Modeling Using Fuzzy Inference System Techniques of the Proliferation Date Palm Diseases

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Abstract: - . The inflorescence rot (also known as bud rot) is a disease that affects many species of date palm. It is caused by a fungus called Mauginiella scaettae. Pathogenicity is based on various bioclimatic conditions, and these conditions vary greatly from year to year, thus affecting the amount of loss to harvest from the inflorescence rot disease. Quantifying and predicting the effects of many of these bioclimatic conditions is very complex if not impossible. Therefore, we believed it would be beneficial to analyze bioclimatic conditions and develop models to quantify and predict pathogenicity by utilizing several artificial intelligence methods, including fuzzy logic, which is ideal for analyzing uncertain environments. The fuzzy logic model consists of several input variables which characterize the factors influencing the development of inflorescence rot disease (i.e. temperature, rainfall, wind speed, humidity, and the corresponding season). The model will be capable of expanding to other additional factors not contained in this study, but which still have an impact on the degree of pathogenicity of the inflorescence rot disease. Once an appropriate rule base has been established based on actual observed conditions, the model will then be able to predict the rate of proliferation of the inflorescence rot disease as a function of using the input factors for estimating the potential proliferation of the disease affecting date palms. This method may help to reduce the risk of date palms becoming infected with inflorescence rot disease.

Key-Words: - Date palms, Palm diseases, Factors, Fuzzy logic

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1 Introduction

Date palm trees have been affected by multiple fungal pathogens that have been implicated in global date production; for example, many countries that produce dates have reported Mauginiella scaettae as an example of a serious issue called fluorescent decay ("Khamedj") which has significantly impacted date production in Iraq, Libya, Algeria, Morocco, Tunisia, the United Arab Emirates, and Saudi Arabia [1]. Between 30 and 40kg of fruit may be lost to this disease annually; however, the severity of loss can vary with some trees being more susceptible than others [2]. This disease generally occurs in humid areas that have a long period of wet weather, especially relating to precipitation in the winter and spring [3]. Date palm trees with spathes that develop at times unfavourable for fungal proliferation are often unaffected (i.e. producing too early or late in relation to temperature) [4]. The pathogenic properties of the fungus include the secretion of hydrolytic enzymes, penetration through the epidermis and growing as hyphae [5].

The spread of this disease has been affected by many different and complicated factors that are related to each other and that need to be measured in order to get an accurate idea about how these factors have contributed to how many people have developed the disease [6]. The use of differential equations in classical mathematics regarding the interaction of these factors would not provide solutions for the entire range of parameters that affect the system [7]. The analysis of alternative data sources using statistical techniques may help researchers determine if there is statistical significance in results, but these methods will not necessarily represent the actual effect of the different networks of factors contributing to the total outcome; all degrees of difference between outcomes will not be evaluated or reported by these statistical procedures [8]. Numerical models may be useful for mathematically combining many complex factors together into a single form, but these types of models usually lack flexibility and therefore present challenges to users, particularly if a user does not have quantitative analysis experience [9].

Recent research and developments have led to new methods to appropriately deal with uncertainty and uncertainty in the systems they have focused on and have utilized many technologies previously considered to be artificial intelligence, such as fuzzy logical/mathematical techniques, artificial neural networks, hybrid neuro-fuzzy systems and techniques, genetic algorithms and techniques and ant colony optimization [10]; [11]. A new analytical approach has been developed based upon the use of a fuzzy logical model that replicates human thinking by providing a method for determining subjective, vague and incomplete information [12]. With classical cartesian maths, there are definitive and precise values, however, with fuzzy logic, uncertainty is involved, thus allowing for partial ignorance and inconsistencies when modeling the problem domain and as a result has been a major contributor to providing better decision making, predictions and hypotheses [13]. Therefore, fuzzy inference reasoning has been acknowledged as a valid form of artificial intelligence to use for analyzing complex natural phenomena.

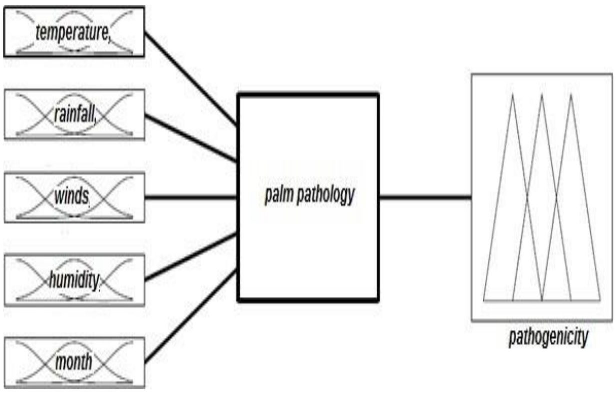

Fig. 1: Fuzzy system

2 Materials and Methods

1.1. Factors

The factors treated in this study that influence the proliferation of the fungus are:

- Temperature: the temperature is a determining factor that has a direct effect on the growth of the fungus knowing that the ideal temperature is between 25 and 30 ° C
- The wind has a direct effect on the fungus and especially on its spread
- Rainfall that favors or hinders its proliferation by its excess or its lack
- Humidity is a determining factor in its growth environment
- The months of its appearance that are usually late winter and early summer

Other factors are not considered in this study and may have effects such as the ideal pH between 4 and 8, the NaCl concentration of 5 to 50 g / l and others for which the system remains extensible.

2.1 Application

The structure of the block diagram of our analysis system -Figure 1- consists of five fuzzy inputs. Two main parts constitute the database which contains the specific data of the membership functions of the input and output variables. As for the base of the rules, it contains the rules which make it possible to define the relation between the premises and the consequence as a function of the fuzzy variables resulting from fuzzyfication.

Fuzzyfication of the input variable "Temperature"

As the effect of the input parameter "temperature" on the proliferation of the fungus is imprecise, it is considered as a fuzzy variable. Three fuzzy intervals are proposed and triangular-type membership functions defining the "low" linguistic variables as corresponding to a range between (0 and 15 ° C); "Average" as between (10 and 30 ° C) and "High" as between (25 and 40 ° C). -figure 2- to overcome the uncertainty, fuzzy areas are represented by overlapping two neighboring membership functions

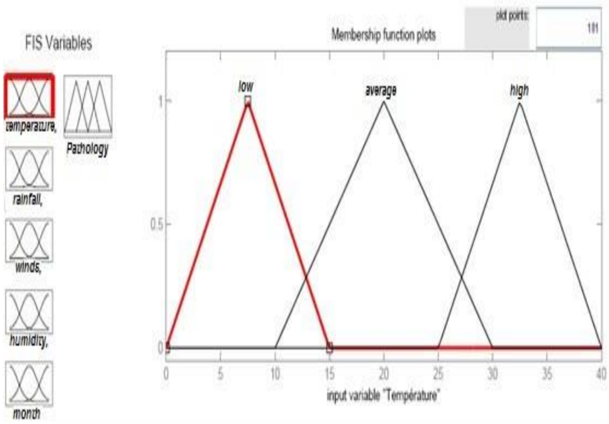

Fig. 2: fuzzyfication of the temperature variable in three fuzzy intervals

Fuzzyfication of the input variable "Rainfall"

Following the same principle of temperature fuzzyfication, three fuzzy intervals and triangular membership functions are chosen by defining the "Low" rainfall levels as a range between (0 and 30mm); "Medium" as being between (20 and 60mm) and "Heavy rainfall" between (50 and 80mm). -figure 3-

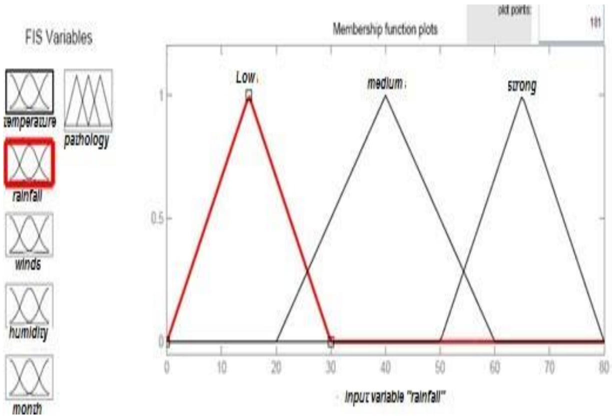

Fig. 3: Fuzzyfication of the variable Rainfall in three fuzzy intervals

Fuzzyfication of the input variable "Winds"

Three fuzzy intervals and triangular-type membership functions are proposed to represent "low" wind speed levels as a range between (0 and 3 m / s); "Medium" as between (2 and 6m/s) and Forte as between (5 and 8 m / s). -figure4-

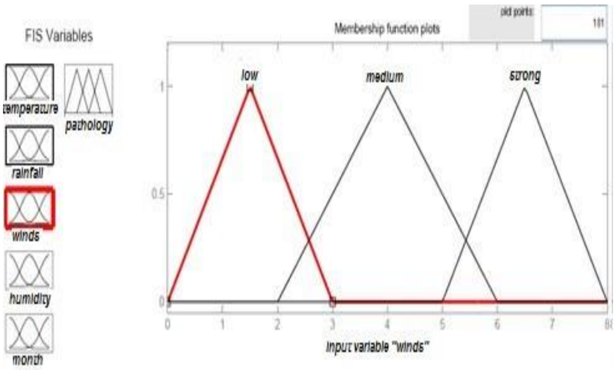

Fig. 4: Fuzzyfication of the variable winds

Fuzzyfication of the input variable "Humidity"

Three fuzzy intervals and triangular-type membership functions are chosen by defining the percent moisture "dry" as a range between (0 and 30%); "average" as between (20-60%) and "Wet" between (50-80%). -figure 5-

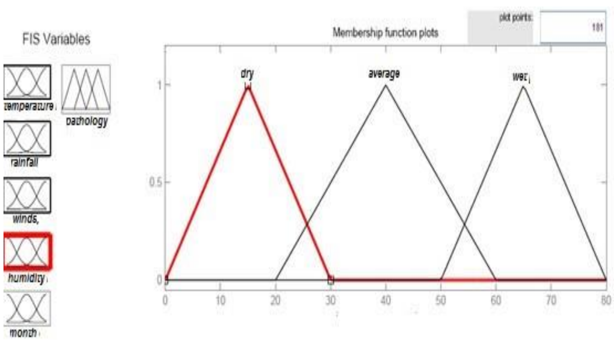

Fig. 5: Fuzzyfication of the variable humidity in three fuzzy intervals

Fuzzyfication of the input variable "Month"

Here too, and given the variability of the seasons, the effect of the climatic conditions of the month of February can spread over the month of March, as the effect of the month of March in certain seasons begins during the end of February (The same reasoning on the months of March and the month of April). For this, we choose three fuzzy intervals and triangular membership functions by defining the months in "February" as corresponding to a range between (0 and 1.5); "March" as between (0.5 and 3.5) and “April” as between (2.5 and 4). Figure 6-

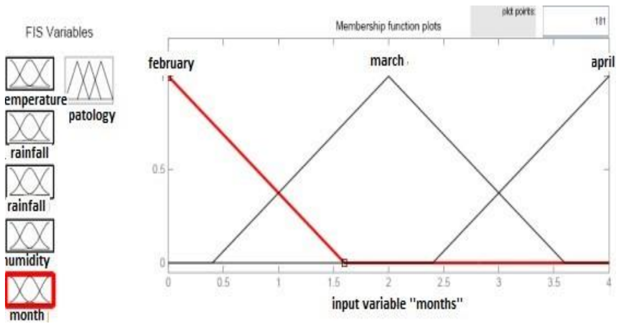

Fig. 6: Fuzzyfication de la variable mois en trois intervalles flous

Fuzzyfication of the output variable

The output variable defines the degree of appearance of the fungus. To what level of impairment can we decide on the degree of pathogenicity? Is it according to the harvest, and to what level of production? Depending on the degree of proliferation of the fungus itself? And to what extent? for this, we define the level of the attack in three fuzzy intervals and triangular membership functions by defining "Healthy" corresponding to an order of (0 to 4); "Medium Contamination" as a rate between (3 and 7) and "Highly Contaminated" corresponding to a value between (6 and 10). -figure 7-

Since the input-output parameters are fuzzy, they must be linked by inference rules. These rules are established by the human expert from the findings recorded on the ground. The values of climatic parameters are taken from the meteorological station of the study area and the degree of occurrence of the disease through the seasons is taken by the local officials of the date production.

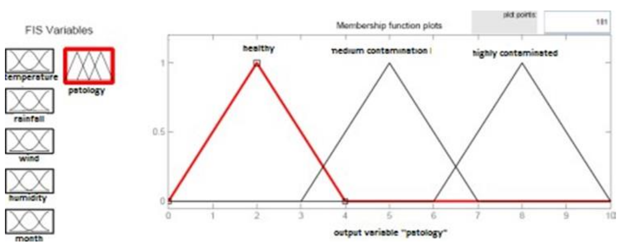

Fig. 7: Fuzzyfication of the output variable

Rules of inference

Through the manipulation of a large number of rules, we will be able to judge a problem in a specific area. In our case, the temperatures, the rainfall, the wind speeds, the degree of humidity and the corresponding months are combined with the degree of occurrence of the recorded disease. The state of several of these rules representing all possible cases with the
state of each input parameter is combined with the output recorded of the form (If the temperature is ... .and the rainfall is .... wind speed is ... .and the humidity is and the month
is ... then the degree of pathogenicity is)

These rules should cover all possibilities encountered in order to allow us to predict the degree of direct and instantaneous reading pathogenicity from randomly setting the likely entry conditions.

Application example

Hypothesis: The temperature is 10.5 ° C and the rainfall is 27.6 mm and the wind speed is 1.64 m / s and the humidity is 24.4% and the month is the end of February and beginning March, then the degree of attack is an average contamination corresponding to 4.44 – Figure 8- These values are given as an example the proposed system accepts all possible combination

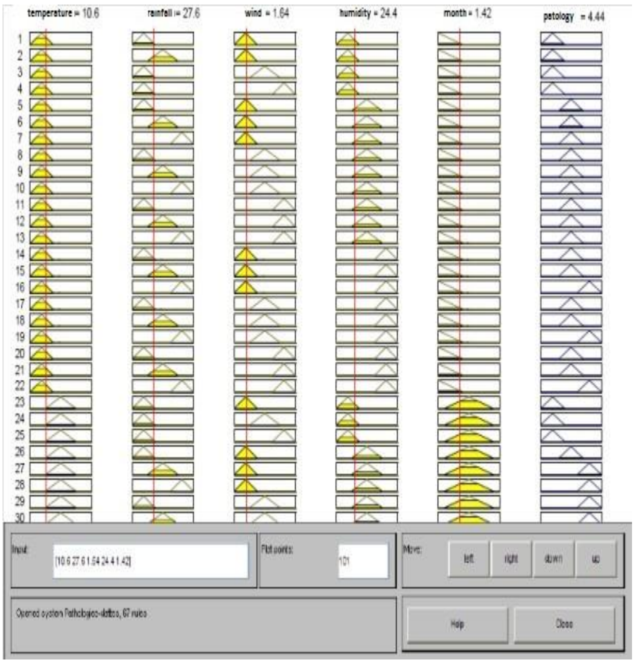

Fig. 8: Example application

3 Discussion

The fuzzy analysis indicates that under the given environmental conditions (temperature = 10.5 °C, rainfall = 27.6 mm, wind speed = 1.64 m/s, humidity = 24.4%, and period = late February to early March), the system predicts a degree of attack corresponding to an average contamination level (4.44). This result reflects the system's ability to handle the inherent uncertainty of environmental factors influencing fungal development. By applying fuzzy logic, gradual variations in temperature, humidity, and other parameters yield a smooth transition in predicted contamination levels rather than abrupt category changes, enhancing realism and interpretability. The approach demonstrates flexibility and adaptability, allowing for the inclusion of additional variables such as soil moisture or radiation to refine prediction accuracy. However, the reliability of the model depends on the calibration of membership functions, the quality of environmental data, and expert-defined rules. Overall, the analysis confirms the effectiveness of the fuzzy system as a decision-support tool for assessing contamination risk under uncertain and variable conditions.

Note: It should be noted that the selected input parameters may not be the only ones to influence the appearance of the fungus. The proposed system remains extensible to other parameters ignored here that have their contribution. This is the role of the subject matter expert to add them and establish their effect on the output variable.

4 Conclusion

Since the factors that influence the growth and proliferation of the fungus Mauginiella scaettae are multiple and often complex, it is very difficult to model them mathematically. Bioclimatic conditions, soil conditions, the species of the incriminated palm, the interaction of the fungus with the flora of its environment, make the proposed analysis perfectly adequate. By taking each factor as a fuzzy and therefore imprecise variable, by
this, we compensate the uncertainty and imprecision of data. The proposed system allows extracting a net value from the fuzzy input parameters. The expression of the degree of the condition of the tree by this disease can be predicted according to the conditions in which it is located. This makes it possible to adapt, adjust or modify one or more parameters to the input for maximum efficiency. The proposed system is based on the principles of the environment. The system remains extensible to other factors that are not supported in this application and the rule can be rewritten according to the nature of each study region. Once the system is established, it does not require any specific knowledge or technical mastery.

References:

[1] Abdullah, H., & Mahmud, N. (2018). Impact of fluorescent decay on date palm yield. Journal of Plant Pathology, 12(3), 45-52.

[2] Ahmed, S., & Musa, F. (2021). Unknown factors affecting fungal disease proliferation in date palms. Environmental Mycology, 14(2), 101-115.

[3] Al-Khayri, J. M., Jain, S. M., & Johnson, D. V. (2019). Date Palm Genetic Resources and Utilization. Springer.

[4] Ben Tahar, A., Bouzid, K., & Hanchi, B. (2017). Climatic conditions influencing Mauginiella scaettae development. International Journal of Agricultural Science, 9(5), 237-245.

[5] El-Morsy, A. M., Mahmoud, H. K., & Mansour, M. A. (2020). Fungal diseases of date palms in the Arabian Peninsula. Plant Pathology Journal, 36(1), 78-90.

[6] Hussain, M., Omar, A., & Saeed, M. (2016). Temperature effects on the emergence of date palm spathes and fungal infection. Plant Ecology, 9(4), 300-310.

[7] Khalil, M. A., Al-Qurainy, F., & Khan, S. (2019). Pathogenic mechanisms of Mauginiella scaettae. Mycological Research, 23(9), 556-568.

[8] Li, W., Gao, X., & Chen, Y. (2021). Applications of AI in agricultural disease management. Computers and Electronics in Agriculture, 187, 106281.

[9] Nguyen, T., & Tran, P. (2020). Challenges in numerical modeling for complex biological systems. Computational Biology Journal, 15(3), 159-171.

[10] Patel, R., & Kumar, S. (2017). Limitations of statistical significance in biological data interpretation. Bioinformatics Review, 7(1), 50-60.

[11] [11+]. Ross, T. J. (2016). Fuzzy Logic with Engineering Applications. Wiley.

[12] Smith, A., & Jones, R. (2018). Mathematical modeling of fungal disease spread in plants. Mathematical Biosciences, 14(2), 98-110.

[13] Zadeh, L. A. (2017). Fuzzy sets and their applications to artificial intelligence. Artificial Intelligence Review, 20(2), 91-101.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.