

Development of a Certainty Factor–Based Mobile Expert System for Palm Tree Pest and Disease Classification

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Abstract Palm trees are economically and culturally significant in many regions, yet they remain vulnerable to a variety of pests and diseases that can cause substantial agricultural losses. This study presents the design and implementation of a mobile-based expert system, PalmExp, which assists farmers and agricultural technicians in identifying six common palm tree pests and diseases using the Certainty Factor (CF) method. The system is built on a knowledge base developed in collaboration with an agricultural expert, incorporating rules that represent symptoms and their associated diseases or pests. The CF model enables the system to handle uncertainty and partial symptom presence, providing a ranked diagnosis with confidence levels. PalmExp is compatible with both Android and iOS platforms and supports bilingual use, making it accessible to a wide range of users, including farmers with limited technical expertise in the Middle East and North Africa regions. Evaluation results show that the system achieved a 95% diagnostic accuracy compared to expert assessments. The evaluation confirmed the accuracy and consistency of the system's diagnostic outputs, supporting its use as a practical expert tool in real-world agricultural environments. This study presents a full implementation and validation of the system, contributing an original research framework for mobile plant disease diagnostics.

Keywords Knowledge-Based System, Expert System, Computer-Assisted Diagnosis, Palm Trees, Pests and Diseases, Certainty Factor, Mobile Application, Agricultural Decision Support

1 Introduction

The date palm (*Phoenix dactylifera* L.) is one of the most vital fruit crops in arid regions of the Middle East and North Africa. Beyond its agricultural value, it plays an essential role in regional economies and food security. Despite their significance, palm trees are highly vulnerable to a variety of pests and diseases, which can severely impact productivity and lead to economic losses [1].

Early detection and diagnosis of palm tree diseases are critical for effective intervention. Traditional diagnostic methods—such as visual inspection, acoustic detection, and manual expert consultation—are time-consuming, labor-intensive, and prone to error [2]. In recent years, the application of Artificial Intelligence (AI) in agriculture has shown great promise for improving diagnostic accuracy and reducing response time.

Among AI-based approaches, Expert Systems (ES) have proven to be effective tools for encapsulating domain-specific knowledge into rule-based decision-making systems [3]. However, prior research on expert systems in agriculture has largely focused on general crops such as tomatoes, bananas, and cocoa, with limited attention to palm trees. Moreover, existing systems are often either web-based or limited to desktop environments, lacking mobile accessibility and real-time field utility.

This study presents PalmExp, a mobile expert system that leverages the Certainty Factor (CF) approach to provide probabilistic reasoning about palm tree diseases. It presents an original research contribution by developing and empirically validating a mobile expert system that applies rule-based reasoning to diagnose date palm diseases and pests. PalmExp is developed as a bilingual (Arabic and English) mobile application and is de-

signed with a user-friendly interface suitable for farmers with varying levels of technological literacy. The system integrates expert-verified symptom datasets and delivers diagnoses based on user input regarding observed symptoms.

The main contributions of this paper are:

- The development of a mobile expert system to diagnose six major palm tree diseases and pests.
- The integration of the Certainty Factor method for rule-based reasoning under uncertainty.
- A fully functional, cross-platform (Android/iOS) application featuring an intuitive user interface and Arabic language support.
- Validation of the system through expert feedback and accuracy testing, achieving 95% diagnostic accuracy.

The remainder of this paper is structured as follows: Section 2 provides background on palm diseases and expert systems; Section 3 reviews related work; Section 4 details the proposed methodology; Section 5 presents evaluation results; Section 6 discusses the implications of the findings; Section 7 concludes the paper; and Section 8 outlines directions for future work.

2 Background

2.1 Palm Tree Diseases and Pests

Date palms are highly susceptible to various pests and diseases that can severely impact fruit quality and yield. Understanding these threats is essential for developing effective management systems. Below are the primary pests and diseases targeted by the PalmExp expert system.

2.1.1 Red Palm Weevil

The Red Palm Weevil (RPW), *Rhynchophorus ferrugineus* Oliv., is considered the most destructive pest of date palms, causing substantial economic losses worldwide [4]. In Saudi Arabia alone, approximately 80,000 palm trees are reported to be infested [5]. Female weevils are attracted by volatile compounds emitted by palm trees, where they lay eggs. Upon hatching, larvae burrow into the tree trunk and feed internally, often without visible external symptoms until severe damage occurs [6]. This makes early detection particularly challenging, underscoring the need for intelligent systems to detect RPW infestations in their early stages.

Female red palm weevils are attracted by specific volatile organic compounds (VOCs) such as ethyl acetate, ethanol, and α -pinene, which are released from wounded or stressed palm tissues. These VOCs serve as strong olfactory cues for host selection [7, 8]. In the Middle East and North Africa, red palm weevil activity typically peaks between March and July, a period that coincides with rising temperatures and increased humidity conditions that enhance both adult weevil flight and larval development [9, 10].

2.1.2 Dust Mite

Dust Mite (DM), *Oligonychus afrasiaticus* McGregor (*Acari: Tetranychidae*), is a pervasive pest found across the Afrotropical, Nearctic, and Palearctic regions [11]. It predominantly affects immature date fruits during the Kimri stage, characterized by high moisture and low sugar content [12, 13]. During this stage, DM populations peak, enveloping fruit bunches in dense webs and causing significant scarring and damage. As fruits mature through the Khalal, Rutab, and Tamr stages, mite populations decrease. Highly prized date cultivars such as Medjool, Deglet Noor, Barhi, and Khalas are particularly vulnerable, with reported damage ranging from 30% to 80% [14].

This variation in infestation intensity across fruit maturity stages is closely linked to changes in fruit chemistry. Immature fruits provide a highly favorable environment for mites due to their elevated nitrogen content, soft texture, and higher levels of moisture and reducing sugars. In contrast, as the fruit ripens, it accumulates phenolic compounds and tannins, and its skin structure becomes lignified, creating chemical and physical barriers that reduce mite colonization and reproduction [14]. These chemical defenses in mature fruits help explain the natural decline in mite populations during the later stages of fruit development.

2.1.3 Black Scorch

Black scorch disease, caused by the fungus *Thielaviopsis paradoxa*, is among the most common fungal threats to palm trees [15]. It affects all parts of the palm, including buds, inflorescences, trunks, and leaves. The infection leads to symptoms such as tissue necrosis, twisting and distortion of leaflets, and charcoal-like lesions. Gariani et al. [16] reported losses exceeding 50% in young palms and fruit production. The pathogen enters through wounds and spreads rapidly under favorable environmental conditions [17].

2.1.4 Lesser Date Moth

The Lesser Date Moth (LDM), *Batrachedra amydraula* (Merriam), is a serious pest in date palm cultivation. Its larvae bore into inflorescences and young fruits, particularly during the flowering and early fruit stages [18]. LDM damage is comparable in impact to fungal infestations, leading to dried, discolored fruits that often detach prematurely [19, 20]. The pest is widely distributed and known to reduce overall fruit quality and marketability.

2.1.5 Fruit Rots

Fruit rot, commonly referred to as Khamedj, significantly limits productivity, with typical losses between 2–15% and up to 80% during severe outbreaks [21]. This disease has been reported across North Africa, Saudi Arabia, and parts of Europe [22, 23]. It causes inflorescence decay and soft tissue breakdown, leading to unmarketable yields and long-term impacts on palm health.

2.1.6 Al-Wijam Disease

Al-Wijam disease was first observed in the Al-Hassa region of Saudi Arabia [24]. Symptoms include stunted growth, leaf yellowing, and reduced fruit size and stalk length. Damage severity varies by cultivar, with yield losses up to 30%. Histological and treatment studies suggest the disease is caused by a phytoplasma, similar to those responsible for lethal yellowing.

2.2 Expert Systems

Expert Systems (ES) are a branch of applied artificial intelligence (AI) developed in the 1960s to emulate human decision-making processes. An ES enables computers to provide expert-level advice and recommendations in a specific domain by using encoded knowledge and inference rules [25].

An ES typically comprises five key components [26]:

- **Domain Expert:** An individual with specialized knowledge in the subject area for which the expert system is being developed.
- **Knowledge Engineer:** A technical specialist responsible for translating expert knowledge into a computable format using AI techniques.
- **Knowledge Base:** The repository of facts and rules derived from the domain expert. It stores information about symptoms, diseases, and decision-making rules.
- **Inference Engine:** The decision-making core of the ES. It compares user-provided inputs with rules in the knowledge base to draw conclusions. The CF (Certainty Factor) method is used here to handle uncertainty and compute diagnostic confidence.
- **User Interface:** The communication layer that interacts with users, collects input, and displays results. It also guides the user with follow-up questions to refine diagnosis.

Expert systems are particularly useful in domains like agriculture, where expert availability may be limited, and consistent decision support is required.

3 Related Work

Expert Systems (ES) have become increasingly valuable tools in agriculture by offering expert-level diagnostic and decision-making support to farmers. These systems enhance the efficiency of pest and disease management by leveraging domain knowledge and intelligent reasoning. Given the diversity of crops and regional variations in disease profiles, there is an ongoing demand for developing ES tailored to specific agricultural contexts.

Although significant progress has been made in designing ES for crops such as tomatoes, cocoa, bananas, and corn, research specifically focused on palm trees remains limited. To address this gap, we conducted a comprehensive review of the literature pertaining to the use of expert systems for plant disease diagnosis, with a special emphasis on palm trees. Our review is organized into two key subsections: (1) expert systems for diagnosing

diseases across various plant species, and (2) systems developed specifically for palm tree diseases.

This structured analysis enables a clearer understanding of the technological landscape, identifies existing limitations, and provides insights that can inform the development of domain-specific solutions for palm cultivation.

3.1 Expert Systems for Diagnosing Plant Diseases

Several studies have demonstrated the utility of expert systems in diagnosing plant diseases using different AI techniques and platforms. However, relatively few of these efforts target palm trees.

In Indonesia (2018), an ES based on Forward Chaining (FC) and the Certainty Factor (CF) method was developed to assist farmers in diagnosing common agricultural pests and diseases [27]. While effective in its localized context, the system lacked adaptability for broader applications. In Libya (2019), a web-based ES implemented with PHP, JavaScript, and MySQL enabled palm tree diagnosis through a user-friendly interface [28]. However, its dependency on internet access limits its utility in remote or rural settings.

In Malaysia (2018), researchers developed a mobile ES for diagnosing cocoa plant diseases using FC and rule-based logic [29]. A follow-up study in 2019 extended this work using Android Studio for app development [30]. Another notable approach employed the Dempster-Shafer method for diagnostic inference, offering expert-level tools and interactive symptom reporting via a web platform [31].

Tomato diseases have been addressed through mobile and web applications using FC and CF methods in both Android and PHP environments [32, 33]. In 2019, Clips-based inference was applied to citrus diseases, enabling user-driven symptom selection [34]. Likewise, corn diseases were diagnosed using CF logic in a dedicated expert system [35].

Banana plant diseases have been tackled using fuzzy logic (PHP-based) and case-based reasoning (CBR) methods [36, 37]. These systems diagnosed diseases by analyzing multiple plant parts and, in the case of CBR, supported offline functionality, a valuable feature for agricultural field deployment.

Table 1 summarizes the distinguishing features of these expert systems, including their reasoning methods, supported crops, implementation technologies, and access modes.

3.2 Diagnostic Systems for Palm Tree Diseases

Research efforts focused specifically on the diagnosis of palm tree diseases remain limited, with only a handful of studies addressing this challenge using modern technological approaches. Three notable studies have explored advanced diagnostic systems targeting palm trees, each leveraging different techniques and technologies.

The first study, conducted in 2018, aimed to evaluate multiple early detection techniques for palm tree infestations [38]. The researchers experimented with a combination of bio-acoustic detection, portable thermal imaging, and X-ray technologies. A

Table 1. Summary of related studies on the diagnosis of plant diseases and pests

Reference	Plant Type	Study Area	Applied Method	Implementation	Natural language	System Advantages
[27]	Palm Tree	Indonesia	Forward Chaining & Certainty Factor	NA	NA	Identifies diseases and pests based on early symptoms to provide early treatment.
[32]	Tomato	Indonesia	Forward Chaining & Certainty Factor	Android Studio (Mobile Application)	NA	Smartphone is more convenient and efficient.
[29]	Cocoa	Malaysia	Rule based System & Forward Chaining	NA (Mobile Application)	English, Malay	Users can interact with expert to get feedback.
[36]	Banana	Indonesia, Malaysia	Fuzzy Logic	PHP, MySQL (Web based)	NA	When developing the system, it will include a diagnosis of all parts of the banana plant.
[28]	Date Palm	Libya	Rule based System & Forward Chaining	PHP, JavaScript CSS, MYSQL (Web based)	NA	Diagnose and prescribe solutions to treat palm diseases anytime anywhere.
[37]	Banana	Indonesia	Case-Based Reasoning	Android Studio (Mobile Application)	English, Indonesian	Offline access. Search for similarities of the previous problem in the database.
[30]	Cocoa	Indonesia	Forward Chaining	Android Studio (Mobile Application)	English, Indonesian	Provide solutions to overcome diseases.
[34]	Citrus	Palestine	NA	Clips	English	This system allows the user to choose the symptoms that he sees in the plant.
[35]	Corn	Indonesia	Certainty Factor	NA	English, Indonesian	Provide solutions to overcome pests and diseases that attack the corn plants.
[33]	Tomato	Indonesia	Certainty Factor	PHP, SQL	English, Indonesian	Allows editing or removal from the symptom list.
[31]	Cocoa	Indonesia	Dempster Shafer	PHP, MYSQL	English, Indonesian	List for experts consisting of symptoms, diseases, rules, symptom reports, user reports.

suite of assessment tools was employed, including a tree radar unit (TRU), digital cameras, densitometers, and thermal sensors. The study demonstrated the potential of these technologies to detect internal and early-stage infestations, although practical implementation in field conditions remained challenging.

In 2019, another study focused specifically on the detection of the Red Palm Weevil (RPW) using thermal imaging techniques [39]. Initially, the researchers applied traditional detection methods such as visual inspection, acoustic monitoring, and chemical attractants. These were then compared against thermal imaging results, which proved to be effective in identifying RPW-infected palm trees in both quarantine and open-field environments. Thermal detection emerged as a non-invasive and rapid diagnostic tool, though it required expensive hardware and trained operators.

A third study, published in 2020, utilized image processing and

machine learning techniques to diagnose palm tree diseases from both visible and thermal images [40]. The research employed Convolutional Neural Networks (CNN) and Support Vector Machines (SVM) to classify visual symptoms. CNNs were used to detect leaf spot and blight spot diseases, while SVMs were applied to identify RAW pest infestations. The models achieved impressive diagnostic accuracies of 97.9% for CNN and 92.8% for SVM. These results validated the effectiveness of AI-driven image analysis for disease detection.

Table 2 summarizes key characteristics and findings from these previous studies.

Despite the encouraging results, all three studies depend heavily on advanced sensing equipment, machine learning algorithms, and specialized image acquisition tools. These requirements pose significant barriers to adoption in rural farming contexts, where access to such resources and technical expertise is often limited.

Table 2. Summary of related studies on the diagnosis of palm tree diseases and pests

Reference	Date of publication	Study area	Implementation method
[38]	2018	Italy, Saudi Arabia	Thermal camera, Tree radar unit (TRU), Digital camera, Densitometer.
[39]	2019	Egypt	Traditional Detection Methods, Thermal Detection Methods, Thermal Infested Palm Detection
[40]	2020	Egypt	Convolutional Neural Network (CNN)

Furthermore, the scope of prior studies has been narrow, addressing only a limited number of pests and diseases.

These limitations underscore the pressing need for diagnostic systems that are not only accurate but also accessible, user-friendly, and capable of functioning without high-end hardware. The PalmExp system was developed in response to this need, offering a mobile expert system powered by the Certainty Factor method, designed to deliver rapid, reliable diagnoses using simple symptom inputs. Its mobile accessibility and offline functionality position it as a practical alternative to high-tech detection systems.

4 Methodology

The development of the PalmExp expert system followed a structured, multi-phase methodology designed to ensure technical accuracy, domain relevance, and user accessibility. The process was carried out in the following nine sequential steps:

- 1. Problem Identification:** Identified the need for an accessible, accurate diagnostic tool to support early detection of palm tree diseases and pests.
- 2. Literature Review:** Analyzed existing plant disease diagnosis systems, with a focus on expert system design, reasoning methods, and mobile applications.
- 3. Requirements Analysis:** Conducted expert consultations to identify the most common palm diseases and pests, and documented their observable symptoms.
- 4. Dataset Collection:** Compiled a structured dataset containing six key palm diseases and pests along with their associated symptoms. The domain expert assigned Certainty Factor (CF) values to each symptom-disease pair.
- 5. Expert System Design:** Developed a rule-based expert system that integrates CF reasoning to handle uncertainty and symptom variability.
- 6. Validation and Testing:** Validated the inference engine using expert feedback and manually verified CF calculations.
- 7. Application Development:** Integrated the expert system into a mobile application using Flutter, ensuring cross-platform compatibility and a user-friendly interface.

8. Implementation Testing: Conducted functionality testing to ensure correct integration of the inference engine into the mobile environment.

9. Performance Evaluation: Compared the system's diagnostic results against those provided by the domain expert to assess diagnostic accuracy and reliability.

4.1 Requirements Analysis

To enable the expert system to accurately diagnose palm tree conditions, a domain expert was consulted to provide a comprehensive list of common palm tree diseases and pests, along with their distinctive symptoms. Six specific conditions were selected based on prevalence and economic impact. For each condition, the expert identified a set of symptoms and assigned a Certainty Factor (CF) value that represents the strength of association between the symptom and the condition.

Table 3 presents the diseases and pests included in this study along with their corresponding symptoms. The presence of these symptoms on a palm tree increases the likelihood of the associated disease or pest being present, which the expert system uses in its diagnostic reasoning.

4.2 Dataset Collection

In the dataset collection phase, the domain expert was asked to assign Certainty Factor (CF) values to each symptom associated with the selected palm tree diseases and pests. These CF values represent the expert's confidence in the association between a symptom and a specific disease or pest. The resulting dataset forms the foundational knowledge base for the expert system. Table 3 presents the CF values assigned to each symptom. This structured information was critical for the subsequent design and implementation of the expert system.

4.3 Expert System Design

The architecture of the proposed expert system is depicted in Fig. 1. The design follows standard ES architecture and incorporates CF-based reasoning tailored for mobile deployment.

- Domain Expert:** A plant pathology specialist who provided domain-specific knowledge, including symptom-disease mappings and CF values.

Table 3. Palm tree diseases and pests focused on in our research, along with their fruit rot and CF values

Disease Code	Diseases	Symptoms	Name of symptoms	Expert CF
H1	Red Palm Weevil	S1	Bored holes	0.8
		S2	Oozing sap	0.7
		S3	Chewing noises	0.8
		S4	Frass (sawdust-like material)	0.75
		S5	Wilting or yellowing fronds	0.8
		S6	Crown collapse	0.7
		S7	Unusual fruit drop	0.7
		S8	Weakening of the trunk	0.7
H2	Dust Mite	S9	Bronzing or Browning of Fruit	0.8
		S10	Premature Drying of Fruit	0.75
		S11	Fines Dust on Fruit and Fronds	0.9
		S12	Decreased Fruit Size and Weight	0.85
		S13	Leaves Discoloration and Lesions	0.75
		S14	Reduced Fruit Yield	0.8
		S15	Honeydew Production and Sooty Mold	0.8
H3	Lesser Date Moth	S16	Fruit Damage	0.85
		S17	Fruit Shedding (Premature Fruit Drop)	0.8
		S18	Webbing on Fruit Bunches	0.75
		S19	Drying and Shriveling of Fruit	0.8
		S20	Entry Holes on Fruits	0.9
		S21	Damage to Fruit Bunch Stalks	0.8
		S22	Presence of Larvae and Pupae	0.95
		S23	Stunted Fruit Development	0.8
H4	Khamedj (Fruit Rots)	S24	Softening of Fruits	0.8
		S25	Dark Brown or Black Rot	0.75
		S26	Foul Smell	0.85
		S27	Shriveling and Drying	0.8
		S28	Premature Fruit Drop	0.85
		S29	Fungal Growth on Fruit Surface	0.95
		S30	Clustering of Affected Fruits	0.85
		S31	Deformation of Fruit	0.8
H5	Al-Wijam Disease	S32	Moisture Retention in the Bunch	0.75
		S33	Leaves Yellowing	0.85
		S34	Wilting and Drying of Fronds	0.8
		S35	Stunted Growth	0.85
		S36	Bending or Drooping of the Central Crown	0.85
		S37	Poor Fruit Development	0.75
		S38	Premature Fruit Drop	0.75
		S39	Gradual Decline of the Tree	0.8
H6	Black Scorch Disease	S40	Vascular Tissue Discoloration	0.9
		S41	Fronds Black Charred	0.9
		S42	Leaflet Dieback	0.9
		S43	Trunk Black Streaks or Lesions	0.95
		S44	Inflorescence and Fruit Damage	0.85
		S45	Heart Rot (Bud Rot)	0.95
		S46	Frond Breakage	0.95
		S47	Internal Tissue Rot	0.9
S48	Premature Death of Palm	0.85		
S49	Gummy Exudate	0.95		

- **Knowledge Engineer:** A team of computer scientists and IT professionals responsible for designing and implementing the system using AI methodologies.
- **Knowledge Base:** A repository containing palm tree diseases and pests, their related symptoms, and expert-defined CF values.
- **Inference Engine:** The reasoning module that applies the CF method to infer diagnoses based on user inputs. This method was selected for its simplicity, interpretability, and ability to represent uncertainty effectively without requiring large datasets.
- **User Interface:** A mobile-friendly interface designed for ease of use by farmers and agricultural workers with varying levels of digital literacy.
- **End Users:** Target users include farmers, agricultural technicians, and other stakeholders involved in palm tree cultivation and management.

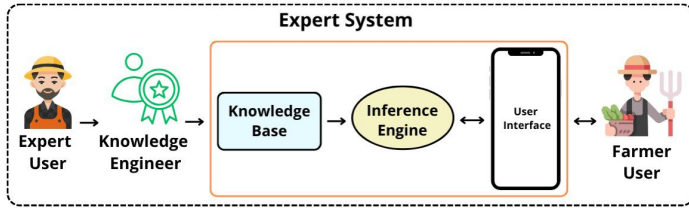


Figure 1. Components of the Proposed Expert System

4.3.1 Certainty Factor Method

The Certainty Factor (CF) method allows the system to model reasoning under uncertainty by combining expert knowledge with user input. It uses two types of inputs:

- **CF_{expert}:** The degree of belief assigned by the domain expert for a specific symptom–disease relationship.
- **CF_{user}:** The confidence level provided by the end user based on observed symptom severity.

The final CF is computed as the product of CF_{expert} and CF_{user}, indicating the joint belief in a particular diagnosis. CF values range from +1 (absolute certainty) to -1 (complete disbelief) [41].

The CF methodology is mathematically defined by the following equations [42]:

$$CF = MB(H, E) - MD(H, E) \quad (1)$$

$$CF = CF_{\text{user}} \cdot CF_{\text{expert}} \quad (2)$$

$$CF_{\text{combine},1,2} = CF_1 + CF_2 \cdot [1 - CF_1] \quad (3)$$

$$CF_{\text{combine},\text{old},3} = CF_{\text{old}} + CF_3 \cdot [1 - CF_{\text{old}}] \quad (4)$$

$$CF_{\text{combine},\text{old},n} = CF_{\text{combine},1,2,\dots,n-1} + CF_n \cdot [1 - CF_{\text{combine},1,2,\dots,n-1}] \quad (5)$$

These equations enable the system to incrementally combine multiple CF values derived from various symptoms, ensuring that the final CF remains within the logical range and reflects the cumulative evidence supporting a diagnosis. Table 4 describes the key terms used in these computations.

Table 4. Notation and Definitions

Symbol	Definition
$MB(H, E)$	Belief in hypothesis H given evidence E (0 to 1).
$MD(H, E)$	Disbelief in hypothesis H given evidence E (0 to 1).
$CF_{\text{combine},1,2}$	Combination of CF_1 and CF_2 .
$CF_{\text{combine},\text{old},3}$	Combination of previous CF and CF_3 .
$CF_{\text{combine},\text{old},n}$	Combination of all CF values up to CF_n .

4.4 Validation and Testing

Prior to deploying the expert system in a mobile environment, the Inference Engine underwent rigorous validation to ensure its accuracy. Expert feedback was solicited to assess the correctness of the system’s diagnostic outputs. Additionally, manual CF calculations were conducted to cross-verify the system’s results and confirm that the CF equations were implemented accurately within the codebase. This validation phase was essential to guarantee that the logic used by the Inference Engine aligned with theoretical expectations and expert judgments.

4.5 Application Development

Upon successful validation of the Inference Engine, the expert system was embedded into a mobile application to facilitate real-time diagnostics in agricultural settings. The application was developed using the Flutter framework within the Android Studio environment [43]. Flutter was selected for its cross-platform capabilities, enabling deployment on both Android and iOS devices.

For backend services, Firebase was integrated to manage user accounts, store diagnostic records, and synchronize data in real-time. Firebase, a cloud-hosted platform built on Google infrastructure, offers robust features including static content hosting, secure user authentication, and real-time database management [44]. Importantly, it also supports offline functionality, ensuring continued access in low-connectivity environments—a crucial feature for field usage.

Fig. 2 illustrates the user flow within the application. Upon launching the app, users are prompted to either sign in or create an account. After authentication, the user initiates the diagnostic process by answering symptom-related questions. Based on the inputs, the system computes the CF values and presents a diagnosis. Users are then given the option to save their results for future reference.

4.5.1 Diagnosing Procedure

The PalmExp application follows a structured diagnostic procedure to determine the most probable disease or pest affecting a palm tree. The steps are as follows:

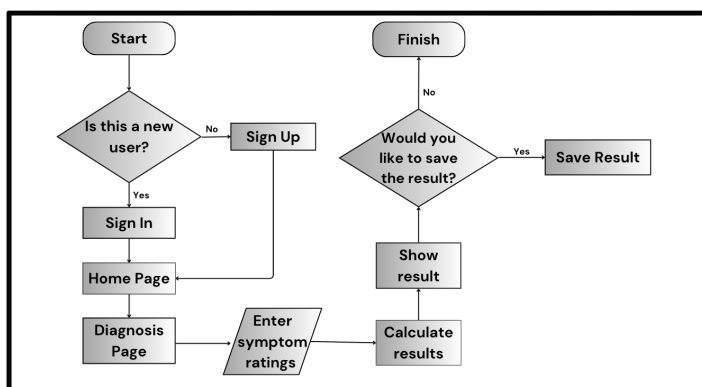


Figure 2. User Workflow Within the PalmExp Mobile Application

1. Users rate observed symptoms on a scale of 0%, 25%, 50%, 75%, or 100%, where 0% indicates absence of the symptom and 100% represents maximum severity.
2. For each symptom, the CF method is applied to compute its diagnostic weight using both user input and expert-defined values.
3. All possible diseases are ranked based on their aggregated CF scores.
4. The disease or pest with the highest CF score is presented to the user as the most likely diagnosis.

4.5.2 Graphical User Interface

The PalmExp mobile application features an intuitive and accessible user interface designed for ease of use across all farmer categories. Upon launching the app, users are prompted to sign in or register. Once authenticated, they are guided to the diagnosis page, which includes a brief explanation of the diagnostic process and a button to initiate symptom assessment, as shown in Fig. 3.

Users then proceed to a symptom assessment screen, where they rate various symptoms based on their observations. Fig. 4 and Fig. 5 show examples of the rating interface for two different symptoms. Upon completion, the application processes the input and displays a diagnostic result screen with the most probable disease and tailored recommendations, as shown in Fig. 6.

4.6 Testing the Application Implementation

To verify the correctness of the application's internal logic, a two-phase validation strategy was employed. First, manual CF calculations were conducted for a given set of symptom scores corresponding to each of the six diseases and pests. Then, the same scores were entered into the application, and the resulting diagnosis was recorded. By comparing these results, we confirmed the accuracy of the implementation. Due to space constraints, detailed validation results are reported for only two representative diseases in this paper.

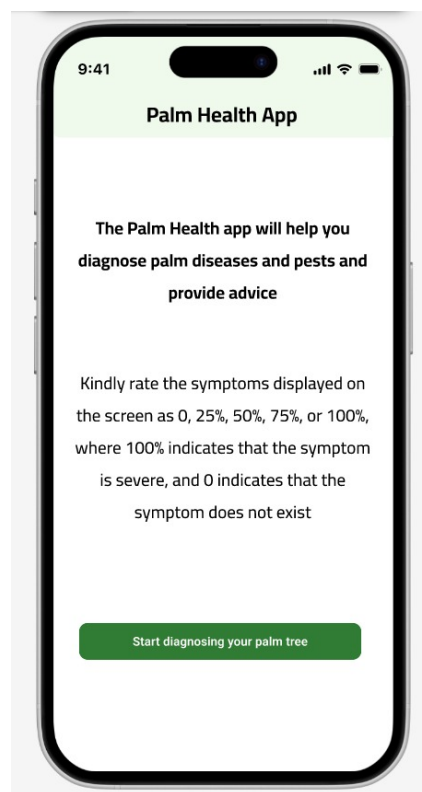


Figure 3. Diagnosis Screen of the Application

4.7 Performance Evaluation of the Application

The effectiveness of PalmExp was evaluated by comparing its diagnostic output against ground-truth diagnoses provided by a domain expert with over 22 years of experience in the field of plant pathology and entomology. It is important to note that the expert did not interact with the application directly; rather, he provided independent diagnoses for a set of 20 real-world cases.

The validation process involved the following steps:

- Collecting palm tree disease cases and obtaining expert diagnoses based on visual symptoms.
- Feeding the same cases into the application using observed symptom values.
- Comparing the application's results with the expert diagnoses.

The system's performance was assessed using accuracy, defined as the percentage of cases where the application matched the expert's diagnosis. This evaluation served as a benchmark to assess the reliability of the mobile expert system in real-world diagnostic scenarios.

4.8 Monitoring Timing Considerations

To support practical application and optimize monitoring efforts, the estimated seasonal peak periods for each of the targeted pests and diseases are summarized in Table 5. This information is intended to guide farmers and agricultural workers in focusing



Figure 4. Symptom Assessment Page Where the User Rates Symptom S24



Figure 5. Symptom Assessment Page Where the User Rates Symptom S41

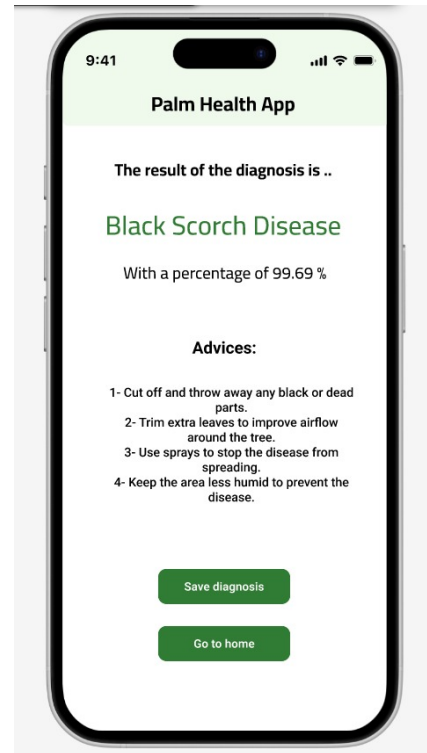


Figure 6. Diagnosis Result Screen

diagnostic efforts during periods of increased infestation likelihood.

Table 5. Estimated Peak Appearance Periods of Targeted Pests and Diseases

Pest / Disease	Peak Appearance Period	Reference
Red Palm Weevil	March – June; September – November	[7], [9]
Dust Mite	April – July	[45], [46]
Black Scorch	June – September	[47], [48]
Lesser Date Moth	March – May	[49], [50]
Fruit Rots	August – October	[51]
Al-Wijam Disease	May – August	[52]

5 Results

The validation results confirmed that the Certainty Factor (CF) computations implemented in the PalmExp application were accurate and consistent with manual calculations. For all six diseases and pests, the CF values computed by the application matched the manually calculated values exactly. Due to space constraints, we present detailed comparisons for two diseases: Khamedj (Fruit Rot) and Black Scorch.

Table 6 shows the step-by-step manual CF calculations for the Khamedj (Fruit Rot) disease (H4), where the user-rated symptom scores ranged from S24 to S32 as: 50%, 0%, 0%, 100%, 75%, 75%, 100%, 0%, and 0%, respectively. Fig. 7 presents the identical diagnostic result generated by the mobile application.

Similarly, Table 7 and Fig. 8 display results for the Black

Scorch disease (H6), where symptom ratings from S41 to S49 were: 0%, 0%, 0%, 100%, 100%, 0%, 50%, 0%, and 25%. The application output precisely mirrored the manually derived CF values.

These identical outcomes across all test cases affirm the correctness of the inference engine’s implementation and confirm the accurate integration of the CF method.

The evaluation of PalmExp focused on its ability to replicate expert-level diagnostic decisions. Twenty real-world test cases, each independently diagnosed by a domain expert, were used as the gold standard. PalmExp processed the same cases, and its outputs were compared to the expert’s diagnoses. The application correctly matched the expert diagnosis in 19 out of 20 cases, achieving a diagnostic accuracy of 95%.

Tables 8 and 9 present the comparison between the expert’s diagnosis and the application’s diagnosis for the two test sets (cases 1–10 and 11–20). The high degree of alignment validates the system’s practical reliability.

The application’s rule-based inference mechanism demonstrated a high level of agreement with expert diagnoses, accurately matching 19 out of 20 test cases. This consistency indicates the robustness of the model in replicating expert decision-making.

6 Discussion

The results obtained in this study demonstrate the effectiveness and practicality of PalmExp as a mobile expert system for diagnosing common date palm diseases and pests. The system

Table 6. Manual Calculations for the Certainty Factor of the Khamedj (Fruit Rot) Disease (H4)

Symptoms	Expert CF	User Rating	CF Manual Calculation
S24	0.8	50%	= 0.8 * 0.5 = 0.4
S25	0.75	0%	= 0.75 * 0 = 0, Combine = 0.4 + 0 * (1 - 0.4) = 0.4
S26	0.85	0%	= 0.85 * 0 = 0, Combine = 0.4 + 0 * (1 - 0.4) = 0.4
S27	0.8	100%	= 0.8 * 1 = 0.8, Combine = 0.4 + 0.8 * (1 - 0.4) = 0.88
S28	0.85	75%	= 0.85 * 0.75 = 0.6375, Combine = 0.88 + 0.6375 * (1 - 0.88) = 0.9565
S29	0.95	75%	= 0.95 * 0.75 = 0.7125, Combine = 0.9565 + 0.7125 * (1 - 0.9565) = 0.9875
S30	0.85	100%	= 0.85 * 1 = 0.85, Combine = 0.9875 + 0.85 * (1 - 0.9875) = 0.9981
S31	0.8	0%	= 0.8 * 0 = 0, Combine = 0.9981 + 0 * (1 - 0.9981) = 0.9981
S32	0.75	0%	= 0.75 * 0 = 0, Combine = 0.9981 + 0 * (1 - 0.9981) = 0.9981 * 100 = 99.81%

Table 7. Manual Calculations for the Certainty Factor of the Black Scorch Disease (H6)

Symptoms	Expert CF	User Rating	CF Manual Calculation
S41	0.9	0%	= 0.9 * 0 = 0
S42	0.9	0%	= 0.9 * 0 = 0, Combine = 0 + 0 * (1 - 0) = 0
S43	0.95	0%	= 0.95 * 0 = 0, Combine = 0 + 0 * (1 - 0) = 0
S44	0.85	100%	= 0.85 * 1 = 0.85, Combine = 0 + 0.85 * (1 - 0) = 0.85
S45	0.95	100%	= 0.95 * 1 = 0.95, Combine = 0.85 + 0.95 * (1 - 0.85) = 0.9925
S46	0.95	0%	= 0.95 * 0 = 0, Combine = 0.9925 + 0 * (1 - 0.9925) = 0.9925
S47	0.9	50%	= 0.9 * 0.5 = 0.45, Combine = 0.9925 + 0.45 * (1 - 0.9925) = 0.9959
S48	0.85	0%	= 0.85 * 0 = 0, Combine = 0.9959 + 0 * (1 - 0.9959) = 0.9959
S49	0.95	25%	= 0.95 * 0.25 = 0.2375, Combine = 0.9959 + 0.2375 * (1 - 0.9959) = 0.9969 * 100 = 99.69%

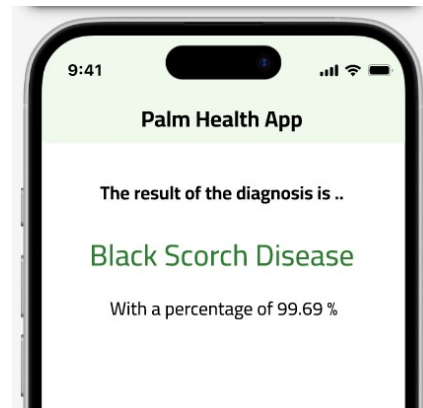
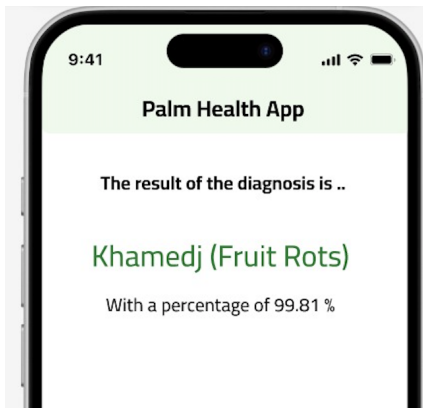


Figure 7. The Application’s Calculations Using the Same Ratings as in the Manual Calculation for the Khamedj (Fruit Rot) Disease (H4)

Figure 8. The Application’s Calculations Using the Same Ratings as in the Manual Calculation for the Black Scorch Disease (H6)

achieved a diagnostic accuracy of 95%, successfully replicating expert decisions in 19 out of 20 test cases. This strong alignment confirms the reliability of the certainty factor (CF)–based inference engine, which allows for probabilistic reasoning while maintaining interpretability.

The use of a rule-based approach grounded in domain expertise presents several advantages over data-driven models. Unlike machine learning techniques that require large annotated datasets and computational resources, PalmExp operates efficiently on mobile devices and can provide real-time results without the need for internet access. This makes it particularly suitable for deployment in agricultural environments where infrastructure and technical support may be limited.

Moreover, the CF method provides a transparent reasoning mechanism that enables users—including non-technical individuals—to understand how diagnoses are reached. This level of explainability is especially valuable in agriculture, where trust in technology depends heavily on clarity and transparency. The structured symptom weighting and modular rule design used in

PalmExp can also facilitate future updates and scalability to additional diseases or crop types.

Despite its promising results, the study is not without limitations. The evaluation relied on a single domain expert, and while the consistency of results is encouraging, broader validation with multiple experts and larger case sets is recommended for future work. Additionally, expanding the system to support more diseases, environmental conditions, and treatment recommendations will further enhance its utility.

In summary, the outcomes of this research not only validate the PalmExp system’s functionality but also contribute to the broader field of explainable AI in agriculture. By combining expert knowledge with interpretable inference methods, this work demonstrates how intelligent diagnostic tools can be made accessible, effective, and trustworthy for practical use in real-world settings.

Table 8. Comparison Between the App’s Diagnosis and the Expert’s Diagnosis for the First Set of 10 Cases

Cases	1	2	3	4	5	6	7	8	9	10
App (Label)	H4	H6	H6	H4	H1	H3	H4	H5	H5	H6
App (CF%)	99.8%	99.7%	99.5%	99.4%	94.1%	84.2%	98.1%	86.6%	77.6%	94.52%
Expert (Label)	H4	H6	H6	H4	H1	H3	H4	H5	H5	H6
Expert (CF%)	99	99	99	99	95	90	99	80	80	95

Table 9. Comparison Between the App’s Diagnosis and the Expert’s Diagnosis for the Second Set of 10 Cases

Cases	11	12	13	14	15	16	17	18	19	20
App (Label)	H3	H3	H3	H5	H3	H5	H3	H5	H3	H5
App (CF%)	96.9%	97.9%	86.9%	81.1%	99.8%	97.8%	91.4%	97.2%	99.3%	94.61%
Expert (Label)	H3	H3	H3	H3	H3	H5	H3	H5	H3	H5
Expert (CF%)	95	98	85	80	100	95	90	95	100	90

7 Conclusions

This paper introduced PalmExp, a bilingual mobile expert system designed to diagnose six of the most common palm tree diseases and pests using the Certainty Factor (CF) reasoning method. The application achieved a high diagnostic accuracy of 95%, aligning closely with expert evaluations in real-world scenarios. The CF-based approach enables probabilistic reasoning, enhancing diagnostic reliability while maintaining interpretability for end users.

PalmExp features a user-friendly interface available in both English and Arabic, making it accessible to a broad demographic, including elderly users and those with limited technical experience. The system supports both Android and iOS platforms, ensuring widespread accessibility across mobile devices. In addition to delivering diagnoses, the application provides actionable advice to help users manage and treat detected conditions. The successful validation of the inference engine and performance testing confirms PalmExp’s practical utility as a mobile agricultural diagnostic tool. The system proved effective in accurately identifying a wide range of palm tree diseases and pests, reinforcing its potential as a valuable tool for early detection and management in agricultural settings.

8 Future Work

Future enhancements to PalmExp can further increase its accuracy, scalability, and functionality. Key directions include:

- **Expanding Disease Coverage:** Integrating additional palm tree diseases and pest conditions based on regional and seasonal variations.
- **Leveraging Community Knowledge:** Incorporating the insights and experiences of experienced farmers to refine the symptom database and improve CF weighting.
- **Advanced Diagnostic Techniques:** Exploring integration of image processing and artificial intelligence methods (e.g., deep learning) for automated visual symptom recognition.
- **Crowdsourced Feedback:** Enabling continuous learning by collecting anonymized user feedback and expert reviews to improve system accuracy over time.

- **Impact Assessment Through Comparative Studies:** Conducting longitudinal field studies to evaluate the real-world impact of early diagnosis on disease incidence and pest population dynamics. This includes performing controlled trials to compare results between users of PalmExp and those relying on traditional methods, with statistical analysis to validate improvements in pest control and crop protection.

These improvements will help position PalmExp as a comprehensive and adaptive platform for palm health management, not only offering accurate diagnosis but also contributing to measurable outcomes in pest and disease mitigation.

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