A study of prototype model in the rule based expert system for the management of mealybugs in grape crop

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ABSTRACT: - This paper presents the development of a prototype model in the rule based expert system for the management of mealybugs disease in grape crop. Mealybug is an insect pest observed in grape crop. Mealybugs occur throughout the year and their management is very crucial near harvest. The prototype model of rule based expert system will help the grape growers, agricultural experts and professional to control or manage the attack of mealybug in grape crop throughout its various life cycle stages. On the basis of information like crop period, whether foundation or forward pruning and appearance of infection of mealybugs etc, this system will suggest various preventive measures and different pesticide treatments.

Keywords:- Expert System, Mealybugs, Pesticide treatment, Insect Pest

I.   INTRODUCTION: -

The most commonly known type of knowledge based system is the rule based expert system in which the experience and knowledge of human experts is captured in the form of IF-THEN rules and facts which are used to solve the problems. An expert system is a computer program that contains the knowledge and analytical skills of one or more human experts.

Grape cultivation is one of the most remunerative farming enterprises in India. Grapes are small round or oval berries. Some contain edible seeds while others are seedless. Grape cultivation faces serious threat from several insect pests and diseases. Insect pests cause enormous economic losses to grape sector every year. To avoid such losses, it is necessary to make use of appropriate pesticides in right dose (i.e. proper combination and ratio) at right time. It is also important to note that, indiscriminate use of pesticides not only adds to the cost of production significantly, but also results in pesticide (chemical substance) residues in the final produce (i.e. grape) and also in soil.

Author has developed a prototype of expert system for the use of various pesticides at different stages of grape crop to control the attack of mealybugs. The paper includes

II.   GRAPE   CROP   IN   MAHARASHTRA (INDIA) :-

Grape is grown under a variety of soil and climatic conditions in three distinct zone namely sub-tropical, hot tropical and mild tropical climatic regions in India.

Nashik, Sangali, Solapur, Pune, Satara, Lature and Osmanabad districts of Maharashtra state comes under Hot tropical climatic region. Vines do not undergo dormancy and double pruning and single harvesting is the general practice in this region. Maximum and minimum temperature is 42°C and 8°C respectively. The major problems in this region are soil and water salinity and drought. Berry growth is impaired and in certain locations pink blush sometimes develops on green berries due to temperature that drop to a low of 8°C. Thompson seedless & its clones (i.e. Tas-A-Ganesh, Sonaka), Anab-e-shahi, Sharad seedless and Flame seedless are the varieties grown in this region.

In India, Maharashtra is a leading state in production of grapes. With regard to agricultural land under grape cultivation and production, Nashik and Sangali districts are forefront in the state. Area under

grapes in Maharashtra is 86.0 thousand ha and production is around 774.0 thousand MT annually. (Source: National Horticulture Board, Govt. of India).

III. INFORMATION ABOUT VARIOUS INSECT PESTS OBSERVED IN GRAPE:

The major insect pests observed in the grapes are e mealybug, thrips, flea beetle, leafhoppers, stem borer and mites. Grape crop is a perennial crop. So farmers have to look after a full one year cycle of the crop.

a) Mealybugs:- Mealybugs occur throughout the year and their management is very crucial near harvest. Mealybugs are cottony in appearance, small oval, soft bodied sucking insects. Adult mealybugs are found on leaves, stems and roots and are covered with white mealy wax. They form colonies on stems and leaves developing into dense waxy, white masses. They suck a large amount of sap from leaves and stems with the help of sucking mouth part.

The mealybug occurs on the grapevine throughout the year. After the harvesting, the mealybug population is confined to vegetative parts. The grapevine is pruned usually in April-May (Foundation pruning). Grape mealybugs remain on the leaves, stem and trunk from April to September. The mealybug population is usually low from June to September.

The mealybug population starts increasing from mid December onwards. During January, they migrate from the trunk, cordons and shoots to developing berries. It attains peak population before harvesting of bunches during March-April. Early pruned crop usually escapes from the mealybug attack as compared to late pruned crop. Heavy sporadic rains and cool temperatures of less than 20°C results in temporary reduction in the mealybug population. The pest population buildup coincides with high temperature of 30-40°C, low humidity (less than 40%) and berry development. The population was low in winter and rainy seasons, and higher in summer months.

b) Thrips:- Thrips are very important insect pests and they occur throughout year and their management is very crucial during flowering and berry setting period (i.e. during the month of November to December). Thrips are small insects, 0.04 inch long, with distinctive feathery wings.

c) Flea beetle:- It is dark metallic greenish-blue or steel-blue and about 3/16 inch long. The most serious damage occurs in the spring. It occurs immediately after both foundation and back pruning and their management is crucial after both pruning.

d) Leaf hoppers:- They are elongated yellow-white. They become grayish yellow before hatching and they are measuring 0.8 mm long. They occur throughout the year and their management is very crucial during flowering period (i.e. during the month of November to December).

e) Stem borer:- Among several infestations, the stem borer is the most serious problem being faced by the grape growers during recent years. Incidence of stem borer is more after foundation pruning especially during November to January.

f) Mites:- They are becoming important pests in recent years and their management is crucial during the month of December to February.

IV. SPECIES OF MEALYBUGS :-

Among the mealybug species infesting grapes in India, the pink mealybug *Maconellicoccus hirsutus* and the citrus mealybug *Planoco-ccus citri* are found causing severe loss in many grape growing areas of Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu.

V. EFFECT OR DAMAGE DUE TO ATTACK OF MEALYBUGS IN GRAPE: -

In recent years, mealybugs have become an increasing threat to grapevine causing heavy loss in the field.

1) Nymphs and adult mealybugs suck the sap from the trunk , cordons, buds, spurs, aerial roots, leaves, shoots, nodes, flower panicles and bunches. Infestations of the growing point especially with the pink mealybug results in malformation of leaves and shoot tips.
2) Honeydew excreted by mealybug nymphs and adults, supports the growth of sooty mould on leaves, shoots and bunches. Sooty and sticky bunches and their white cottony wax masses are unfit for marketing as table grapes.
3) Raisins cannot be prepared from such infested bunches.
4) The pest attack weakens the grownup vines. In case of severe mealybug infestation young vines often die.
5) The grape mealybug causes losses up to 100 per cent in severe cases in the vineyard.

VI. CONTROL OR MANAGEMENT OF MEALYBUGS ATTACK IN GRAPE CROP:-

Management of Mealybugs can be planned well in advance especially immediately after both April and October Pruning.

Pruning: In Maharashtra, the vines are forced to undergo rest for about a month immediately after harvesting. This helps in storing the food material in the mature parts of the vine. The canes are cut back in April by keeping 1-2 buds which develops into canes in 4-5 months. The dried canes are also removed. Here it is called "Back pruning" or" Foundation" or "Growth Pruning".

In the month of September-October, these canes are pruned for fruiting. This pruning is called "Forward pruning" or "Winter Pruning". Vines, which have attained the age of one year can be subjected to this pruning. The level of forward pruning depends upon the region, variety and vine vigour. Normally the vines start yielding in about 5 months from forward pruning.

Mealybugs are hard to kill pests on several crop plants. All the stages of the mealybugs are covered with waxy coating and therefore it is difficult to control the mealybugs with conventional insecticides. Cultural, mechanical, biological and chemical methods of control have to be adapted throughout the year to control the mealybug population thus preventing the loss caused by the mealybugs.

Here after foundation as well as forward pruning, several mealybugs controlling steps are suggested as below.

A) After Foundation Pruning (April to October)
1) In April/May, collect and destruct the pruned material from mealybug infested gardens
2) In April/May, Remove loose bark and destruct the debarked material.
3) Immediately after pruning, remove and destruct the loose bark and swab or wash stem and arms with 2 ml of Dichlorvos 76 EC+ 2 gm of fish oil resin soap in a liter of water.
4) At the time of harvesting in March-April, Collect and destruct the mealybug - infested bunches of grapes.
5) Immediately after pruning, apply sticky bands like 'Track-trap' or 'Bird Tangle Foot' on arms or on main stem before appearance of mealybugs on canes or bunches.
6) Immediately after pruning, remove weeds and alternate host plants like hibiscus, bhindi, custard apple, guava etc. in and nearby vineyards.
7) Mealybugs control often involves the control of caretaking ants that are important for the proper development of mealybugs. Without ants, mealybugs population are small and slow to invade new areas. Therefore, management of mealybugs often includes the control of ant species.
   Throughout the year, find out and destroy the ant colonies with drenching of Chlorpyriphos 20 EC @ 2.5 Ml/L or apply Malathion dust @ 25 Kg/ac.
8) After 30 – 45 days after foundation pruning and if infection of mealybugs observed then apply foliar spray of

Methomyl 40 SP @ 1Gm/L or Dichlorvos 76% EC @ 2 Ml/L.

9) After 45 – 60 days after foundation pruning and if infection of mealybugs observed then apply spray of Phosalone 35 EC or Malathian 50 EC 2 Ml/L.

10) After 75 – 90 days after foundation pruning and if infection of mealybugs observed then release Australian lady beetle adult or grub Cryptolaemus montrouzieri @ 5,000 per ha/year.

11) After 105 – 120 days after foundation pruning (i.e. during high humid months) and if infection of mealybugs observed then apply foliar spray of Verticillium lecanii or Beauveria bassiana (2×10^8 cfu/ml) @ 5 Gm/L or 5 Ml/L.

B) After Forward Pruning (October to April)

1) Immediately after forward pruning, remove and destruct the loose bark and swab or wash stem and arms with 2 ml of Dichlorvos 76 EC+ 2 gm of fish oil resin soap in a liter of water.

2) Immediately after forward pruning, apply sticky bands like 'Track-trap' or 'Bird Tangle Foot' on arms or on main stem before appearance of mealybugs on canes or bunches.

3) Immediately after forward pruning, remove weeds and alternate host plants like hibiscus, bhindi, custard apple, guava etc. in and nearby vineyards.

4) Throughout the year, find out and destroy the ant colonies with drenching of Chlorpyriphos 20 EC @ 2.5 Ml/L or apply Malathion dust @ 25 Kg/ac.

5) After 30 – 45 days after forward pruning and if infection of mealybugs observed then apply foliar spray of Methomyl 40 SP @ 1Gm/L or Dichlorvos 76% EC @ 2 Ml/L.

6) After 45 – 60 days after forward pruning and if infection of mealybugs observed then apply spray of Buprofezin 25 SC @ 1000-1125 Ml/Ha.

7) After 75 – 90 days after forward pruning and if infection of mealybugs observed

then release Australian lady beetle adult or grub Cryptolaemus montrouzieri @ 5,000 per ha/year.

8) After 90 – 105 days after forward pruning and if infection of mealybugs observed then apply foliar spray of Verticillium lecanii or Beauveria bassiana (2×10^8 cfu/ml) @ 5 Gm/L or 5 Ml/L.

9) After 105 – 120 days after forward pruning and if infection of mealybugs observed then apply foliar spray of Buprofezin 25 SC @ 1000-1125 Ml/Ha.

10) After 120 – 135 days after forward pruning and if infection of mealybugs observed then apply foliar spray of Azadirachtin 1% @ 2 Ml/L or 5% @ 1 Ml/L.
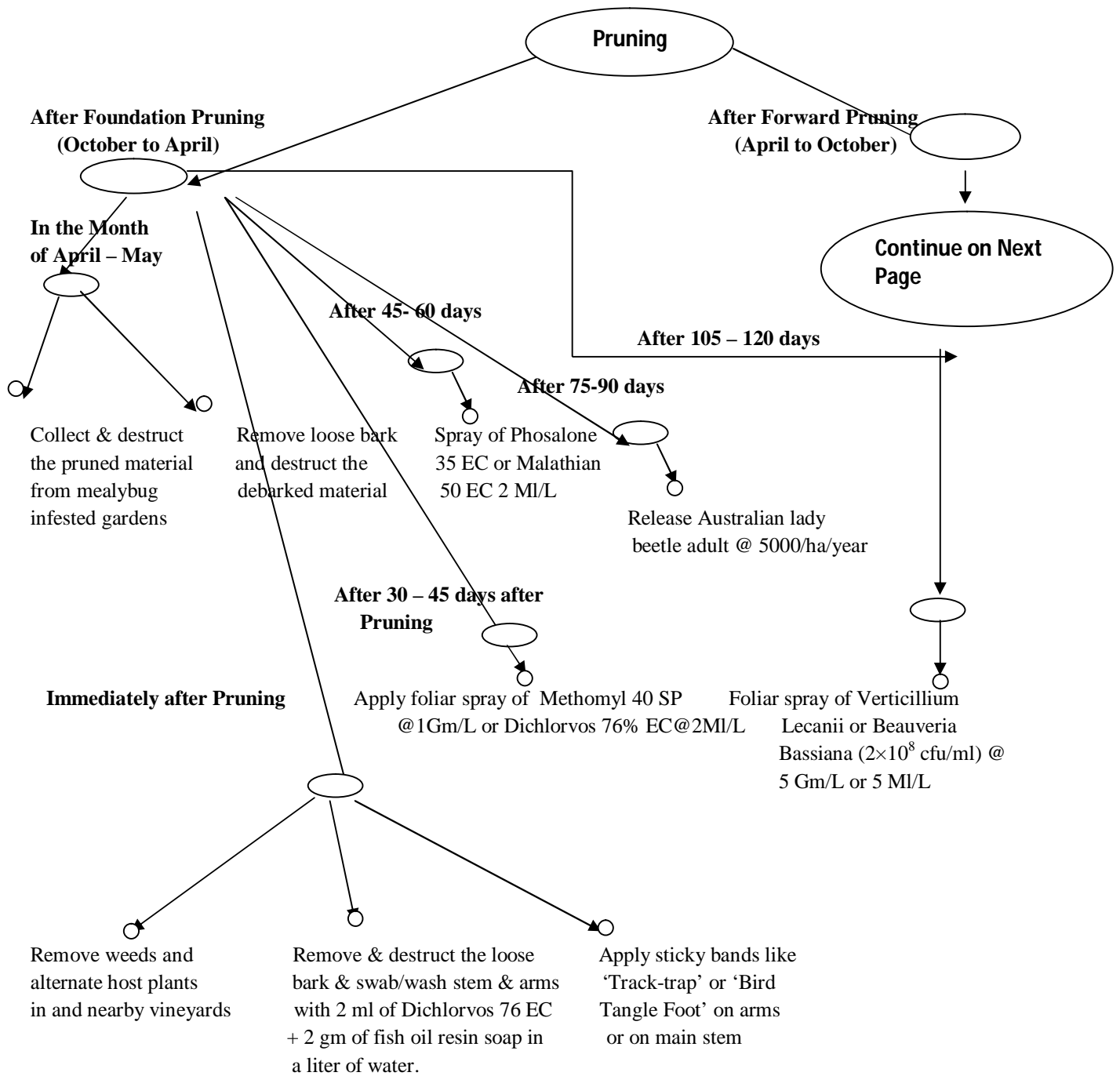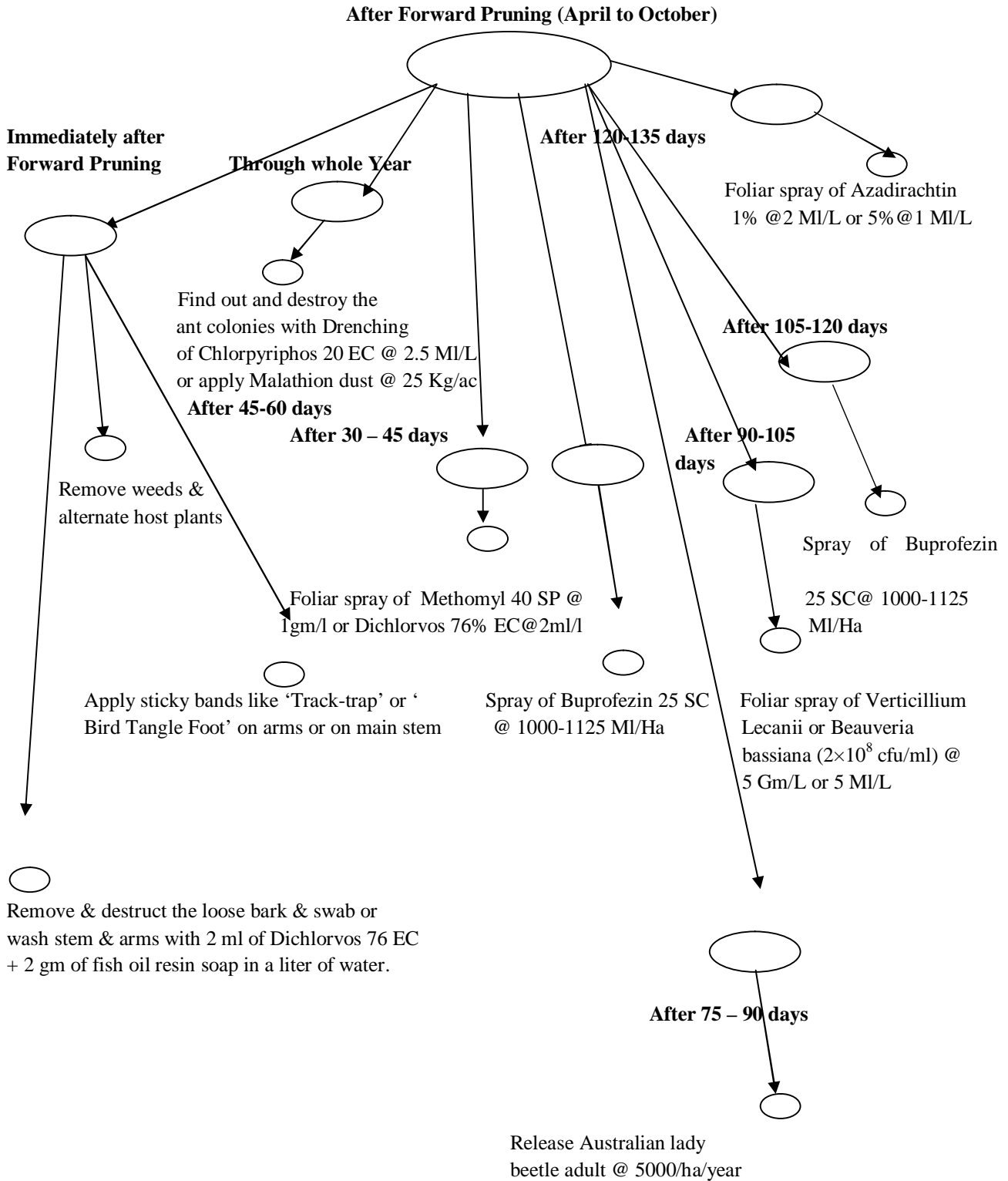
VII. RULE BASE DEVELOPMENT : -

The rule based system uses rules in the form of IF-THEN. The IF part needs to be satisfied by the facts for the goal i.e. to fire the THEN part. The knowledge base is a collection of knowledge in the domain area. Here domain is to study the pest named mealybugs and to suggest various pest control treatments against it. In this paper, expert knowledge is acquired in the form of If-then rules to suggest pest control treatment on the basis of input given by the user. End user enters information like type of pruning, number of days after pruning, temperature, humidity etc. The prototype model will accept this information and suggests different pest control treatments.

Rule based systems differ from standard procedural or object-oriented programs in that there is no clear order in which code executes. Instead, the knowledge of the expert is captured in a set of rules, each of which encodes a small piece of the expert's knowledge. Each rule has a left hand side and a right hand side. The left hand contains information about certain facts and objects which must be true in order for the rule to potentially fire i.e. execute. Any rules whose left hand sides match in this manner at a given time are placed on an agenda. Then right hand side is executed and finally it is removed from the agenda. The agenda is then updated and new rule is picked to

execute. This continues until there are no more rules on the agenda.

Following rules illustrates how the knowledge base has been represented in the form of 'IF-THEN' rules.

Pruning

After Foundation Pruning (October to April)

After Forward Pruning (April to October)

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In the Month of April – May

After 45- 60 days

After 105 – 120 days

After 75-90 days

Collect & destruct the pruned material from mealybug infested gardens

Remove loose bark and destruct the debarked material

Spray of Phosalone 35 EC or Malathian 50 EC 2 Ml/L

Release Australian lady beetle adult @ 5000/ha/year

After 30 – 45 days after Pruning

Immediately after Pruning

Apply foliar spray of Methomyl 40 SP @1Gm/L or Dichlorvos 76% EC@2Ml/L

Foliar spray of Verticillium Lecanii or Beauveria Bassiana ($2{\times}10^{8}$ cfu/ml) @ 5 Gm/L or 5 Ml/L

Remove weeds and alternate host plants in and nearby vineyards

Remove & destruct the loose bark & swab/wash stem & arms with 2 ml of Dichlorvos 76 EC + 2 gm of fish oil resin soap in a liter of water.

Apply sticky bands like 'Track-trap' or 'Bird Tangle Foot' on arms or on main stem

After Forward Pruning (April to October)

**Immediately after
Forward Pruning**

Through whole Year

After 120-135 days

Foliar spray of Azadirachtin
1% @2 Ml/L or 5%@1 Ml/L

Find out and destroy the
ant colonies with Drenching
of Chlorpyriphos 20 EC @ 2.5 Ml/L
or apply Malathion dust @ 25 Kg/ac

After 105-120 days

After 45-60 days

After 30 – 45 days

**After 90-105
days**

Remove weeds &
alternate host plants

Spray of Buprofezin

25 SC@ 1000-1125
Ml/Ha

Foliar spray of Methomyl 40 SP @
1gm/l or Dichlorvos 76% EC@2ml/l

Apply sticky bands like 'Track-trap' or '
Bird Tangle Foot' on arms or on main stem

Spray of Buprofezin 25 SC
@ 1000-1125 Ml/Ha

Foliar spray of Verticillium
Lecanii or Beauveria
bassiana (2×10^{8} cfu/ml) @
5 Gm/L or 5 Ml/L

Remove & destruct the loose bark & swab or
wash stem & arms with 2 ml of Dichlorvos 76 EC
+ 2 gm of fish oil resin soap in a liter of water.

After 75 – 90 days

Release Australian lady
beetle adult @ 5000/ha/year

VIII. RULE BASE SYSTEM FOR THE MANAGEMENT OF MEALYBUGS :

For the goal driven forward chaining expert system, the final goals are: suggesting proper ratio of Pesticides and other preventing actions. Anyone can have 20 resulting combinations (If-then rules in Rule base), based on which he/she decide which Pesticide should be used against attacked pest at which stage. The system ultimately has to reach one of these goals after processing all the parameters under each rule to complete the evaluation process and provide the final decision about the management of mealybugs. On which system suggest appropriate ratio of pesticides.

Following rules represents the experts knowledge in the form of IF-THEN rules.

Rule #1
IF CROP PERIOD IS IN APRIL-MAY
AND VINE IS INFESTED BY MEALYBUGS
THEN COLLECT AND DESTRUCT THE PRUNED MATERIAL FROM MEALYBUGS INFESTED GARDENS

Rule #2
IF CROP PERIOD IS IN APRIL-MAY
AND VINE IS INFESTED BY MEALYBUGS
THEN REMOVE LOOSE BARK AND DESTRUCT THE DEBARKED MATERIAL.

Rule #3
IF CROP PERIOD IS IMMEDIATELY AFTER FOUNDATION PRUNING
THEN REMOVE AND DESTRUCT THE LOOSE BARK AND SWAB OR WASH STEM AND ARMS WITH 2 ML OF DICHLORVOS 76 EC + 2 GM OF FISH OIL RESIN SOAP IN A LITER OF WATER

Rule #4
IF CROP PERIOD IS AT THE TIME OF HARVESTING IN MARCH-APRIL
AND VINE IS INFESTED BY MEALYBUGS
THEN COLLECT AND DESTRUCT THE MEALYBUG - INFESTED BUNCHES OF GRAPES.

Rule #5
IF CROP PERIOD IS IMMEDIATELY AFTER FOUNDATION PRUNING
AND VINE IS INFESTED BY MEALYBUGS
THEN APPLY STICKY BANDS LIKE 'TRACK-TRAP' OR 'BIRD TANGLE FOOT' ON ARMS OR ON MAIN STEM BEFORE APPEARANCE OF MEALYBUGS ON CANES OR BUNCHES.

Rule #6
IF CROP PERIOD IS IMMEDIATELY AFTER FOUNDATION PRUNING
THEN REMOVE WEEDS AND ALTERNATE HOST PLANTS LIKE HIBISCUS, BHINDI, CUSTARD APPLE, GUAVA ETC. IN AND NEARBY VINEYARDS.

Rule #7
IF CROP PERIOD IS IN BETWEEN 1 DAY AFTER PRUNING UPTO HARVESTING (ROUND THE YEAR)
THEN FIND OUT AND DESTROY THE ANT COLONIES WITH DRENCHING OF CHLORPYRIPHOS 20 EC @ 2.5 ML/L OR APPLY MALATHION DUST @ 25 KG/AC.

Rule #8
IF CROP PERIOD IS IN BETWEEN 30-45 DAYS AFTER FOUNDATION PRUNING
AND TEMPERATURE IS IN BETWEEN 30 TO 40^0c
AND HUMIDITY IS LESS THAN 40%
AND VINE IS INFESTED BY MEALYBUGS
THEN APPLY FOLIAR SPRAY OF METHOMYL 40 SP @ 1GM/L OR DICHLORVOS 76% EC @ 2 ML/L.

Rule #9
IF CROP PERIOD IS IN BETWEEN 45-60 DAYS AFTER FOUNDATION PRUNING
AND TEMPERATURE IS IN BETWEEN 30 TO 40^0c
AND HUMIDITY IS LESS THAN 40%
AND VINE IS INFESTED BY MEALYBUGS
THEN APPLY SPRAY OF PHOSALONE 35 EC OR MALATHIAN 50 EC 2 ML/L.

Rule #10
IF CROP PERIOD IS IN BETWEEN 75-90 DAYS AFTER FOUNDATION PRUNING
AND VINE IS INFESTED BY MEALYBUGS

THEN RELEASE AUSTRALIAN LADY BEETLE ADULT OR GRUB CRYPTOLAEMUS MONTROUZIERI @ 5,000 PER HA/YEAR.

Rule #11
IF CROP PERIOD IS IN BETWEEN 105-120 DAYS AFTER FOUNDATION PRUNING
AND CROP PERIOD IS IN BETWEEN HIGH HUMID MONTHS
AND VINE IS INFESTED BY MEALYBUGS
THEN APPLY FOLIAR SPRAY OF VERTICILLIUM LECANII OR BEAUVERIA BASSIANA (2×10^8 CFU/ML) @ 5 GM/L OR 5 ML/L.

Rule #12
IF CROP PERIOD IS IMMEDIATELY AFTER FORWARD PRUNING
THEN REMOVE AND DESTRUCT THE LOOSE BARK AND SWAB OR WASH STEM AND ARMS WITH 2 ML OF DICHLORVOS 76 EC + 2 GM OF FISH OIL RESIN SOAP IN A LITER OF WATER

Rule #13
IF CROP PERIOD IS IMMEDIATELY AFTER FORWARD PRUNING
AND VINE IS INFESTED BY MEALYBUGS
THEN APPLY STICKY BANDS LIKE 'TRACK-TRAP' OR 'BIRD TANGLE FOOT' ON ARMS OR ON MAIN STEM BEFORE APPEARANCE OF MEALYBUGS ON CANES OR BUNCHES.

Rule #14
IF CROP PERIOD IS IMMEDIATELY AFTER FORWARD PRUNING
THEN REMOVE WEEDS AND ALTERNATE HOST PLANTS LIKE HIBISCUS, BHINDI, CUSTARD APPLE, GUAVA ETC. IN AND NEARBY VINEYARDS.

Rule #15
IF CROP PERIOD IS IN BETWEEN 30-45 DAYS AFTER FORWARD PRUNING
AND TEMPERATURE IS IN BETWEEN 30 TO 40^0c
AND HUMIDITY IS LESS THAN 40%
AND VINE IS INFESTED BY MEALYBUGS
THEN APPLY FOLIAR SPRAY OF METHOMYL 40 SP @ 1GM/L OR DICHLORVOS 76% EC @ 2 ML/L.

Rule #16
IF CROP PERIOD IS IN BETWEEN 45-60 DAYS AFTER FORWARD PRUNING
AND TEMPERATURE IS IN BETWEEN 30 TO 40^0c
AND HUMIDITY IS LESS THAN 40%
AND VINE IS INFESTED BY MEALYBUGS
THEN APPLY SPRAY OF BUPROFEZIN 25 SC @ 1000-1125 ML/HA.

Rule #17
IF CROP PERIOD IS IN BETWEEN 75-90 DAYS AFTER FORWARD PRUNING
AND VINE IS INFESTED BY MEALYBUGS
THEN RELEASE AUSTRALIAN LADY BEETLE ADULT OR GRUB CRYPTOLAEMUS MONTROUZIERI @ 5,000 PER HA/YEAR.

Rule #18
IF CROP PERIOD IS IN BETWEEN 90-105 DAYS AFTER FORWARD PRUNING
AND TEMPERATURE IS IN BETWEEN 30 TO 40^0c
AND HUMIDITY IS LESS THAN 40%
AND VINE IS INFESTED BY MEALYBUGS
THEN APPLY FOLIAR SPRAY OF VERTICILLIUM LECANII OR BEAUVERIA BASSIANA (2×10^8 CFU/ML) @ 5 GM/L OR 5 ML/L.

Rule #19
IF CROP PERIOD IS IN BETWEEN 105-120 DAYS AFTER FORWARD PRUNING
AND TEMPERATURE IS IN BETWEEN 30 TO 40^0c
AND HUMIDITY IS LESS THAN 40%
AND VINE IS INFESTED BY MEALYBUGS
THEN APPLY FOLIAR SPRAY OF BUPROFEZIN 25 SC @ 1000-1125 ML/HA.

Rule #20
IF CROP PERIOD IS IN BETWEEN 120-135 DAYS AFTER FORWARD PRUNING
AND TEMPERATURE IS IN BETWEEN 30 TO 40^0c
AND HUMIDITY IS LESS THAN 40%
AND VINE IS INFESTED BY MEALYBUGS
THEN APPLY FOLIAR SPRAY OF AZADIRACHTIN 1% @ 2 ML/L OR 5% @ 1 ML/L.

Sample Rule:

Consider following rule from above rule base,

Rule #8
IF Crop Period Is In Between 30-45 Days After Foundation Pruning
And Temperature Is In Between 30 To 40^0c
And Humidity Is Less Than 40%
And Vine Is Infested By Mealybugs
THEN Apply Foliar Spray Of Methomyl 40 Sp @ 1gm/L **Or** Dichlorvos 76% Ec @ 2 Ml

Here forward chaining method is used to reach to the result. The available data is stage of crop life cycle (i.e. Foundation pruning), age of crop (i.e. 30-45 days after pruning), temperature and humidity. Hence Rule # 8 is selected, because its antecedent matches the available data. Now the consequent is added to data. Nothing more can be inferred from this information, but we have now accomplished our goal of suggesting pesticide treatment for "Mealybug" disease. Thus forward chining is implemented here. In this way remaining rules are prepared.

IX. IMPLEMENTATION : -

Many expert systems are built with products called expert system shells. The shell is software which contains the user interface, knowledge base and a inference engine. The knowledge engineer uses the shell to build a system for a particular problem domain. For the proposed study, author developed a prototype model using ASP.net and Ms-Access.

X. CONCLUSION : -

This Knowledge Based System is helpful to grape growers, agricultural professional and academicians to take decision related to the management of Mealybugs disease in grape crop. i. e. they have to use preventive actions and pesticides to control pests which attack on grape. As a pesticide treatment, this system suggests different pesticide to control single pest. So here grape growers get choice of selecting pesticide by considering different companies and their prices. This expert system checked by grape growers as well as agricultural expert and initial feedback collected which have been positive. With further work, the scope of the expert system can be widened.

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