EXPERT SYSTEM FOR PADDY PRODUCTION MANAGEMENT

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ABSTRACT

This paper presents an expert system for Paddy production management. This expert system gives advice to Paddy growers in Egypt to improve Paddy productivity. The system contains two main parts namely: strategic part and tactic part. The strategic part gives a strategic advice (i.e. list of agricultural operations) before cultivating Paddy crop. The strategic part contains four sub-systems namely: variety selection, land preparation & planting, irrigation, and, fertilization. The tactic part diagnoses the problems that occurrs during Paddy growing season and gives advice about how to control these problems. The tactic part contains two sub-systems namely: disorders diagnosis and treatment.

Key Words: Expert System, Agricultural Expert System, Paddy Expert System

1. Introduction

Agricultural production is a complex problem that involves many parameters and requires very complicated optimization and modeling steps. The overall production management problems involve, among other aspects, land preparation, water and fertilizers requirements, pest control, variety selection. The crop production management problem also includes the lack of enough experts to support the agricultural growers, and the heavy dependence upon the experiences of these experts. This makes the choice of the expert system approach for the solution of this problem a suitable one.

The Central Laboratory for Agricultural Expert System (CLAES) has been gained a considerable experience in developing expert systems in agricultural domain. These knowledge based systems cover different agricultural production management problems and applied for different crops **[Rafea, 1994]**. The objective of this paper is to present an expert system for paddy production that covers the tactic and strategic knowledge based systems **[Edrees, 1999a].** The strategic part consists of variety selection, land preparation, irrigation, and, fertilization subsystems. The tactic part consists of disorders diagnosis and treatment subsystems.

CommonKADS methodology **[Wielinga, 1994]** is used to represent the knowledge. Each subsystem consists of domain, inference, and task knowledge. Domain knowledge consists of domain ontology, and domain models. Domain ontology presents the vocabularies that are used in the domain models. These vocabularies are categorized into concepts, properties of concepts, and legal values of properties. Inference knowledge shows all inference steps used by the system in solving the problem, it does not show the control sequence of these inference steps. Task knowledge is actually the algorithm of the expert system, it shows the control sequence of the inference steps to achieve system objective.

The layout of this research consists of six sections including this section. Section two introduces the common knowledge base that is used by strategic part and tactic part. Section three describes the strategic knowledge based subsystems. Section four summaries the tactic knowledge based subsystems. Section five overviews the implementation issues, while section six concludes the outcomes of this work.

2 COMMON KNOWLEDGE BASE

This section presents the ontology and models that are used by all sub-systems. The common knowledge base prevents redundancy and multiple application of the same knowledge base **[Edrees, 2000]**. The common knowledge base contains common domain knowledge and common inference knowledge.

The common knowledge contains common ontology and common domain model. The common ontology contains six concepts namely: plantation, soil, plant, operation, pesticides, and fertilizers. The *abstraction* model is common for most sub-systems and it contains a relation between plant age and plant growth stage. The common inference contains two inference steps namely: *calculate* and *abstract*. The *'calculate'* inference step compute plant age from planting date and current date. The '*abstract'* inference step determines plant growth stage using the '*abstraction'* model. Figure (1) shows soil concept as a sample of common ontology, while figure (2) shows sample of abstraction and determination models.

concept soil;
properties:
Salinity: numeric;
source of value: user;
cardinality: single;
Salinity-Status : {normal, high};
source of value: derived;
cardinality: single;

Figure 1 Soil Concept

(plant: age > 20 and <=35&
plantation: planting-type = transplantation &
plant: variety = sakha102)
ABSTRACT
(plant: growth-stage =tillering])

(plant: age > 35 and <=65 &
plantation: planting-type = transplantation &
plant: variety = sakha102)
ABSTRACT
(plant: growth-stage =heading])

Figure 2 Sample of Abstract Model

3 STRATEGIC KNOWLEDGE BASED SUB-SYTEMS

The strategic knowledge based sub-systems give strategic advice in advance either before planting or during growing season. These sub-systems are variety selection, land preparation & planting, irrigation, and fertilization. The knowledge of each sub-system is presented in terms of CommonKADS, which are domain knowledge, inference knowledge, and task knowledge. The following subsections introduce a brief description of these sub-systems.

3.1 Variety Selection

This sub-system advises the users about the most suitable variety for his/her plantation based on the specific circumstances of the farm and the user requirements **[El-Azhary, 1998]**. The domain knowledge of this sub-system contains two models, namely: *suggestion*, and *selection* The inference knowledge contains three inference steps namely: *specify, select, and count.*

The *suggestion* model contains a relation between the environmental conditions and the suitable varieties that is used by '*specify'* inference step to suggest the paddy varieties suitable for the surrounding environments. The *selection* model contains a relation between user requirements and the corresponding varieties that is used by '*select'* inference step to select, the most suitable varieties reflecting the user requirements. The '*count'* inference step just counts the specified varieties. Figure 3 presents the domain knowledge, while figure 4 presents inference and task knowledge.

concept grain;
properties:
length: {short, long};
source of value: user;
cardinality: single;
transparency: { transparence, not transparence};
source of value: user;
cardinality: single;
odour: {aromatic, not aromatic};
source of value: user;
cardinality: single;
expected yield: universal;
source of value: derived;
cardinality: single;
blast-resistance: {resistant, susceptible};
source of value: derived;
cardinality: single;
milling-output: [65, 75];
source of value: derived;
cardinality: single;
growth-period: [125, 160]
source of value: derived;
cardinality: single;

Figure 3(a): Sample of domain ontology

(soil: salinity = normal &
irr-water: availability = regular &
irr-water: quality = fresh OR mixed)
SUGGEST
(variety: name = [Giza171, Giza176, Giza177, Giza178, Giza181,
Sakha101, Sakha102, Egyptian-yasmeen])

(soil: salinity = saline OR irr-water: availability = irregular OR
irr-water: quality = drainage)
SUGGEST
(variety: name = [Giza178])

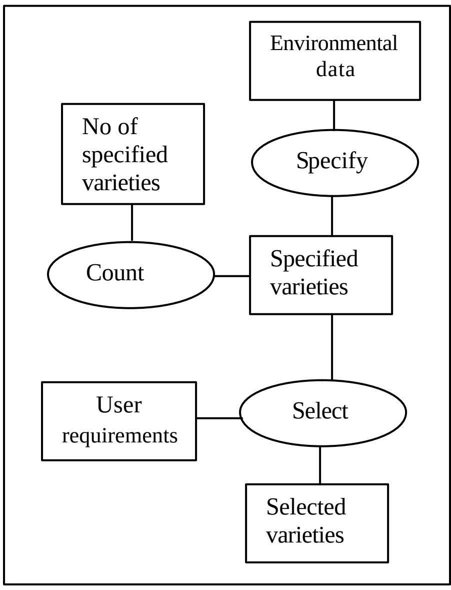
Figure 3(b): Sample of *Suggestion* Model

(variety:name = Sakha102 &
grain: length = short-grain &
grain: transparency = transparence &
plant: growth_duration =short)
SELECT
(variety: selected = [Sakha102])

(variety: name = Giza171 &
grain: length = short-grain &
grain: transparency = transparence &
plant: growth_duration = long)
SELECT
(variety: selected = [Giza171])

Figure 3(c): Sample of *Selection* Model

Figure 3: Sample of Variety Selection Domain Knowledge



task: rice variety selection;
task-definition:
goal: get suitable rice variety;
input: environmental data, user requirements
output: selected varieties

task-body:
type: composite
subtasks: specify- select -, count
additional-roles: specified varieties, No. of specified varieties;

control-structure:
specify (E: environmental data → S: specified varieties),
count (S → N: no. of specified varieties),
IF N > 1 THEN
BEGIN
select (S, U: user requirements → Se: selected varieties),
DISPLAY(Se)
END
ELSE DISPLAY(specified varieties)

Figure (4): inference and Task Knowledge of *Variety Selection*

3.2 Land Preparation and Planting

Land preparation gives specific advises to the user about how to prepare his/her specific land for paddy cultivation, while planting gives the suitable planting methods according to user specific inputs data **[Edrees, 1998]**. The domain model of this sub-system contains two models namely: *establishment plan* and *assignment*. The inference knowledge contains three inference steps namely: *establish, assign, and select*.

The *establishment plan* model contains a relation between farm description and strategic plans that is used by *establish* inference step to generates a recommended plan and an alternative plans. The *assignment* model contains a relation between farm description, user plan and assigned operations. This relation is used by *assign* inference step to assign values for all operations. The select inference step permits the user to select the suitable strategic plan.. Figure 5 presents the domain knowledge, while figure 6 presents inference and task knowledge

concept operation;
properties:
date: universal;
source of value: derived;
cardinality: single;
tool: : universal;
source of value: derived;
cardinality: single;
method: universal;
source of value: derived;
cardinality: single;
advice: universal;
source of value: derived;
cardinality: single;
value: {true, false};
source of value: derived;
cardinality: single;

Figure 5a Sample of Domain Ontology

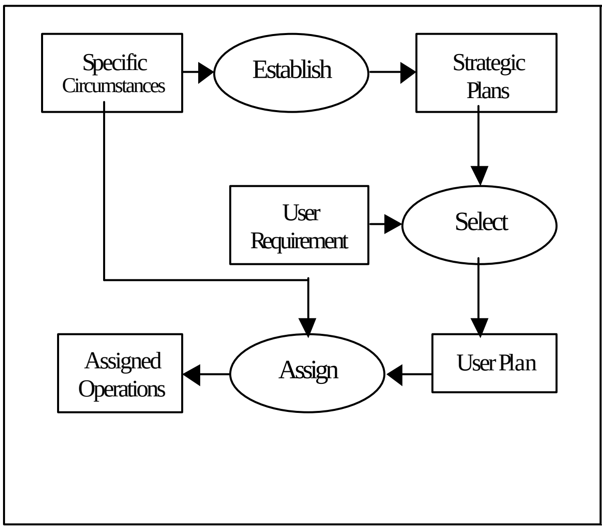
(soil: salinity-status = normal &
plantation: planting = drill)
ESTABLISH
(plan: name = [First_plow, Second_ plow, leaser_leveling, Planting, basin_dividing, flooding_water, Drain_water] &
plan: type = recommended)

Figure 5b Sample of Establishment plan Model

(plow: value = true&
plantation: previouscrop=yes&
Soil: Salinity-status =normal)
ASSIGN
(plow: tool = chisel &
operation: date = before planting &
method = plow soil with depth 25 cm then leave it 3-5 days to dry
plan_priority = unique

Figure 5c Sample of Assign

Figure 5 Sample of Domain Knowledge



task: land preparation and planting
task definition:
goal: operations for land preparation &planting
input: farm circumstances, user requirements
output: list of agricultural operations
task body
type: composite
subtasks: establish, display, select, assign
additional-roles: strategic plans, user plan, assigned operations
control structure:
establish (F:farm circumstances→ S: strategic plans),
DSPLAY (S);
select (S, U:user ulan);
FOR each operations in U do;
Operation: value = true;
end
assign (F, operations → AO:assigned operations)
DSPLAY (AO)

Figure 6 Inference and Task knowledge of Land Preparation & Planting

3.3 Irrigation

This sub-system advises the users with irrigation schedule, which includes water-flooding status during plant stages **[Edrees, 1999b], [Rafea, 1995]**. The advice is based on the user specific situation such as water quality, salinity status, and growth stage of plant. The domain model of this sub-system consists of two models namely: *irrigation plan model and instantiation* model. The inference knowledge contains two inference steps namely: *select and insatiate.*

The *irrigation plan* model contains a relation between plantation description and irrigation plan that is used by '*select'* inference step to generate irrigation operations. The *assignment* model contains a relation between farm description, plant description, and assigned operations that is used by '*assign'* inference step to assign values for irrigation operations. Figure 7 presents the domain knowledge, while figure 8 presents inference and task knowledge

concept irr-operation;
properties:
start-date: date;
source of value: derived;
cardinality: single;
end-date: date;
source of value: derived;
cardinality: single;
flooding-status: universal;
source of value: derived;
cardinality: single;
method: universal;

Figure 7a: Sample of Domain Ontology Model

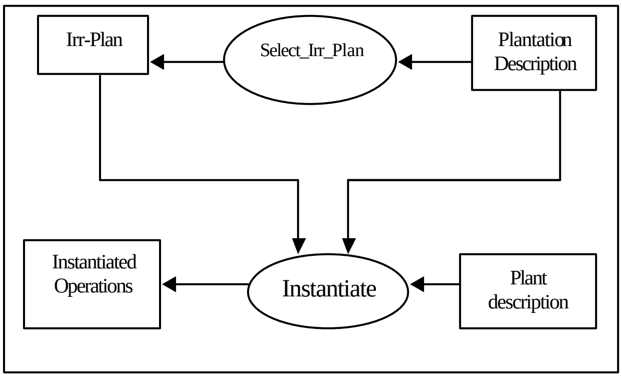
(irr_water: water-source= mixed &
soil: salinity-status = normal)
ESTABLISH
(plan: operation-name = [Irr_op1, Irr_op2, Irr_op3, Irr_op4, Irr_op5, Irr_op6, Irr_op7]

Figure 7b Sample of Establishment plan

(irr-op1: value = true &
soil: salinity = normal &
irr_water: water-source= mixed &
plantation: planting-type = transplanting)
ASSIGN
(irr-op1: flooding-status = cover soil with water in depth 2-3 cm &
irr-op1: start-date = function37 &
irr-op1: start-date = function38 &
irr-op1:method = "soil must be covered with water during this

Figure 7c Sample of Assign Model

Figure 7 Sample of Domain Ontology Model of



task: irrigation
task definition:
goal: irrigation schedule
input: plant and plantation description
output: irrigation schedule
task body
type: composite
subtasks: select, assign
additional-roles: irr-plan
control structure:
select(PD:plantation description → IP:irrigation plan),
instantiate (PD, plant description IP → AO:assigned operations)
DSPLAY (AO)

Figure 8 Inference and Task knowledge f Irrigation

3.4 Fertilization

The fertilization subsystem gives fertilization schedule, which includes fertilizer type, fertilizer quantity, fertilizer name, and application time **[Edrees, 1999b]**. The domain model of fertilization subsystems consists of three models namely: '*determining fertilization requirements*', '*fertilization selection*', and '*instantiation*'.. The inference knowledge contains four inference steps namely: *determine fert reqs*, *establish*, *select*, *and instantiate.*

The '*determining fertilization requirements*' model contains a relation between plantation description and fertilization requirements that is used by '*determine fert req*' inference step to generates fertilization requirements. The '*fertilization selection*' model contains a relation between farm description, fertilization reqs., and fert-plans that is used by '*establish*' inference step to generate fertilization recommended plan and fertilization alternative plans. The '*instantiation*' model contains a relation between plantation description, plant description, user fert plan, and assigned fert operation. This relation is used by *instantiate* inference step to generate assigned fertilization operations. Figure 9 presents the domain knowledge, while figure 10 presents inference and task knowledge.

concept fert-operation;
properties:
date: date;
source of value: derived;
cardinality: single;

fert-name: universal;
source of value: derived;
cardinality: single;

fert-qty: universal;
source of value: derived;
cardinality: single;

method: universal;
source of value: derived;
cardinality: single;

Figure 9 a Sample of Domain Ontology Model

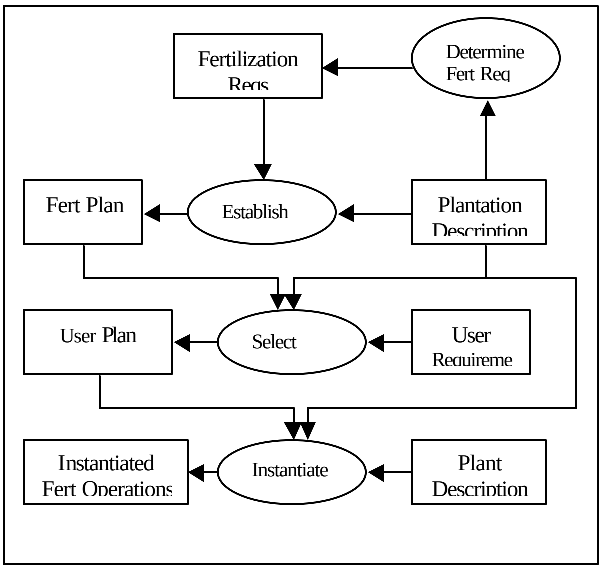
(plant: variety = giza171 &
plantation: previous-crop = legumes)
DETERMINE
(fertilizer: n-qty = 36 kg &fertilizer: p-qty = 15 kg &
fertilizer: n-qty = 48 kg]

Figure 9 b Sample of Determine Model

(nitrogen-fert-op: value = true &
soil: salinity = normal &
irr_water: availability = regular &
plantation: planting-type = transplanting&
fertilizer: FCFN)
ASSIGN
(nitrogen-fert-op: date = before covering soil with water &
nitrogen-fert-op: fert-name = function 7 &
nitrogen-fert-op: fert-qty = function3 &
nitrogen-fert-op:method = "apply fertilizer during plowing")

Figure 9c Sample of Assign Model

Figure 9 Domain Knowledge of Fertilization



task: fertilization
task definition:
goal: fertilization schedule
input: plant and plantation description, user requirements
output: fertilization schedule
task body
type: composite
subtasks: determin-fert-req, establish, assign
additional-roles: fert-plan, user plan, fertilization reqs
control structure:
determine (plantation description, determing→ FR: fertilization reqs),
establish (FR, plantation description → FP: fert plans),
DSPLAY FP);
select (FB, U:user ulan);
FOR each operations in U do;
Operation: value = true;
end
instantiate (plant description, plantation description, U → AO: assigned operations)
DSPLAY (AO

Figure 10 inference and Task knowledge of Fertilization

4 TACTIC KNOWLEDGE BASED SUB-SYTEMS

The tactic knowledge based systems diagnose the problems that occur during the growing season and advise user how to control these problems. It contains two sub-systems namely: diagnosis and treatment sub-systems. The following two sub-sections describes these two sub-systems.

4.1 Disorder Diagnosis

The purpose of this sub-system is to find the causes of the abnormal observations on the paddy plant **[El-Azhary, 1999b]**. The domain knowledge of this sub-system contains two models, namely: *suspicion*, and *differentiation*. The inference consists of three inference steps, *predict, generate observations, and differentiate.*

The *suspicion* model contains a relation between the user complaints and the suspected disorders that is used by *predict* inference step to generate the suspected disorders. The *differentiation* model contains a relation between the additional observations and the confirmed disorders that is used by *differentiate* inference step to confirm the disorder(s) The *generate observations* inference step generates the additional observations related to the current situation. Figure 11 presents a sample of the domain knowledge, while figure 12 presents inference and task knowledge.

concept plant;
properties:
complaint: universal;
observation: universal;
concept leaves;
sub-type-of: plant;
properties:
color_status: {normal, abnormal}
differentiation-of complaint(plant);
color: {yellow, blue green, green, red, pale green, brown, whitening, bronze}
differentiation-of observation(plant);

Figure 11(a): Sample of domain ontology

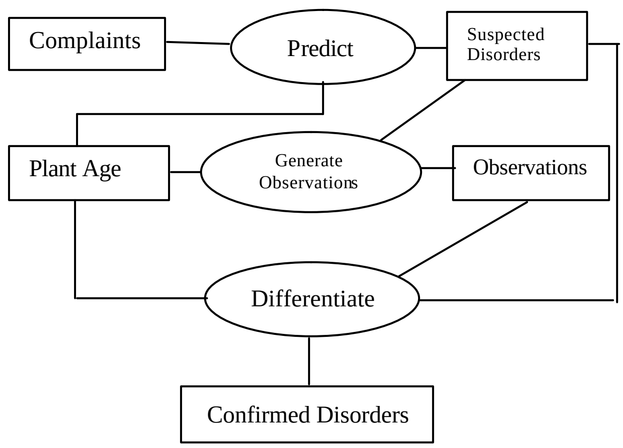
(leaves: color-status = abnormal)
SUSPECT
(nutrition deficiency & physiological diseases & nematode & foot rot & root rot & earth worm)

Figure 11(b): Sample of *suspicion* model

disorders: suspected = foot rot &
plant: appearance = elongation &
leaves: color = pale green)
CONFIRM
(disorders: value = foot rot)

Figure 11(c): Sample of *differentiation* model

Figure 11: Sample of disorder diagnosis domain knowledge.



task: rice disorder diagnosis;
task-definition:
goal: get the causes of the abnormal observations;
input: complaints, Plant age;
output: confirmed disorders
task-body:
type: composite
subtasks: predict, generate observations, differentiate
additional-roles: suspected disorders, observations;
control-structure:
OBTAIN (complaint),
predict (C: complaints, P → S: suspected disorders),
generate observations(S, P: Plant Age → O: observations),
differentiate (S, O, P → Con: confirmed disorders),
PRESENT(Con)

Figure 12: Inference and Task Knowledge of disorder diagnosis

4.2 Disorder Treatment

This sub-system provides the user with treatment of the disorders**[El-Azhary, 1999a]**. It contains two domain models namely: *treatment*, and *advice*. The *treatment* model contains two relations, namely: *treat*, *treated-by*. The *advice* model contains two relations namely: *recommend and is-recommend-when*. The inference structure consists of six inference steps namely: *specify*, *obtain*, *match-1*, *match-2*, *assign1*, and *assign2*.

The *treated-by* is a relation between a disorder and its remedy pesticides, that is used by *specify* inference step. The *treat* is a relation between a pesticide and its related disorders that is used by *match-1* inference step. The *recommend* is *a* relation between a disorder and its related advice, that is used by *specify* inference step also. The *is-recommended-when* is a relation between an advice and the disorders that is used by *match-2* inference step.

Assign1 inference step assigns disorders to each pesticide by performing intersection between the related disorders and the infested disorders. *Assign2* inference step assigns disorders to each advice. Figure 13 presents the domain knowledge, while figure 14 presents inference and task knowledge.

concept insecticides;
  sub-type-of: pesticides;
concept fungicides;
  sub-type-of: pesticides;
instance Fuji-1 ;
  of fungicides;
  property-value:
    concentration = 200 - 400 Liter /400 cm^3/feddan;
    application_method = foliar application;
instance Furidan;
  sub-type-of insecticides;
  property-value: concentration = 6 kg/feddan
    application_method = soil drench

Figure 13(a): Sample of domain ontology

(Beam) TREAT (rice blast)
(Fuji-1) TREAT (rice blast)
(Furidan) TREAT (stem rot & rice stem borer & rice leaf miner & bloody worm & earth worm)

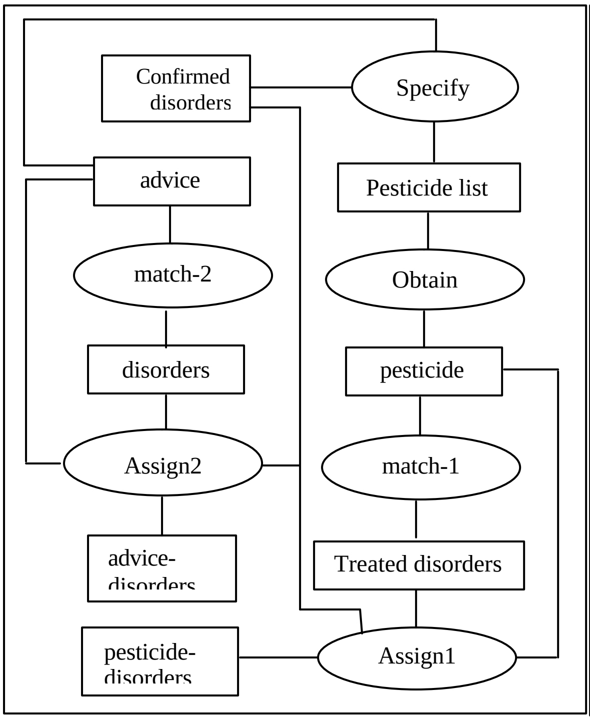
(bloody worm) TREATED-BY (Furidan; Diazinon; Fura-Z; Sumithion)
(rice stem borer) TREATED-BY (Furidan; Diazinon, Fura-Z)
(rice blast) TREATED-BY (Fuji-1, Beam)

Figure 13(b): Sample of *treatment model*

(advice = dry soil for 3-5 days) IS-RECOMMENDED-WHEN (phosphor deficiency; potassium deficiency ; zinc deficiency; root rot; bloody worm)
(potassium deficiency) RECOMMEND (advice = dry soil for 3-5 days)
(zinc deficiency) RECOMMEND (advice = dry soil for 3-5 days; advice = improve drainage system)

Figure 13(c): Sample of *advice model*

Figure 13: Sample of disorder treatment domain knowledge model.



task: faba bean disorder treatment;
  task-definition:
    goal: get treatment and recommendation for the infested plant;
    input: confirmed disorders;
    output: pesticide-disorders, advice-disorders;
task-body:
    type: composite;
    subtasks: specify, obtain, match-1, match-2, assign-1, assign-2;
    additional-roles: pesticide list, pesticide, advice, treated-disorders, disorders;
control-structure:
    specify(d: confirmed disorders $\rightarrow$ pl:pesticide list, a:advice)
    $\forall$ (p) : p $\in$ pl DO
    Begin
      obtain(p $\rightarrow$ p': pesticide)
      match-1(p' $\rightarrow$ d': treated-disorders)
      assign-1(p', d', d $\rightarrow$ pd: pesticide-disorders)
    End
    $\forall$ (ad) : ad $\in$ a DO
    Begin
      match-2(ad $\rightarrow$ ds: disorders)
      assign2-(ad, ds, d $\rightarrow$ add: advice-disorders)
    End

Figure 14: Inference and Task Knowledge of *disorder treatment*

5 Implementation Overview

The paddy expert system was implemented using Knowledge Representation Object Oriented Language (KROL) shell under Windows 98 **[Shaalan, 1998], [Rafea, 1997]**. It was developed at CLAES. The system was verified and tested in CLAES and it is ready to be test in the field. Figure 15 shows snapshots of running diagnosis sub-system.

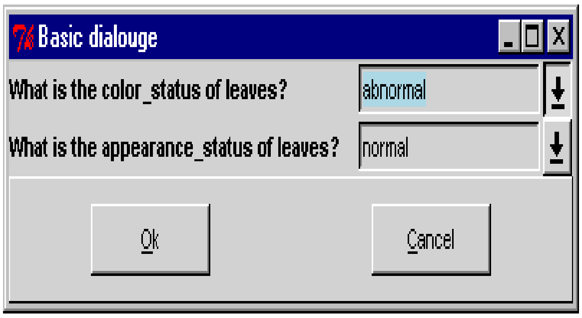


Figure 15a Inquiring About Use Complaints

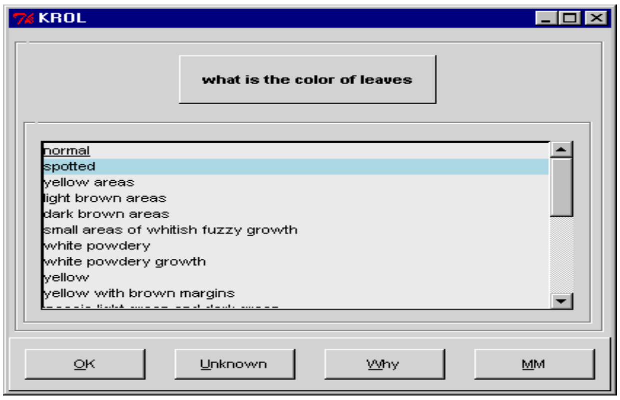


Figure 15b Inquiring about Leaves Color

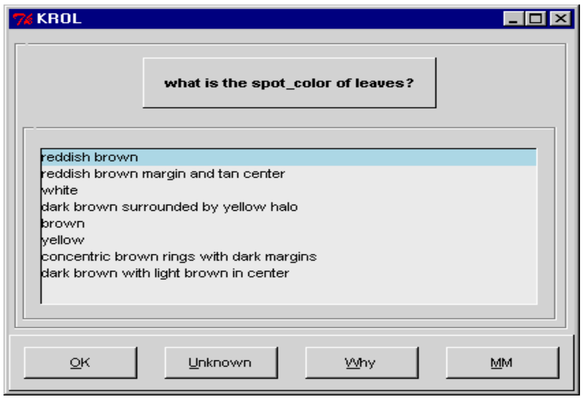


Figure 15c Inquiring about Spot Color

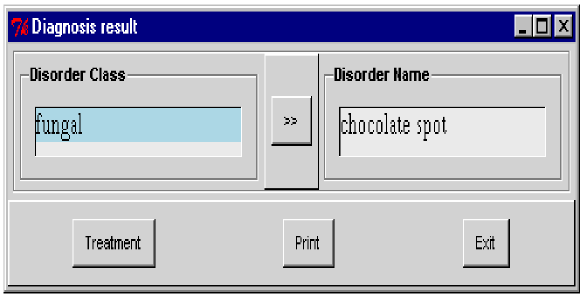


Figure 15d Displaying the Results

Figure 15 Sample of running Diagnosis sub-

6 Conclusion

A paddy expert system was developed, verified and tested. The system will be tested in the field to be mature enough and capable to be used by Extension officers and paddy researchers. It gives strategic advice, which enable paddy growers to apply the right operation at the specific time. This enables users to avoid the problems that may occur during growing season. The system also solves tactic problems that may occur during growing season. It diagnoses the problems and advises users how to control these problems either by agricultural operations or chemical operations.

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