this urban agriculture, it is possible to decrease with the use of technologies. In this context, the Internet of Things (IoT) can help. The IoT is a global network that links physical objects using cloud computing, web applications and communication networks. It allows devices to communicate, access information on the Internet, store and retrieve data and interact with users, creating environments intelligent, wide spread and always connected. Besides, to model the information and knowledge of small local farmers represented by them empirical, we will use the concept of knowledge representation that will allow to formalize in a symbolic this domain.

This work is focused on knowledge representation for smart farms. In addition, to mention the trends of the technologies addressed, allowing us to infer how the state of the art in the area will develop in the near future.

2. METHODOLOGY

The survey of related works survey research found in the literature that addresses intelligent agricultural environments for banana production (Musa spp) using knowledge representation using IoT.

The survey was done through a bibliometric review based on the work of Johan A. Wallin [9] and conducted according to (PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyzes), the protocol of preferred report items for systematic reviews and meta-analyzes.

The bibliometric survey was chosen because it is a method designed to answer a specific question, and makes it possible to collect, select and critically analyze the studies. The sources of a bibliometric study are, therefore, articles from original studies available in a database. In sections, 2.1, 2.2, and 2.3 are presented all the stages of the process adopted to conduct the bibliometric survey of the literature. The steps of the methodology used are described below: Section 2.1 named as a research method, we present the discussion of the search for works done at Google Scholar in the last 10 years, in the 2010-2020 interval, using the terms “Knowledge representation”, “Smart Farm”, “loT” and “Banana”. Section 2.2 presents the exclusion and inclusion criteria for works that will contribute to the review presented and, in addition, inform the data collection process that was used to gather the necessary information for the discussions presented in the subsections. In section 2.3, considering all the information collected, we present the conclusion about the review and where the new trends can go.

2.1 Research Method

The research method used consists of bibliometric analysis to quantify the scientific production on a given topic. This methodology finds a limited number of essential journals that are supposed to have the most relevant literature published on a given subject [10; 11].

This step consists of conducting a lean review focusing on the use of knowledge representation in smart farms being conducted according to the protocol of the preferred reporting items for systematic reviews and meta-analysis (PRISMA).

In this review, the electronic database used was Google Scholar. From there, we sought to research scientific articles, reviews, technical notes, master's dissertations, doctoral theses, as well as experience reports published in the last ten years (2010-2020). It is assumed that all published works are available online since this procedure is common in computer science.

In addition, the online tool Wordcloud (https://www.jasondavies.com/wordcloud/) were used to mine the most important words in the texts found. The conditions used in the Wordcloud website tool were: Spiral - Rectangular; Scale - n; 5 orientations from -60 to 60º; and number of words – 353.

Four keywords were determined as a search criterion for the survey of the database: Knowledge representation, smart farm, Iot and Banana. After defining the database and topics of interest, and the groups of search terms were defined. They have been pre-arranged as follows to create a Research Strategy: “Knowledge Representation AND Smart Farm”, “Knowledge Representation AND Smart Farm AND IoT”, and “Knowledge Representation AND Smart Farm AND IoT AND Banana”. After collecting all returned works, the analysis process was carried out. The analysis was based on three approaches, namely:

• 1 - Quantify annually all works during the study period.

• 2 - Quantify national and international work.

• 3 - Critically analyze the content of the title, abstract and keywords and determine which works will have adherence and relevance to this research.

In the analysis process, the inclusion criteria used were:

• Inclusion criteria - only works written in English were maintained, so the congruence of our work with the recovered works were analyzed.

• Inclusion criteria - screening of titles.

• Inclusion criteria - screening of abstract and keywords.

The results of the studies are presented in the following sections.

2.2 Results and discussions

A total of 108 scientific papers were found addressing the topic of intelligent agricultural environments for the production of bananas (Musa spp) using the representation of knowledge with the use of IoT. There was an increasing linear trend between the number of jobs and the study period, as shown in figure 1, R 2 = 0.82. 106 international works and 02 national works.

The research problem is to assess the following: How many scientific articles address the topic of smart farms using knowledge representation. How this theme has been distributed over the past 10 years. Check in the articles surveyed, studies that foster systems that support farmers and identify knowledge representation about smart farming approaches that make it possible to describe the main trends in the area.

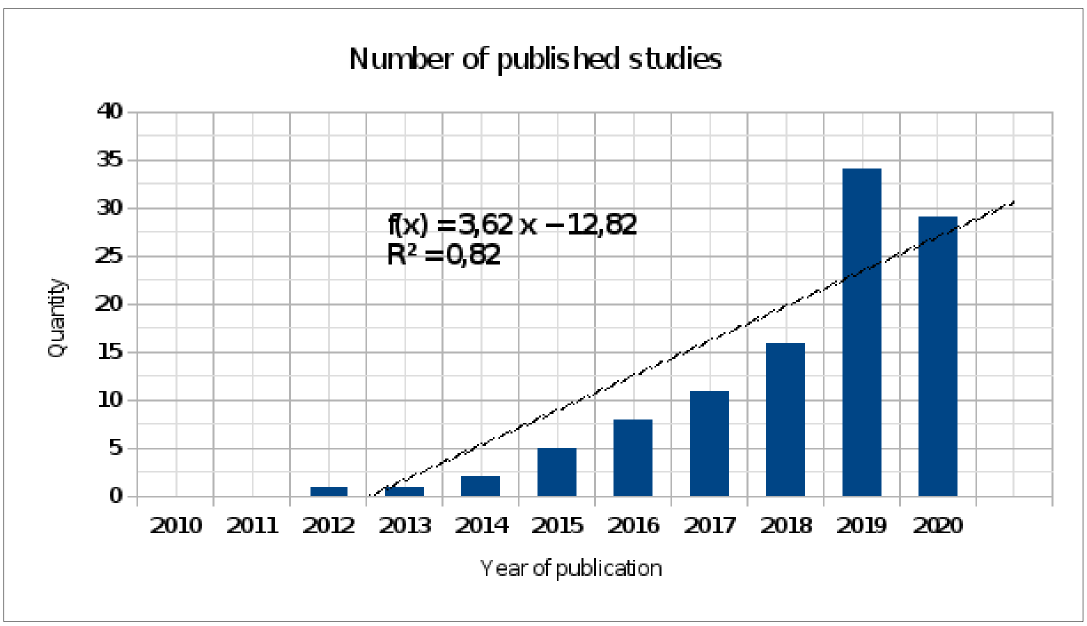

Figure 1: Number of published works related to the terms "knowledge representation," smart farm,"" IoT "and" Banana "in the last 10 years. Date of extraction at Google Scholar on 24/01/2021.

Thus, according to figure 3, continuing the extratification process, after applying the first inclusion criterion, 107 articles remained in the sample and one was rejected. After analyzing all retrieved articles, 8 duplicate articles were identified and removed. In the application of the second inclusion criterion, the works that were found in the research stage were eliminated based on the information provided in the title. Thus, 47 articles remained in the sample of 52 were rejected. In the application of the third inclusion criterion, the works were kept only for further processing if the abstract satisfied the research theme, the focus of the work is smart farms. Thus, 28 articles remained in the sample and 19 articles were rejected. The other articles were read in full and classified according to the research presented. Therefore, after reading 28 articles, 4 articles were excluded because they did not correspond to the objective of this research, as they focused on other themes. Twenty-four articles were considered eligible, 16 articles on intelligent agricultural environments using knowledge representation, 4 articles classified as a knowledge representation on various crops and 4 articles classified as intelligent agricultural environments for banana production (Musa spp) are using knowledge representation with the use of IoT.

To contribute to the extratification process, text mining was carried out. Text mining is a variation of data mining that allows data extraction from text documents [12]. The result of the analysis performed is shown in figure 2 according to the works considered.

Figure 2: Word clouds of the 24 eligible papers

2.2.1 Intelligent agricultural environments using knowledge representation

Systems for smart farms are based on the idea of taking advantage of Information and Communication Technologies (ICT) to improve the efficiency, productivity and effectiveness of agricultural operations [13]. It is noticed that from 2010 until 2012, only 1 work was found on Intelligent agricultural environments using knowledge representation. In the following years, 2013 until 2017, this number increased, increasing to 7 works found.

However, as of 2018, it appears that the theme has been growing over time, with 8 more works being found in the period from 2018 to 2020. Various types of systems are presented to collaborate in improving efficiency or productivity of agricultural operations, including the following: A framework based on Multi-Agent systems (MAS) and Machine Learning techniques, such as neural networks and evolutionary algorithms, in the work entitled "FIoT: an agent-based framework for self-adaptive and self-organizing applications based on the Internet of things "[14]. A research paper, covering state-of-the-art agricultural systems and big data architectures, both in research and commercial status, to bridge the knowledge gap between agricultural systems and big data exploitation, entitled "Toward smart farming: systems, frameworks and exploitation of multiple sources" [15].

In the paper, "Understanding the Internet of Things: definition, potential, and societal role of a fast evolving paradigm," the evolutionary stages, that is, the generations, that have characterized the development of IoT, with the motivations for its triggering, were presented , one being smart farms, where the status of the crop and land is under control, many of the production procedures can be activated remotely by the farmer, sales can be synchronized with the production, and the use of resources corresponds to the real needs.

However, extremely relevant systems are easy to deploy and use. Otherwise, the setup and maintenance costs outweigh the benefits [16]. Another paper entitled as "Toward a semantically enriched computational intelligence (SECI) framework for smart farming" advocates the use of Semantically Enriched Computational Intelligence to manage the complex tasks of smart farming. Specifically, he proposes ontology-based Fuzzy Logic to deal with inaccuracies inherent in the smart farming domain [17]. In "M-learning for promoting advancements in agriculture: an innovative educational model for Ethiopian farmers" the research proposes an educational model for all farmers to learn and expose the latest technologies in agriculture as well as peer interaction to solve critical issues during farming [18]. In the paper "Representing situational knowledge for disease outbreaks in agriculture" an automated situational knowledge projection system for disease outbreak in agriculture was presented. The system supports farmers and agricultural consultants in obtaining and maintaining alerts about disease outbreaks in cultivated crops. It models objects such as autogenic plants and crop plots, and their relationships, in situations observed by an environmental monitoring system. He uses a mechanistic disease pressure model to obtain knowledge about observed situations from forecast data for various climate parameters [19]. In the article "How artificial intelligence improves agricultural productivity and sustainability: a global thematic analysis," the author presents the potential benefits of Artificial Intelligence that are expected in agriculture, filling the missing gaps for a comprehensive understanding of the goals motivating the adoption of AI and its impacts [20]. In the paper "Ontology driven AI and Access Control Systemsfor Smart Fisheries" a smart fisheries ecosystem was presented, where the architecture describes various interactions that occur between Internet-connected devices.

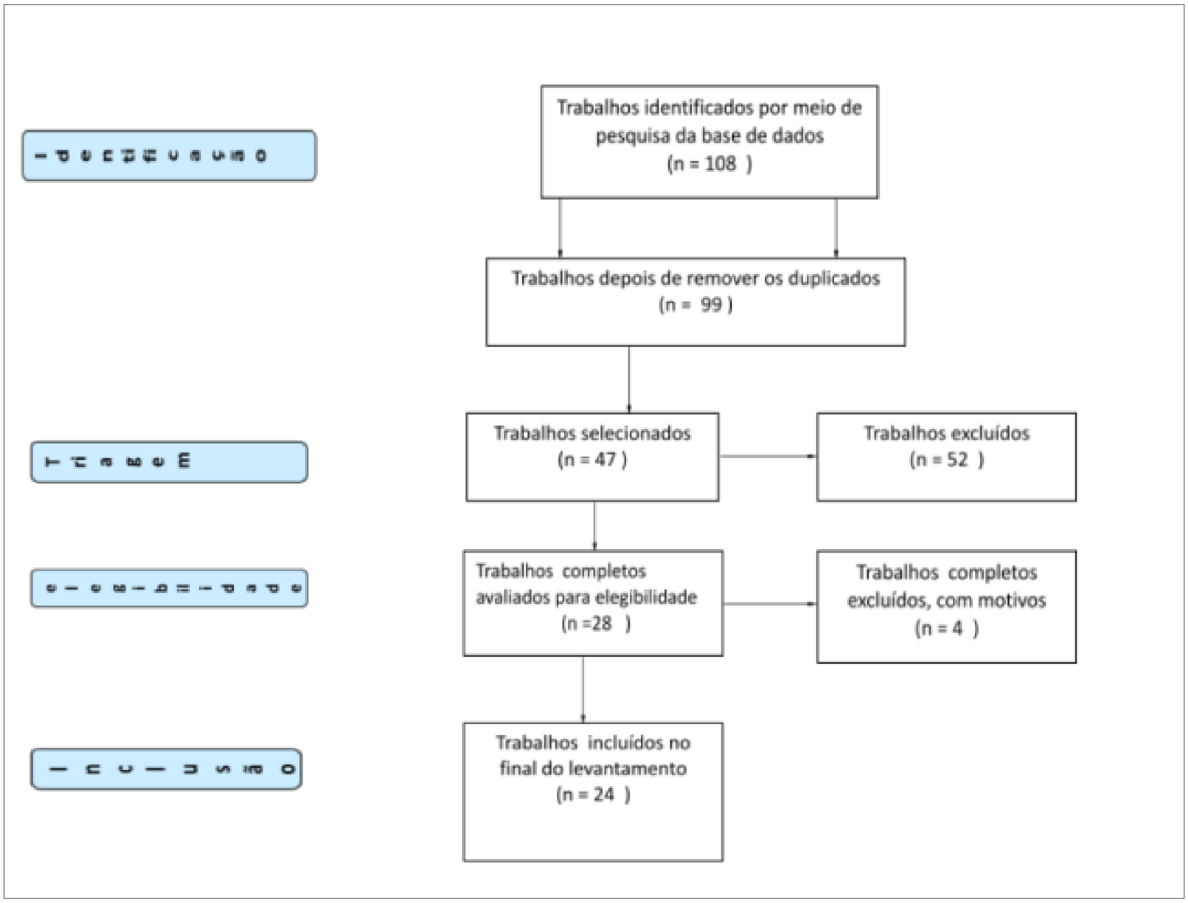

Figure 3: Flowchart of the process according to the protocol of preferred reporting items for systematic reviews and meta-analyzes (PRISMA)

An architecture-based smart fishing ontology was developed and an Attribute-Based Access Control System (ABAC) was implemented where access to smart fishing resources is granted by evaluating requests. It was also discussed how access control decisions are made in various use case scenarios of a smart fishing ecosystem [21]. In another paper "Modeling quanti-fied things using a multi-agent system" an overview of the concept of Quantified Things (QTs) and the main requirements for creating QT applications was provided. In addition, an agent-based model was presented as a solution to meet these requirements. To illustrate the use of this model, an example of one of the Quantified thing applications was derived: "Quantified Fruit". Using the concept of "Quantified Fruit," some fruit warehouses using sensors to monitor environmental conditions such as temperature, relative humidity, lighting, and some gases that can affect fruit ripening. In turn, they inserted these collected data into a cloud database and consequently enable knowledge sharing [22]. In the article, "Deep learning for IoT big data and streaming analytics: a survey" the author provides a comprehensive overview of the use of a class of advanced machine learning techniques, i.e., deep learning (DL), to facilitate analysis and learning in the IoT domain. The author started by articulating characteristics of IoT data and identified two main treatments for IoT data from a machine learning perspective, i.e., analysis of big data of IoT and streaming data analysis of IoT [23]. In "Ontologies and artificial intelligence systems for the cooperative smart farming ecosystem" a connected cooperative ecosystem was developed that defines sensors and their communication between different entities along with a cooperative hub with cloud support. Member farm and cooperative ontologies were developed to capture data and various interactions happening among the shared resources.

This paper can help generate AI supported insights for farmers and the cooperative. Several cooperative farming use case scenarios were discussed to demonstrate the functioning of the intelligent cooperative ecosystem [24]. In "Internet of things (Iot) and cloud computing for agriculture:an overview" reports that the development of knowledge-based systems for the agricultural sector should be focused on the Internet of Things, including geomatics or 3S (RS, GIS and GPS), sensor technology, WSN, RFID and cloud computing. The increased use of geomatics in agriculture is contributing to greener agriculture and greater environmental stewardship, while maintaining the economic viability of agricultural enterprises. Satellite and aerial imagery play a significant role in modern agriculture.

Advances in image sensors and Wireless Sensor Networks (WSNs) help identify and delineate the landscape for manageable food production zones at the field level faster and more effective than before and at much higher resolutions [12]. In the article, "Ontology-based Big Data Analysis for Orchid Smart Farming" the Orchid Smart Farming Recommendation System (OSFRS) was developed to link information between the ontology and the knowledge-based repository. The values measured by the sensor devices (IoT) are stored in the relational database management system that will combine concepts and this database to transform the data recorded in the ontology (classes and instances) into RDF format [25]. In the article "Internet of things for smart agriculture: technologies, practices and future direction" various potential IoT applications and the specific problems and challenges associated with IoT deployment for enhanced agriculture was reviewed.

To focus on specific requirements, the devices and wireless communication technologies associated with IoT in agricultural applications are comprehensively analyzed. Investigations are done on sensor-enabled IoT systems that provide intelligent services for smart agriculture [26].

2.2.2 Knowledge Representation of Various Crops

The field of knowledge representation aims at formalism that allow processing information and knowledge represented in symbolic form. Such formalism go beyond simple data storage and offer the possibility of connecting parts of information and turning implicit information into explicit information through semantic evaluation [27].

The presented research gathers few works on knowledge representation for some cultivation. In 2017 one paper was found. As of 2019, only three papers were found. The following works are presented below, "Landscaping the use of semantics to enhance the interoperability of agricultural data," "Knowledge representation and data sharing to unlock crop variation for nutritional food security", "Decision support for grape crop protection using ontology" and "Domain knowledge graph-based research progress of knowledge representation", respectively. In the paper [28], the main objective is to indicate the tasks where semantics is used or be used for the treatment of agricultural data and to expose the highlighting of bottlenecks, limitations and impacts on interoperability of the current situation of semantics in agriculture. In the paper [29], the development of a crop dietary nutrition ontology (ONDC) was proposed, which exposes a controlled and structured vocabulary for dietary composition and nutritional function, examples of specific use cases and different end users who would benefit from the use of ONDC terms in their database searches are provided. This development is transform the way crops can be compared in terms of optimal dietary nutritional values. In [30] the development of a system using ontology, semantic web rule language and image processing techniques for pest and disease management in grapes, particularly in the tropical region of India, was detailed. The main objective of the system is to minimize the use of pesticides and fungicides by preventing the occurrence of pests and diseases through information about the climatic conditions and their relationship with the occurrence of pests and diseases. The system was named PDMGrapes.

For the knowledge base of the system, the knowledge available in different formats about grapevine pests and diseases is converted into ontology. Favorable climatic conditions for the occurrence of pests and diseases are mentioned by the rules of SWRL - Semantic Web Rule Language. Grapevine diseases were identified by means of image processing techniques. Finally, [31], introduces the concepts related to knowledge representation and analyzes the knowledge representation of knowledge graphs by category, including some graphs of classic knowledge and several typical domain knowledge graphs. The paper also discusses the development of knowledge representation according to the difference of entities, relationships and properties. In addition, it also presents the unsolved problems in knowledge representation in the study of domain knowledge graphs.

2.2.3 smart farming environments for banana production using knowledge representation using IoT

According to the Food and Agriculture Organization of the United Nations (FAO), in 2017, banana (Musa spp) was produced in 128 countries and is one of the most consumed fruits in the world. Among the numerous varieties of fruits produced in Brazil, banana (Musa spp) stands out, not only for being the most widespread but also for being the most consumed by all social classes [32]. In 2017, the world production of banana (Musa spp) reached approximately 125.3 million tons. The four largest producers were India with 30.5 million tons, China with 22.8 million tons, Indonesia with 7.2 million tons, and Brazil with 6.7 million tons. Because it is one of the most popular tropical fruits grown in the country [33], increasing productivity, profitability of farms, obtaining high quality products and in quantities that meet the demands of consumer markets, both domestic and foreign, are strategies for the success of national banana farming [32]. So, the use of expert systems based on knowledge, facts and reasoning techniques to solve problems that can usually be solved only by experts in the field, has been a very important research topic for agriculture.

According to the works found, from 2016 began the development of Expert Systems with knowledge representation for banana (Musa spp) production using IoT. The works are "Xbee-based WSN architecture for monitoring of banana ripening process using knowledge-level artificial intelligent technique," "Expert System selection of superior Banana seeds using forward chaining method with a web application", "Rational System for Diagnosing Banana Disorders" and "Banana Knowledge Based System Diagnosis and Treatment", respectively.

For [34], monitoring focused on banana (Musa spp) ripening, demonstrates the use of an Xbee-based wireless sensor network (WSN). The role of the network architecture of the proposed work discusses in detail about the ability to monitor the condition of all necessary diagnostic parameters and ripening stages of banana (Musa spp). Furthermore, different features are part of the prototype, such as the use of a gas sensor. These resources are used for training the Artificial Neural Network (ANN) through the back propagation (BP) algorithm. The experimental results show that the designed WSN architecture can identify the condition of banana (Musa spp) in the storage area (post-harvest). To account for this challenge can be developed a monitoring system for agricultural environments, low cost, which uses IoT and knowledge representation to assist the decision-making process in the process of planting and harvesting, monitoring the climatic and soil variables for the best use of the crop.

According to the work [35], a system was developed to maintain the knowledge of the expertise of an expert in agriculture, especially banana trees, so that the system be used as an intelligent assistant in his area as a source of knowledge of the user. The direct chaining technique was used which is a search technique that starts with known facts and then, associates these facts to the IF sections of the IF_THEN rules. Based on the implementation results, it was found that the direct chaining expert system becomes easier for farmers, determining the banana (Musa spp) seeds according to the applied criteria can work smoothly and is easy to use.

According to the work [36], the main goal of this expert system is to obtain the proper diagnosis of Musa acuminata disease and the correct treatment.

In this paper, the design of the proposed Expert System has been produced to help farmers, people interested in agriculture and agricultural engineers in diagnosing many of the diseases of musa acuminata, such as Panama wilt, Mycosphaerella leaf spot, yellow sigatoka, black sigatoka, Anthracnose, Moko disease/bacterial wilt, tumbling or bacterial soft rot, and others.

The expert system presents an overview of the musa acuminata diseases, the cause of the diseases and the treatment of the disease, where possible, is provided. The Delphi language was used to design and implement the system. The results of the musa acuminata disease diagnosis system was evaluated by farmers, agricultural technicians and agriculture professors who were satisfied with the performance.

According to [37], the system was developed to use the knowledge extracted from farmers' complex information to continuously update and improve the developed system. In addition, the system diagnoses and provide appropriate advice on diseases of banana (Musa spp). One of the key elements of this research was to find the appropriate language to diagnose the disease and the current situation in the knowledge base. Expert systems allow for effective querying. Production rules were used to capture the knowledge. The expert system was developed using CLIPS with Delphi 10.2 as the user interface. The expert system produced good results in analyzing banana disease cases tested and allowing the system to determine the correct diagnosis in all cases.

3 CONCLUSION ABOUT REVIEW

The number of papers on smart farming environments using knowledge representation and smart farming environments using knowledge representation with the use of IoT had a significant increase over time, showing that there is the relevance of this topic. Both the use of expert systems and ontologies has increased by 57.9% over the past 10 years. However, the most covered topics when talking about Intelligent Systems for agricultural environments using knowledge representation are expert systems with the use of rules, because it is the best known way of representing knowledge currently used in small systems using production systems to encode condition-action rules. Thus, rules remain the most widely applied due to their ease of development. With the correct development of technologies, the use of smart systems can allow the application of applied technologies to the field, helping small banana (Musa spp) producers by increasing agricultural efficiency, which results in many economic and environmental benefits.

CONFLICT OF INTEREST: NONE

CREDIT AUTHOR STATEMENT

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