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Research Article

An Expert System for Identification of Nutrients Deficiency/ Disorder and Their Management Advisories in Mango (*Mangifera indica L.*)

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ABSTRACT

When a nutrient deficiency/disorder symptom starts to become visible in a commercial crop, an accurate identification is necessary to support its scientific management/control. In some cases diagnosis is easy and orchardist can easily identify however in others, it needs expert opinion. Diagnosing nutrients disorder and deficiency symptoms in mango requires substantial expertise. The expertise of an expert in a particular domain is not generally available on demand. It is also difficult to retain expertise. Therefore, to make expertise more easily accessible to the mango orchardists and retain it, expert system software on nutrients disorder/deficiency in mango has been developed. Out of several nutrients *viz*., potassium, boron, manganese, zinc and copper, etc., are reported to be in short supply for optimum plant growth and productivity of mango in India. The expert system is developed by using forward chaining method of reasoning to reach the conclusion. The system is developed using programming language instead of using costly expert system shell software. After diagnosing the deficiency or disorder symptoms, the system advises the scientific management options. Therefore, this expert system will compliment the human expert in advisory on management aspect of nutrients deficiency/disorder. This expert system is menu based user friendly software that starts diagnosis from a question-answer based session and re-confirmation of symptoms based on visual symptoms of affected images. This reconfirmation session based on visual symptoms of affected part of plant ensures high level of diagnosis accuracy.

Key words: Expert system, Mango, Nutrients, Deficiency, Disorder, Identification, Advisory, Management

Introduction

Majority of the mango orchards across the country, suffer from nutrient inadequacies and rarely fertilizers are applied to the mango except by very limited progressive growers. Nutrient status of mango orchards of central and western Uttar Pradesh have shown the deficiency of Mn, Zn and Cu to the tune of 92, 23 and 45 per cent while 75 per cent orchards showed low organic carbon content (Ravishankar *et al*., 2010; Kumar *et al*., 2015). The study also indicated that 63.8, 78.7, 85.1 and 10.6 per cent leaf samples were deficient in K, Zn, Cu and B. In Konkan region of Maharashtra Zn deficiency is recorded in 47.9 to 70.2% soils in Thane, Ratnagiri and Sindhudurg districts while 21% soils in Sindhudurg are deficient in Cu (Kumar and Ravishankar, 2013). Boron deficiency is a major production constraint of Mango cv Alphonso in the western coast, Maharashtra as well as in U.P. (Adak *et al*., 2017). The leaf and soil B status was recorded low with an average of 23 and 0.25 mg kg^{-1} respectively. About 60% of the orchards were found to be deficient in B (Raja *et al*. 2005).

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To determine elemental plant deficiencies, most agriculturists rely primarily on visual symptoms, soil analysis and plant tissue analysis. The location of the initial symptoms of nutrient deficiency generally occurs on either new or old leaves. If symptoms appear on new leaves, the deficiencies could be of iron, zinc, manganese, copper, boron, chlorine, calcium, or sulfur, however, symptoms on old leaves shows the deficiencies of nitrogen, phosphorus, potassium or magnesium. Productivity and fruit quality of mango is adversely affected due to nutrient imbalance and their deficiencies in plant tissue (Shukla *et al.*, 2013; Bhrighvanshi *et al.*, 2014; Adak *et al.*, 2016b). Plants show nutrient deficiency symptoms on leaves/ fruits only when the nutrient level in the plant tissue has gone too low to support growth and development. On the other hand, once nutrient concentrations fall below critical values and if these deficiencies are not corrected well in time the fruit yield and quality as well as trees growth will be severely affected and it may take several years for tree health and production to fully recover (Adak *et al.*, 2016a).

An expert system is a computer program that uses artificial intelligence to solve problems within a specialized domain that ordinarily requires human expertise. It uses non-numerical domain-specific knowledge to solve problems with a competence comparable with that of human experts. An Expert System also called the Knowledge Based System which uses structured data as input to synthesis knowledge for solving a problem. Expert systems combine the experimental and experiential knowledge with the intuitive reasoning skills of a multitude of specialists to aid orchardists' in making the best decisions for their crops (Verma *et al.*, 2015). There are number of advantages of an expert system over human expertise. The knowledge contained in expert system is permanent, transferable, consistent and affordable while knowledge of human expert is perishable, difficult to transfer, unpredictable and expensive, respectively. (Verma *et al.*, 2015*)*. In an organization the source of competitive advantage lies not in the knowledge but application of knowledge. The knowledge application system such as expert system, facilitates the transfer of knowledge between various communities of practice (Man Singh *et al.,* 2007).

Keeping in view the limitations of mango growers in diagnosis of the different nutrients deficiency/disorder and facilitating timely decision for the management of the nutrients deficiency/disorder, an expert system for diagnosis of nutrients deficiency/disorder and its management advisories in mango has been developed at CISH, Lucknow. This paper describes the development of a rule-based expert system for the diagnosis of nutrient deficiency of mango and to suggest the appropriate treatments/ management/control guide-lines. The system can be used as a diagnostic tool by orchardists and for educational and extension purposes in mango production. It provides a diagnosis based on the description of the external appearance or behaviour of the affected tree. Corresponding pictures accompany the most important symptoms and certain measures to be taken are proposed (Mahaman *et al.*, 2002). The system provides support to improve the decision-making ability of Orchardists, extension workers, researchers, managers, trainers, etc.

Materials and Methods

Architecture of Expert System

An object oriented approach was used for presenting rules in knowledgebase of expert system in form of Object- Attribute-Value (O-A-V) that allows developing knowledge base without the need of costly expert system shell software (Yialouris and Sideridis, 1996.). The present system is developed using programming language (MS® Visual Basic) instead of using costly expert system shell software. The following standard steps were followed for development of expert system software:

(i) Knowledge acquisition: It involves acquiring heuristic and factual knowledge pertaining to particular domain from different sources.The reliability of diagnostic expert system depends on the quantity and quality of knowledge that it

handles, i.e. the number of disorders it can diagnose and the appropriate representation of the domain expert knowledge. This can be achieved by the knowledge engineer with a knowledge acquisition procedure. Knowledge acquisition is the most critical and problematic phase in the expert system development (Yialouris and Sideridis, 1996). Knowledge acquisition though critical, has always been the bottle neck in developing expert system (Gaines, 1987).

An expert system aims to act as human reasoning process giving the same advice and making the same decisions as a human expert (Huirne and Dijkhuizen, 1992. During the knowledge acquisition procedure, particular attention was paid to the accuracy of description of the symptoms and related problems associated with the main mango disorders.

(ii) Knowledge representation (KR): A knowledge base (KB) contains the domain knowledge required for solving a specific problem. The knowledge base is represented in the form of rule base in our system (Harmon and King, 1985). The symptoms of different crop disorders are represented as object–attribute–value (O–A–V) as given in Table 1 (Yialouris and Sideridis, 1996). The KB is internally represented in tabular form as a relational database using MS® Access 2007*. Each condition of a rule can be a simple sentence which is true or false, or an O-A-V triplet.

The knowledgebase contains expert's knowledge in the given domain. The knowledge is represented in the linguistic form of IF-THEN rules (Table 2). Although different KR methodologies exist such as rules, frames, semantics nets, etc. but rule-based Knowledge Representation is the most commonly used methodology for developing agricultural expert systems.

However, for developing a robust expert system comprised with IF-THEN rule based logical models was used as the conventional expert system development technique was not sufficient.

One of the most important design considerations behind this expert system was to provide the best user-friendliness. So we tried to keep graphical user interface simplest. The startup screen of expert system is presented in Fig. 1. The knowledge base consists of simple IF-THEN rules in form of forward chaining i.e. cause-to-effect (Table 2).

Forward chaining method: Cause → Effect;

Backward chaining method: Effect → Cause

Table 1. Approaches: Rule-based table of relations between symptoms and disorder/deficiency

Mango disorder/deficiency	Boron Deficiency	
Boron deficiency Symptom	Appears on	fruit
	Has colour	Brown to black
	Has shape	irregular
	Symptoms	Cracking on fruit OR Internal breakdown of fruit OR black tip of fruit

Table 2. An example of knowledgebase rule to diagnose Boron deficiency disorder

```
Rule 1.
  If Option1.Value = True OR Option3.Value = True OR Option5.Value = True Then
MsgBox "IT IS A CASE OF BORON DEFICIENCY", vbInformation, " Disorder diagnosis"
  IntResponse = MsgBox("The disorder is BORON defficiency. Do you want information of its
  management/control options?", vbYesNo + vbQuestion, "mango -Expert")
Else
  MsgBox "Please go back and try other options"
End If
```

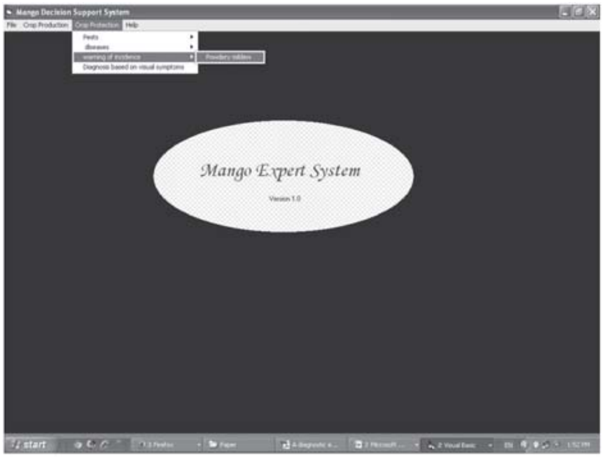


Fig. 1. Snapshot of the startup page of expert system for mango

The program codes (IF…then…… rule) shown in Table 2 are based on 'Option' control boxes in the screen in figure 3:

OPTION1=Are there crackings on the fruit?

OPTION2= Is there black tip of the fruit?

OPTION3=Is there internal breakdown of mango fruit?

(iii) User Interface: The interaction between the system and the user was kept as simple as possible. The Expert System provides the user, at the beginning of the consultation mode, the options to confirm or reject some of the very common symptoms. First of all, the user finds out the infected part of the plant and the type of infection (Fig. 2), If the type of infection has a very common symptom, such as a spot, the system prompts the user to determine the special characteristics of the spot (Fig. 3) e.g. the colour and shape of spot. After supplying the system with this initial information, the system applies the data to the Knowledge Base and, asking for supplemental data from the user, tries to make a diagnosis. If the system diagnoses one or more disorders, it then provides option to display the management/control/treatment guide-lines (Fig. 5).

(iv) Evaluation of expert system: The expert system was evaluated following the conventional expert system evaluation methodologies. The overall system evaluation research study included verification and validation processes (Harrison, 1991).The verification process ensured that the knowledge in the system is complete, accurate and consistent according to required specification.

The verification process of the KB ensures that the system is free from the induced error by developer as well as insuring matching between inputs of different development phases (El-Kornay *et al*., 2000).

The knowledgebase was verified after compilation of all the rules and we made necessary alterations to ensure accuracy. Verification was done to ensure that there are no dead-end lines of reasoning that would result in unknown conclusions derived through the inference process. All the possible bugs in the system were located by the verification process. The functional performance was thoroughly checked. We ensured by running the software time and again by providing different combinations of all the possible inputs. The results given by the system have been validated with domain experts. It was found that the system performance was as expected. The ES has been tested and found working satisfactorily on MS Windows XP, 2003, 2007 and 8.1.

Results and Discussion

In this paper, an object oriented approach of presenting rules in knowledgebase of expert system in form of Object-Attribute-Value have been utilized that allows developing knowledge base along with expert system directly without expert system shell software. The expert systems for diagnosis of major nutrient disorders viz., Potassium, Boron, Copper have been developed. After diagnosis, the expert system advises the management options for diagnosed disorders (Figs. 2-11).

Example: Diagnosis and management advisory for Boron disorder in mango tree using expert system.

Step-1: Select part of tree affected by disorder

Step-2: Options describing symptoms; and for re-confirmation by examining image with symptoms

Fig. 2. Screen for initiation of diagnostic

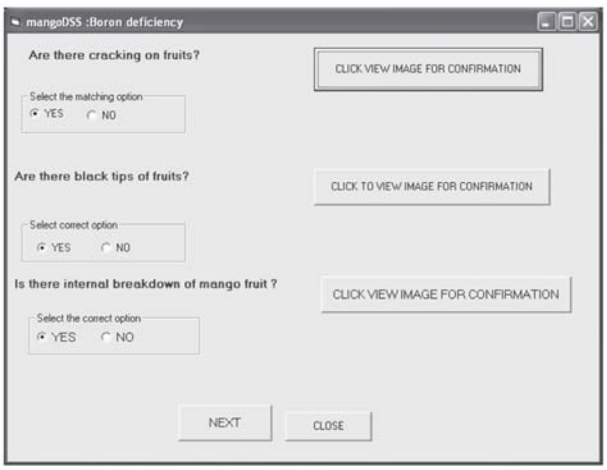


Fig. 3. Question-Answer screen & image based re-confirmation: BORON

Step-3: Disorder symptom re-confirmation through image

Fig. 4. Visual re-confirmation: option-1(fruit cracking)

Step-3(a): Disorder symptom re-confirmation through image- another case

Fig. 5. Visual re-confirmation: option-2 (Black tip)

Step-4: Detected disorder

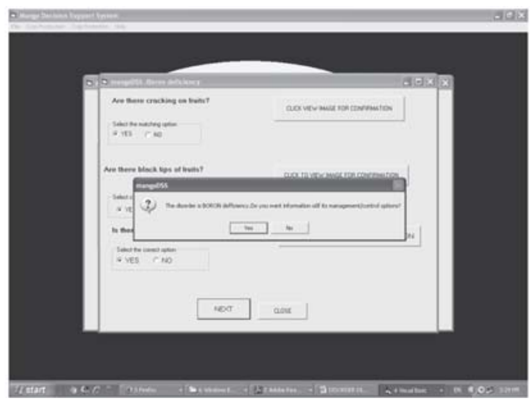


Fig. 6. Snapshot of screen displaying the detected disorder –Boron

Step-5: Management advisory on detected disorder

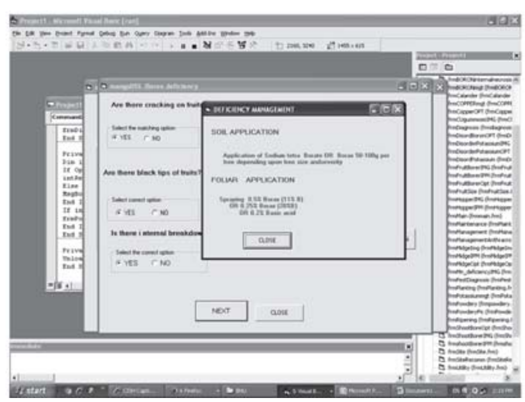


Fig. 7. Snapshot of screen (on the top of screens-center) displaying the management advisory for Boron disorder

Diagnosis of Potassium Deficiency

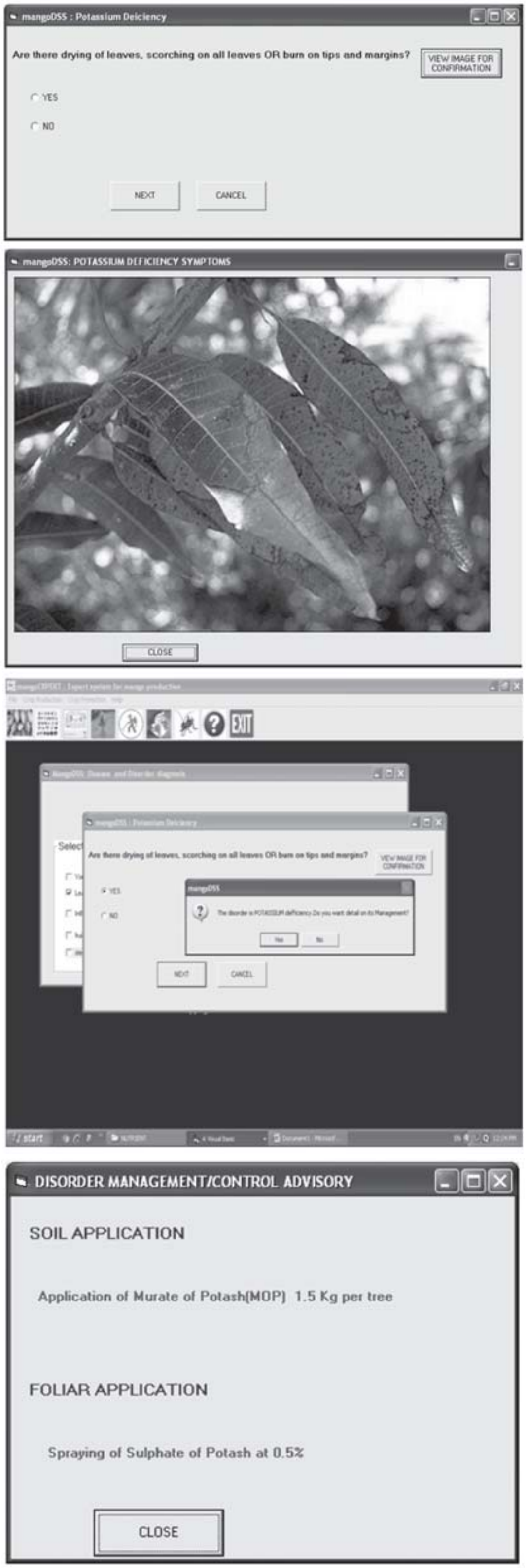


Fig. 8. Snapshot of screen displaying the management advisory for Potassium disorder

Diagnosis of Copper Deficiency

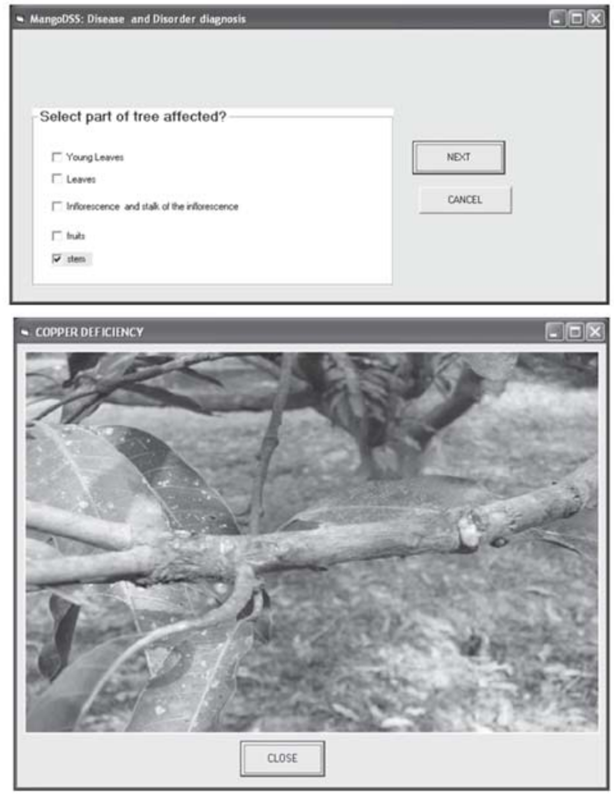


Fig. 9. Snapshot of screen displaying the management advisory for Potassium disorder

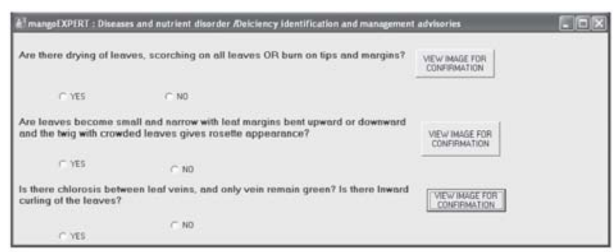
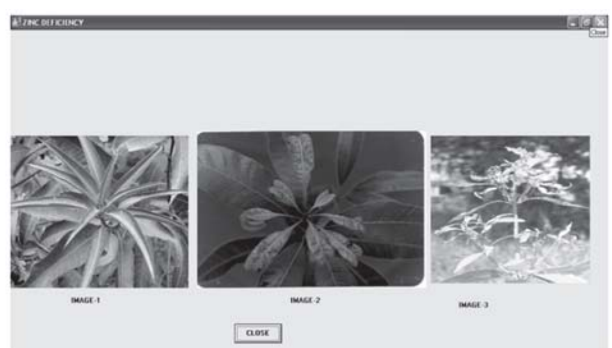


Fig. 10. Snapshots of screen displaying the deficiency symptoms for Zn and Mn



Contd....

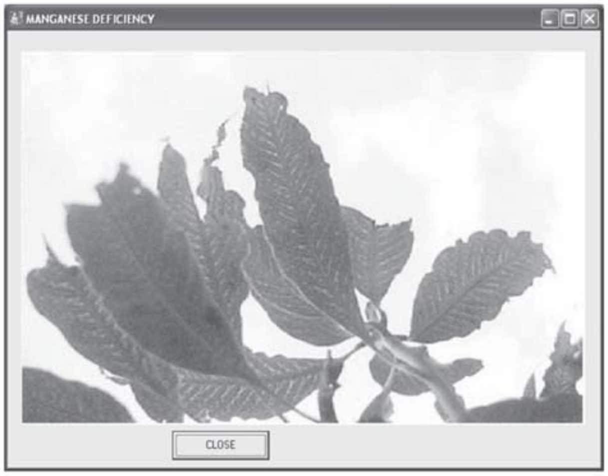


Fig. 11. Image based re-confirmation of deficiency symptoms for Zn and Mn

Similarly, one may use the expert system for other cases of disorders like Zn and Mn (Fig. 10). The process of diagnosis and getting management advisory is very user friendly.

Conclusions

In this work, an object oriented approach of presenting rules in knowledgebase of expert system in form of Object- Attribute-Value have been used that allows development of expert system directly using a programming language as front-end and a database management system as back-end, without using expert system shell software , is presented. The expert system for diagnosis of five major mango nutrient disorders *viz.,* Potassium, Boron, Cu, Zn, Mn have been developed. After diagnosis, the software advises suitable management options for management of identified disorder/ deficiency. This software is being expanded to cover all pests' diseases and disorders of mango. The system would serve as effective knowledge dissemination tool and would empower orchardist in taking right decision in mango production.

References

Adak, T., Kumar, K. and Singh, Vinod Kumar. 2016a. Variations in soil physical properties, distribution and storage of micronutrients in soil as influenced by high density mango (*Mangifera indica* L.) plantations. *Journal of Soil and Water Conservation* **15**(1): 75-86.

Adak, T., Kumar, K. and Singh, VK. 2017. Micronutrient management for mango and guava orchards: farmers' perspective. *Tropical Plant Research* **4**(1): 180-182.

Adak, T., Singh, V.K., Kumar, K. and Singh, Vinod Kumar. 2016b. Soil properties in high density mango orcharding- a basis for orchard sustainability. *GERF Bulltin of Biosciences* **7**(1): 10-16.

Bhrighvanshi, S.R., Adak, T., Kailash, K., Singh, A. and Singh, Vinod Kumar. 2014. Impact of varying soil moisture regimes on growth and soil nutrient availability in mango. *Indian Journal of Soil Conservation* **42**(1): 68-73.

El-Korany, A., Rafea, A., Baraka, H. and Eid, S. 2000. A structured testing methodology for knowledge-based systems, *In*: Database and Expert Systems Applications: Springer, pp. 427-436.

Gaines, B.R. 1987. An overview of knowledge acquisition and transfer. *International Journal of Man-Machine Studies* **26**(4): 453-472.

Harrison, S.R. 1991. Validation of agricultural expert system. *Agricultural System* **35**: 265-285.

Harmon, P. and King, D. 1985. Expert Systems: Artificial Intelligence in Business. Wiley, New York, NY, 283P.

Huirne, B.M.R. and Dijkhuizen, A.A. 1992. Application of decision support systems in farm management. *In: Preprints of European Workshop on Integrated System in Agricultural Informatics*, Bonn. pp. 61-71.

Kumar, K., Adak, T. and Singh, VK. 2017. Green manuring and nutrient management impacting soil properties and sustainability of mango orchard. *Journal of Soil and Water Conservation* **16**(1): 72-78.

Kumar, K. and Ravishankar, H. 2013. Integrated nutrient management in mango (*Magnifiera indica* L.) with special reference to Konkan region. Presented in the National seminar on "Soil Fertility, Degradàtion and Contaminants" held at Dr Babasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, Maharashtra during May 8-9, 2013.

Kumar, K., Adak, T. and Singh, V.K. 2015. Status and distribution of micronutrients in mango orchards under subtropical region of Uttar Pradesh, India. *Journal of Agricultural Physics* **15**(2): 127-139.

Jun-chen, LAI, Bo, MING, Shao-kun, LI, Ke-ru, WANG, Rui-zhi, XIE and Shi-ju, GAO. 2010. An image-based diagnostic expert system for corn diseases. *Agricultural Sciences in China* **9**(8): 1221-1229

Mahaman, B.D., Harizanis, P., Filis, I., Antonopoulou, E., Yialouris, C.P. and Sideridis, A.B. 2002. A diagnostic expert system for honeybee pests. *Computers and Electronics in Agriculture* **36**: 17-31.

Man Singh, G., Reichgelt, H. and Bryson, K.O. 2007. CPEST: An expert system for the management of pests and diseases in the Jamaican coffee industry, *Expert System with Applications* **32**: 184-192.

Ploetz, R.C. and Prakash, O. 1997. Foliar, floral and soil borne diseases. *In: The Mango: Botany, Production and Uses*. Ed. Litz, R.E., CABI Publishing, U.K., pp. 281-326.

Raja, M.E., Anil Kumar, S.C. and Raju, Y. 2005. Boron deficiency in mango (*Mangifera indica* L.): A cause delineation study in acidic soils of Maharashtra, India. *Soil Science and Plant Nutrition* **51**: 751-754.

Ravishankar, H., Kumar, K., Singha, A. and Adak, T. 2010. Integrated nutrient management in mango and guava. *Indian Journal of Fertilizers* **6**(11): 12-21.

Shukla, S.K., Mishra, D., Adak, T. and Kumar, K. 2013. Constraints in production to consumption chain of mango in Malihabad, Lucknow, Uttar Pradesh. *Current Adavances in Agric. Sci.* **5**(1): 87-91.

Verma, H.C., Shukla, P.K., Pandey, B.K. and Misra, A.K. 2015. An expert system for mango disease diagnosis and management. *Progressive Horticulture* **47**(3): 401-406.

Yialouris, C.P. and Sideridis, A.B. 1996. An expert system for tomato diseases. *Computers and Electronics in Agriculture* **14**: 61-76.

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