DECISION MAKING IN INTEGRATED PEST MANAGEMENT AND BAYESIAN NETWORK

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ABSTRACT

Timely availability of expert support to the farmers for appropriate decision-making on 'whether and what pest management option is required' is imperative for effective Integrated Pest Management (IPM). For several decades Economic Threshold Level (ETL) has been the basis for decision-making but in modern IPM emphasis is given on agro-ecological situation wherein IPM decisions are based on large range of pest relevant information such as crop health, natural enemies, weather etc. beside pest incidence scientifically obtained through farmers' field scouting. But large farming community in India can rather obtain the tentative information of this kind, consisting uncertainties. Bayesian Network (BN),anartificial intelligence approach could help in developing technique/model to deal with tentative pest relevant information which can be used in field scouting based IPM Decision Support Systems (DSSs) to automate the process of advising appropriate pest management option to the farmers on the basis of tentative agro-ecological situation of their fields.

KEYWORDS

IPM, field scouting, decision-making, ETL, agro-ecological situation

1. INTRODUCTION

Excessive, injudicious and irrational use of chemical pesticide by the farmers for pest control causes significant damage to the environment, human health and also negatively impacts the crop production. There is a growing awareness world over on the need for promoting environmentally sustainable agriculture practices. Integrated Pest Management is a globally accepted strategy for promoting sustainable agriculture [10]. The IPM has been evolving over the decades to address the negative impact of chemical pesticides on environment ultimately affecting the interests of the farmers. The major goal of IPM is not to eradicate all pest populations but rather to accept a tolerable pest density above the Economic Threshold Level[6]. For several decades ETL has been the basis for IPM decision-making but in modern IPM emphasis is being given on field agro-ecological situation where pest management decisions are based on larger range of field observations such as crop health, natural enemies' population, and weather etc. beside pest information. Easy and timely availability of expert support on IPM decision-making is the biggest problem faced by the farmers in India. 'Whether and what pest management option is required' is the most important decision concern of the farmers. Many ICT based DSSs as web-based applications are available in the country but most of them provide information about for pest identification and management. Some initiatives have also been taken to provide ETL based decision support to the farmers on 'weather and what pest management option is required' which

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capture quantitative pest information scientifically obtained by trained pest scouts through regular field scouting. But there are no DSSs to provide decision support to the farmers on 'weather and what pest management option is required' on the basis of farmer's field agro-ecological situation neither there are techniques which can be used in these DSSs for selecting appropriate pest management option on the basis of tentative agro-ecological information obtained by the farmers. Large Indian farming community cannot scientifically observe such certain information rather they may obtain tentative information. Hence, Bayesian Network is widely used in ecological decision-making could be the suitable approach to develop expert technique/model for selecting appropriate pest management option on the basis of tentative agro-ecological information obtained from farmer fields. The technique thus developed can be used in field scouting based DSSs to automate the process of providing field agro-ecological situation based pest management advisories to the farmers.

2. DECISION-MAKING IN IPM

Decision-making is a mental process resulting in the selection of an action among several alternative solutions. Every decision-making process produces a final choice [4].Decision-making starts with the identification of a problem, which requires the collection of all relevant information for critical analysis of the problem. This analysis leads to development of a set of available alternative courses of actions to solve the problem; only realistic solutions should be selected considering multiple criteria e.g. effectiveness, benefits, costs and the constraints e.g. ease of implementation and technical or legislative constraints. Based on this analysis, the best solution is selected, and the decision is converted into an action [9].

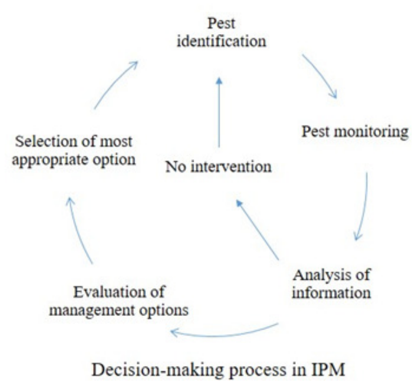

Fig: 1 IPM Decision making

Decision-making in IPM is a dynamic and complex process (Fig. 1) which requires much more knowledge and support than the conventional agriculture. The core of IPM framework is the decision-making process. The first decision concerns pest identification and second decision concerns 'whether and what pest management option is required'. Regular field scouting is the corner stone of the IPM. Whenever the decision maker notices any pest activity while scouting the field, he needs to identify the pest and scientifically observe the exact pest and other relevant information necessary for IPM decision-making. After the analyzing the information observed, first decision to be made is whether pest management action is required and if so, what is the most appropriate option; physical, biological or chemical, their doses, application methods, frequency etc. In IPM, sustainable biological, physical, and other non-chemical methods which are safer to environment and human health are preferred to chemical methods [9].

ETL VS. AGRO-ECOLOGICAL SITUATION, BASIS FOR IPM DECISION-MAKING

ETL is an important concept for IPM which integrates biology and economics and uses pesticides, or other management actions, only when economic loss in anticipated [6]. ETL is the best known and widely used concept in making IPM decisions but here are many reasons for not to use this method. One of the problems of the ETL is that it is based on parameters that are changing all the time, and that are often not known. ETL is defined as the population density at which control measures should be initiated against an increasing pest population to prevent economic damage. It is expressed as insect numbers. It is calculated on the basis of management cost per hectare, price of the farm produce/ kilogram and expected damage (kilogram/pest). So, it is possible to estimate the pest management cost but is very difficult to know the farm produce while crop is still growing. Similarly, pest damage too cannot be predicted as it depends upon many factors: crop health, weather, presence of pest natural enemies etc.

Analysis of field agro-ecological situation considers large rage of pest relevant information such as crop health, weather conditions and natural enemies' population beside pest incidence thus is more holistic approach than ETL. In agro-ecological situation based IPM, understanding the intricate interactions in an ecosystem can play a critical role in pest management. Agro-ecological situation based IPM results in more reduction of chemical pesticide usage and conserves the agro-ecosystems in comparison to ETL based IPM. Farmers cannot base decisions on only a simple pest count but have to consider many other aspects such as crop health, natural enemies and weather condition etc. Hence, IPM specialists have realized the limitations of the ETL and gradually shifted towards agro-ecological situation based IPM decision-making.

3. LIMITATIONS OF EXISTING FIELD SCOUTING BASED IPM DECISION SUPPORT SYSTEMS

In spite of development and wide spread of ICT, still there are limitations to the use of DSSs in IPM. One of the major limitation is that pest management DSSs do not adequately consider all aspects of IPM. Most of the available DSSs address only specific aspect of IPM. Several DSSs require too much time to use because of delays in data processing or tedious and input requirements whereas pest is very dynamic specie and can cause significant crop losses if not managed timely. For effective and successful IPM, farmer need easy and timely access to the knowledge or expertise so as to make appropriate decision as per his field situation.

Most of the IPM DSSs have been built to provide support on pest identification and their management. Only few DSSs are available andthese too provide real-time decision support to the farmers on the basis of pest situation in their fields 'whether pest incidence level has reached near ETL or crossed ETL'. These DSS scapture the quantitative pest incidence information scientifically obtained by trained pest scouts through regular scouting of farmer fields and produce ETL based pest reports to the experts so as to select appropriate pest management option to be advised to the farmers. Whereas in modern IPM the basis of IPM decision making has changed to field agro-ecological situation instead of pest ETL which requires large range of certain pest relevant information scientifically obtained from farmer fields through regular field scouting. But regular scientific observation of such information form farmer fields require large number of trained manpower which is a difficult and costly proposition for state plant protection agencies. So, can the farmers themselves do the filed scouting? They can, but large farming community is not able to scientifically observe such information rather they can obtain tentative information which consists lot of uncertainty. But there are no techniques available which can be used in field scouting based DSSs to select appropriate pest management option on the basis of tentative pest relevant information to be advised to the farmers.

4. BAYESIAN NETWORK

Bayesian Network is a key computer technology for dealing with probabilities in Artificial Intelligence. BN is one of the most effective theoretical models for uncertain knowledge expression and reasoning [1]. Probabilistic reasoning approaches such as Bayesian network [7] can be useful to develop technique for selecting appropriate pest management option on the basis of uncertain or inexact pest and other relevant information obtained through scouting of farmer fields. It was found through the literature review, that there have been very little efforts to use BN for pest management decision-making specifically for "whether and what pest management option is required' on the basis of tentative agro ecological situation of farmer fields. BN can be of great use in developing technique to better deal with this kind of tentative information obtained by farmers from their fields for selecting appropriate pest management option.

BN graphical model that represents a set of random variables and their conditional dependencies via anAcyclic Directed Graph (ADG). Because a Bayesian network is a complete model for the variables and their relationships, it can be used to answer probabilistic queries about them. Formally, a BN is a pair (G; P) where

G = (V; E) is a directed acyclic graph whose set of nodes V = {X1, X2, ………Xn} represents the system variables and whose set of arcs E represents direct dependence relationships among the variables, and

P is a set of conditional probability distributions containing a conditional probability distribution P (Xi/pa (Xi)) for each variable X given the set of parents pa (Xi) in the graph.

The joint probability distribution over V can be recovered from this set P of conditional probability distributions applying the chain rule as:

$$P(X1, \ldots\ldots, Xn) = \prod_{i}^{n} P\,(Xi/pa\,(Xi))$$

The process of obtaining the graph and the probabilities of a BN can be done either manually, from experts' knowledge on the domain, or automatically, from databases [3].

BN that can represent and solve decision problems under uncertainty are called BDN. It is a generalization of a Bayesian network, in which not only probabilistic inference problems but also decision making problems can be modeled and solved. BN only contain chance nodes, each representing a random variable, while BDN also contain decision nodes representing the options available to decision makers and utility nodes representing the decision makers' preferences. Arcs

coming into decision nodes represent the information that will be available when the decision is made. Arcs coming into chance nodes represents probabilistic dependence.
BN has been effectively used in ecological decision making [8]. New computational methods and techniques keep increasing BN'S abilities and range of practical applications [5]. Nevertheless, there are very few experiences of its usage in pest management [2].

5. CONCEPTUAL BAYESIAN NETWORK MODEL FOR IPM DECISION-MAKING

5.1 Problem Description

So the major decision concern of the farmers related to IPM is to decide whether and what pest management option to apply on the basis of tentative agro ecological situation of his field. Whenever he notices any pest activity, he needs to notes down the date of observation, information about crop condition, level of pest incidence, natural enemies and weather condition from his field.

Crop condition is measured in terms of its phenology. The level of pest incidence, presence of natural enemies and weather condition are important to estimate the intensity of the attack The crop condition, along with the intensity of pest attack, determines whether there is need to apply plant health treatment or not and if yes then what is the correct IPM option. So by using the conditional relationship among these agro ecological factors, a conceptual BN model has been built for selection of appropriate pest management option.

5.2 Model Structure& Parameterization

The construction of BN model structure included: identifying the important variables and establishing the links between variables. Based on knowledge elicited from literature and domain experts, BN model for agro ecological situation based IPM decision making was constructed. Six prominent variables (nodes) of interest were identified in this case; *level of pest incidence, presence of natural enemies, weather conditions, crop health, pest intensity and IPM options.* Level of pest incidence, natural enemies and weather are the parent nodes of pest intensity and pest intensity and crop health are the parent nodes for IPM option. Figure 2 shows the Bayesian model for field agro ecological situation based IPM decision making. The nodes in the BN model represent the variables, with their causal relations depicted by black arrows.

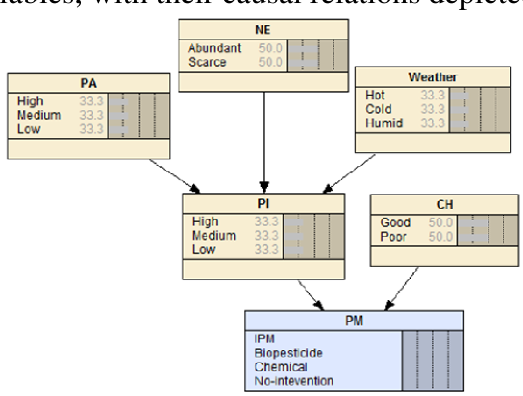

Fig. 2 conceptual BN model for agro ecological situation based IPM decision-making

To keep the BN model for IPM decision making as simple as possible, each node was discretized into necessary states only. The definition of these states was performed through literature review and expert consultation. In the model—Crop Health (CH) and Natural Enemies (NE) nodes are binary and other are ordered value. The conditional probabilities of these nodes are estimated basedon the data records available with public research institution, to keep the size of the CPs manageable, each node have been assigned the fewest number of states necessary.

6. Implementation of Bayesian Network model for IPM Decision Support

CPTs for conceptual BN model were approximated. Actual CPTs could be defined based on data analysis of the records available for agro ecological regions or on the basis of expert knowledge and subsequently the model is evaluated. Model evaluation helps ensure the model's interactions and outcomes are feasible. The model can be tested by applying different agro ecological scenarios (i.e. combinations of inputs) and examining whether the resulting probabilities are reasonable and logical. Ideally, the accuracy of the model should be tested with empirical data, but in many studies that use BNs these data are not available, at least not voluminously[11].

Once model is evaluated, input obtained from farmers for level of pest incidence, natural enemies, and weather and crop health be propagated to the model for PA, NE, weather and CH nodes, which changes the CP of PM node. CP of PM node would be deciding the pest management option to be applied in the farmers filed. Higher CP for PM node will lead to selection of stronger IPM option application and for moderate CP, milder IPM option be selected. If CP for PM node is very low than, there is no need for application of any pest treatment. The model thus validated could be used in IPM DSSs for selecting appropriate pest management option to be advised to the farmers on the basis of tentative agro ecological information provided by as model input.

7. Conclusion

Many DDSs have been developed for IPM by private and public organizations in the country but for extension workers only few for farmers. Most of these DSSs are either web database or information systems which provides information particularly on pest identification and management. Little efforts have been made to develop field scouting based DSSs to provide real-time decision support to the farmers. Even those few available field scouting based DSSs use pest ETL as the basis for decision-making capturing quantitative pest incidence information only instead of field agro-ecological situation, more holistic approach. But agro ecological information obtained by the farmers form their field is tentative and contains uncertainties. Bayesian network has unique advantage in dealing with uncerta in information. In following study, we found that use of Bayesian networks will be perfect approach to develop technique/model for selecting appropriate pest management option on the basis of tentative agro-ecological information obtained by the farmers through field scouting. Subsequently the technique thus developed can be used in field scouting based IPM DSSs to automate the process of decision support to the farmers.

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