Influence of Weather on Pest & Disease Development and Outbreak: Weather Based Forewarning Models for Pest & Disease Incidences, Pest & Disease Weather Calendar

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Problem of Pests & Diseases in Bangladesh

- It is estimated that 4-14% of rice yield in **Bangladesh** is lost every year by different **insect pests.** Bacterial leaf blight (BLB) and nematode (ufra) are now the serious **diseases** in rice. But the technologies resistant to **pests and diseases** are still very limited.
- Minor pests that could be easily controlled in the past became strong plant attackers now that are proving difficult to keep under check.
- Rice, wheat, corn, potato, mango, papaya, coconut, tomato, brinjal, tea and other major crops are increasingly coming under attack from the invasive alien pests and plant diseases.
- The pest is also attacking brinjal, tomato, chilli and many other vegetable crops besides causing large-scale damage in tea plantations.

Causes of the pest problem:

- **Monoculture:**
- **Extension of cultivated areas:**
- **Intensive cultivation**
- **Faulty crop husbandry**
- **Frequent application of subleathal dose of same pesticides**

Information required tackling the Pest problem

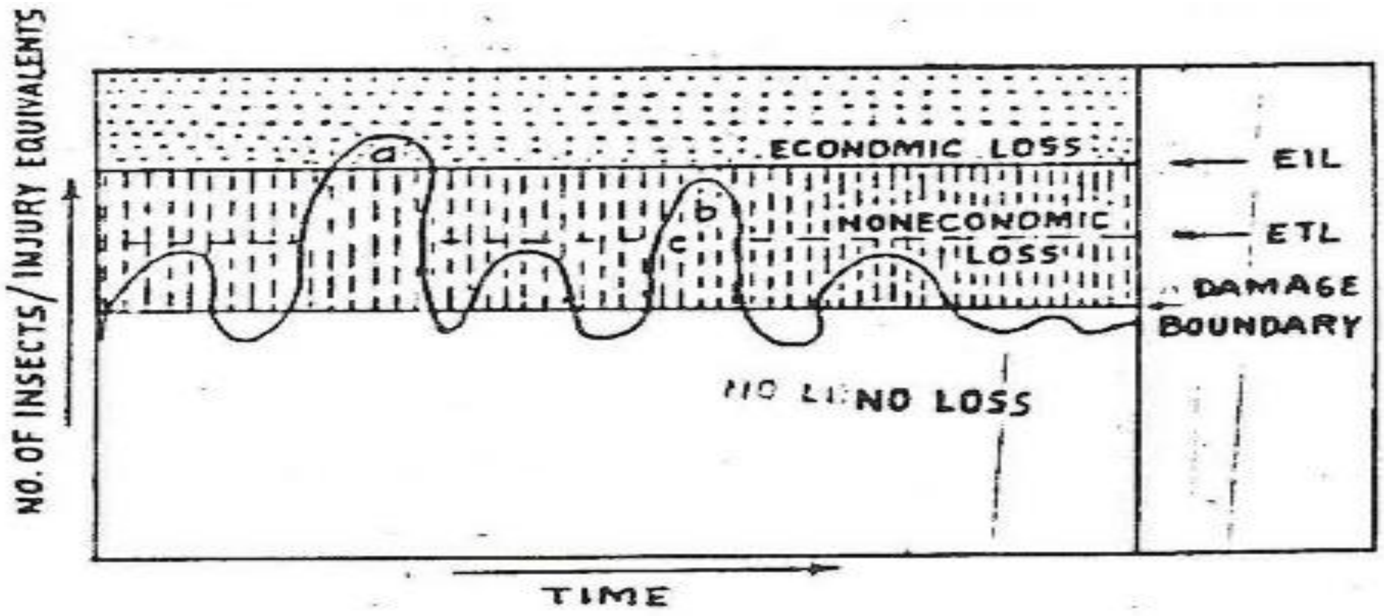
1. **Plant aspect**
2. **Pest aspect**
3. **Environmental aspect**
   - **The abiotic component of an environment consists the soil and climatic factors.**
   - **Soil affects greatly the life of pest**
   - **Climatic factors**
4. **Equipment and personnel aspect**

Concept of injury levels

- Most crops harbor wide variety of insect.
- Potentially most of these could cause havoc but only a few of them actually damage the crop.
- The concept of injury level was propounded to enable us to identify the population level at which an insect could cause damage to the crop.
- Most popular terms used in this connection are the economic injury level (ETL) and economic threshold level (ETL).

Economic threshold level (ETL)

- It is the best-known and most widely used index in making pest management decision.
- It is defined as the population density at which control measures should be initiated against an increasing pest population proved economic damage.
- Although expressed in insect numbers, ETL, is, in fact, a time parameter, with pest numbers being used as an index for when to implement management strategies.



Weather, climate and insect pest

- No precise and universal applicable theory for how population of pest is regulated in nature.
- Within broad limits, climate governs general distribution of insect.
- Weather affects the number of insects within their areas of distribution and fluctuation in numbers around the margins of the area.
- Insects are limited in space and in number by many factors, some of which are not directly associated with weather and climate.
- But in the main an insect is so completely embedded in atmospheric factors that they must be considered as a great importance in controlling its occurrences.
- Weather effects on insect often act over a short period and the critical period may be missed in the field and completely hidden in the published weather data.
- In a day or a few days, weather factors may reduce a population of insects capable of divesting a crop to one of no economic importance.

Continued: **Weather, climate and insect pest**

- Often investigators have overlooked this factor of timeliness, although in such insect as chinch bugs and grasshoppers it can be most important.
- Temperature alone may do in controlling the distribution of insects. Within the normal area of occurrence, the temperature often affects the number of generations in a season and by increasing the number of individuals within any one generation.
- Temperature and moisture often act together to limit the number or distribution of insects. High temperature and high humidity encourage the spread of a fungus disease that attack many species of grasshopper. For instance, disease may decimate whole population, nearly to the exclusion of other limiting factors.
- The food habits of insects are as diverse as they are important. But as they eat and how much they eat is largely controlled by the weather and climate in which they find themselves suited.
- So responsive insects are insects to their meteorological environment that we must have knowledge of its effect if we are to understand, extend or refine their control.
- We must know the direct effect of all we
- ather factors and the indirect effects, such as those on hosts, parasites and predators. We can consider the climate of an area and fit certain crop parasites into the expected climatic performances in order to reduce depredation of pests. We can measure weather and give short range forecast.
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Climatic Parameters influencing insects

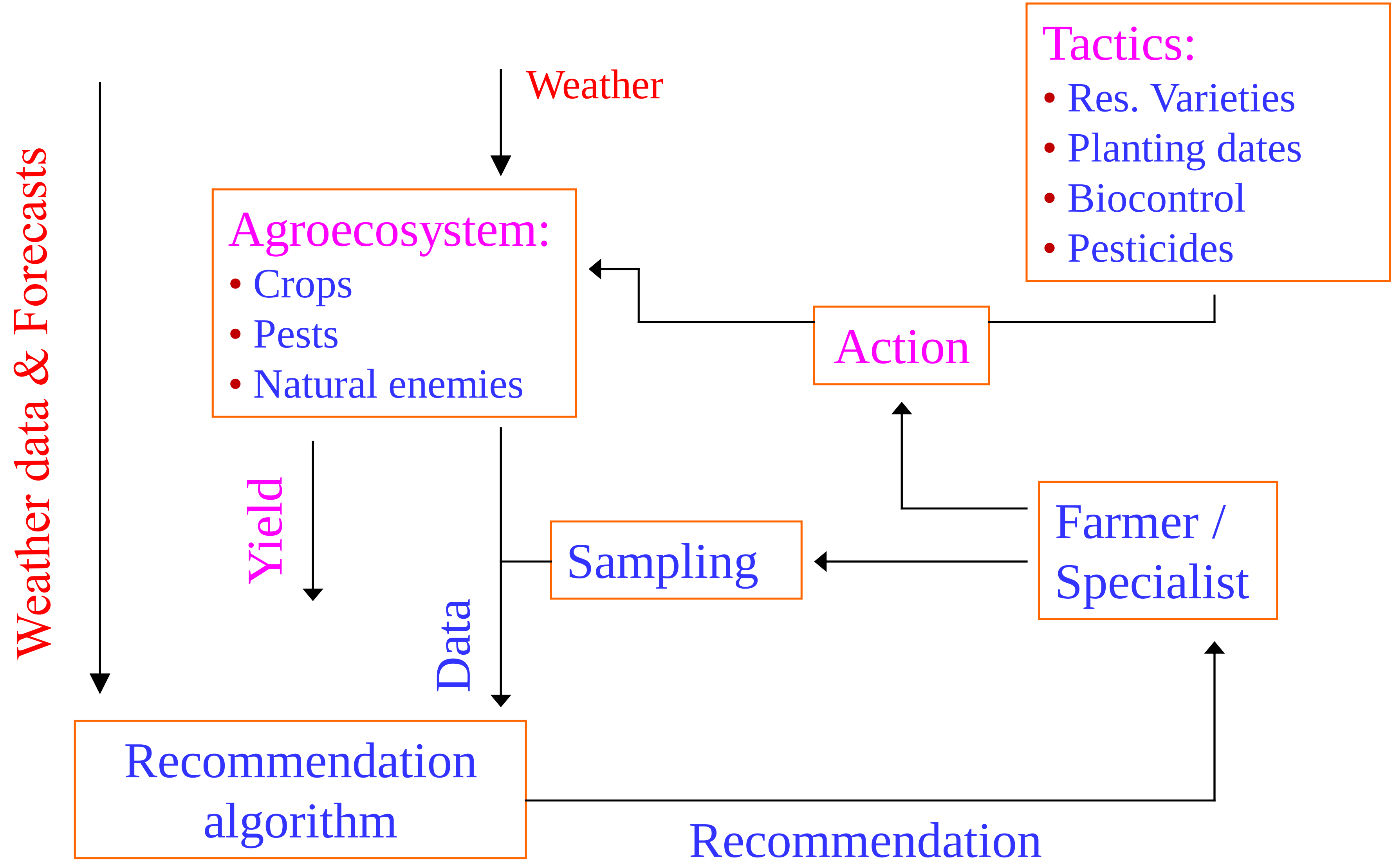
Macro

- Temperature (Max and Min) (insect development)
- Rainfall (Amount and distribution) (insect emergence & oviposition, washout)
- Relative Humidity (Morning and Afternoon) (egg hatch)
- Sunshine hours / solar radiation (oviposition, egg hatch)
- Wind speed and direction (migration, dispersal)
- Synoptic weather conditions (temperature modification; migration)

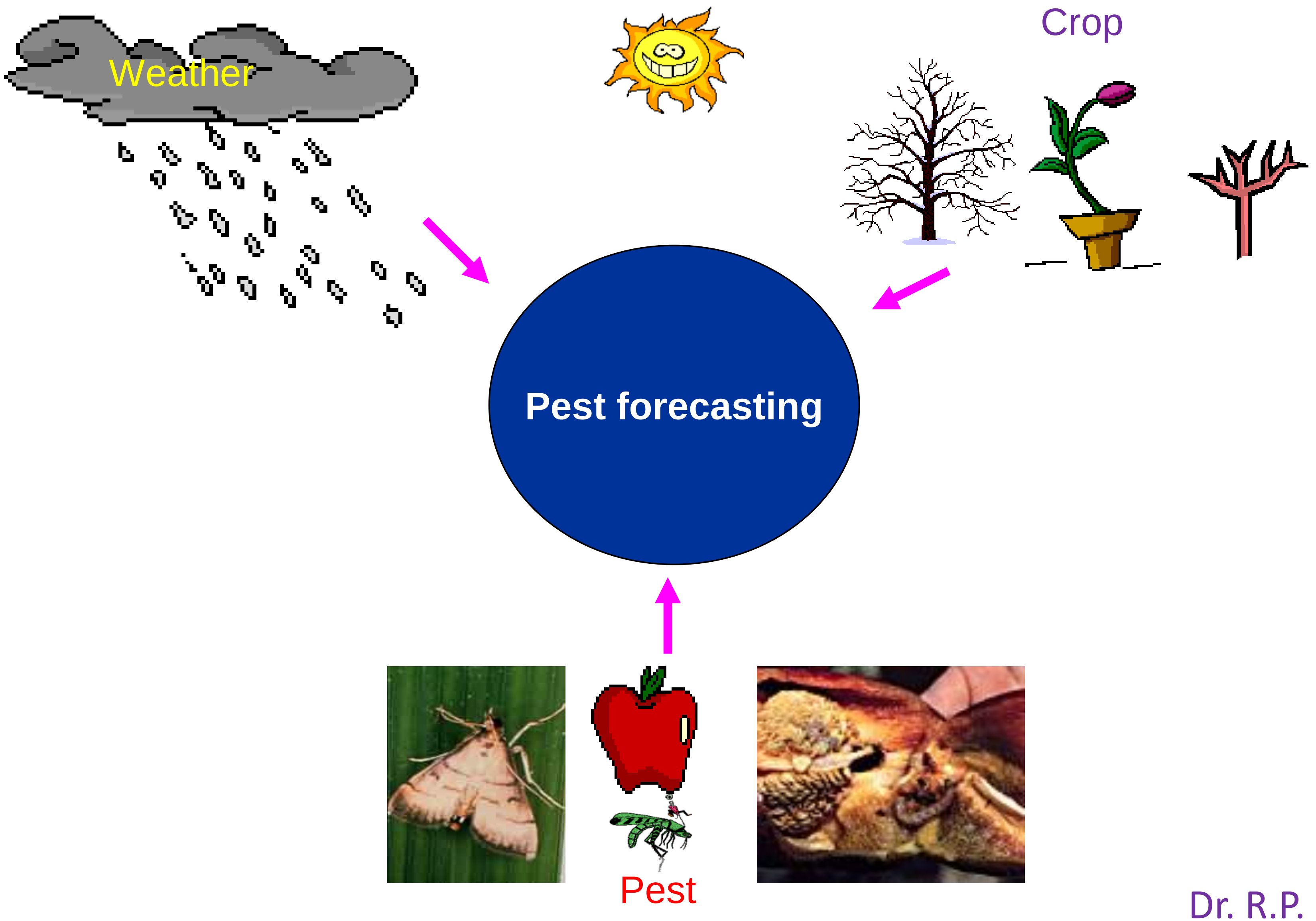
Micro

- Leaf wetness / Dew
- Canopy temperature
- Humidity in crop stand
- Soil temperature and moisture

Pest management system



Forewarning models for outbreak of pests



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Forecasting pest attack

- Advance information on the impending situation of population or forecast on the epidemic outbreak of pest is useful for remaining in preparedness to face the exigencies.
- For operational aspects of pest outbreak the basic investigation on the following direction are essential.

1. Quantitative measurement of population of the pest insect should be carried out based on ecological zone..
2. As a supplement to the quantitative observation other aspects of insect pest mainly the life history and biology are also required to study.

3. Observations on the field population of pests are required to be tenuously out to gain ideas on the population dynamics of the insect in a particular locality. Collation of these observation and analysis of data make the forecasting possible.

Prediction

- Forecast on initiation of infestation.
- Forecasting by field observation.
- Forecasting by prediction.
- Forecasting based on climatic zones

➢Zone of natural abundance.

➢Zone of occasional abundance

➢Zone of possible abundance

What Data and What models

- Historical data
- Model parameters from lab experiments
- Current field experimental data, pest / disease distribution data; crop data
- Qualitative data / knowledge / assumptions

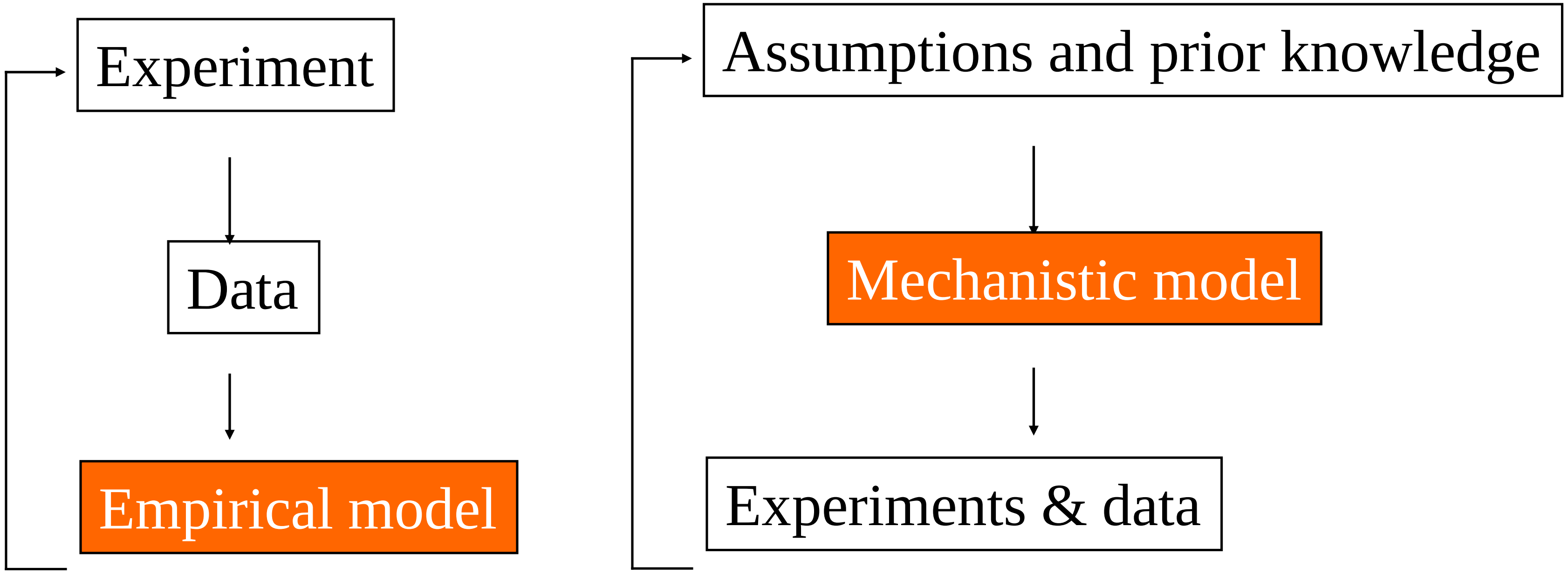
- Differential equations
- Multivariate analysis
- Population dynamics modeling
  - Quantitative / size
- Simulation modeling
  - Timing of attack
  - Stochastic
    - Simple probabilistic
    - Complex
      - Monte carlo

Problems in long-term database

- ❑ **missing data**
- ❑ **limited seasonal data (time series data)**
- ❑ **lack of sowing dates**
- ❑ **inconsistency in sampling**
- ❑ **inconsistency in data formats**
- ❑ **lack of absolute population counts**
- ❑ **crop damage assessment data**

Types of models

- Empirical or mechanistic (description with understanding)
- Deterministic (quantitative) or stochastic (probabilistic)
- Static or dynamic (time varying)
- Discrete (output at fixed intervals) or continuous (results for every instant in time)



Forecasts based on heat sums (degree-days)

- Assume rate / temperature relationship to be linear
- Predict the timing of attack (start / peak pest activity of the population)
- Unsuitable for insect populations that have polymodal patterns of development
- Insect resting phases are ignored
- Ignores variability in rates of development between individuals within a population & cannot readily predict the spread of activity

Model / outputs depend on data

Data	Model/output
10-15 years, time series	Week-wise forecasts Peak intensity Time at first appearance Time at Peak Time of crossing threshold
10-15 years, point estimate	Peak intensity Crop damage
10-15 yrs, qualitative data	Logistic models
5-6 years, time series	Week-wise forecasts not possible Combined model
5-6 yrs, point estimate	-
1 yr, time series	Non-linear models

Developments in Pest Management

- Simple prediction rules
- Crop-pest-weather relationships (correlation and regression)
- Weather based advisories
- Effect of weather variables on insect development
- Life cycle
- Degree-day approach
- Data mining and neural network techniques
- Remote sensing techniques

Forewarning models:

Advantages:

- Protect crops from pest outbreak
- Minimize pesticides application
- Protect environment

Disadvantages:

- Availability and quality of weather inputs are not always appropriate,
- The use of some specific models require purchase and maintenance of expensive devices, and
- Models do not always reproduce field reality and their predictive ability is often questionable.

The general model for multiple regression is similar to the model for simple linear regression.

Simple linear regression model:

$$y = \beta_0 + \beta_1 x$$

Multiple regression model:

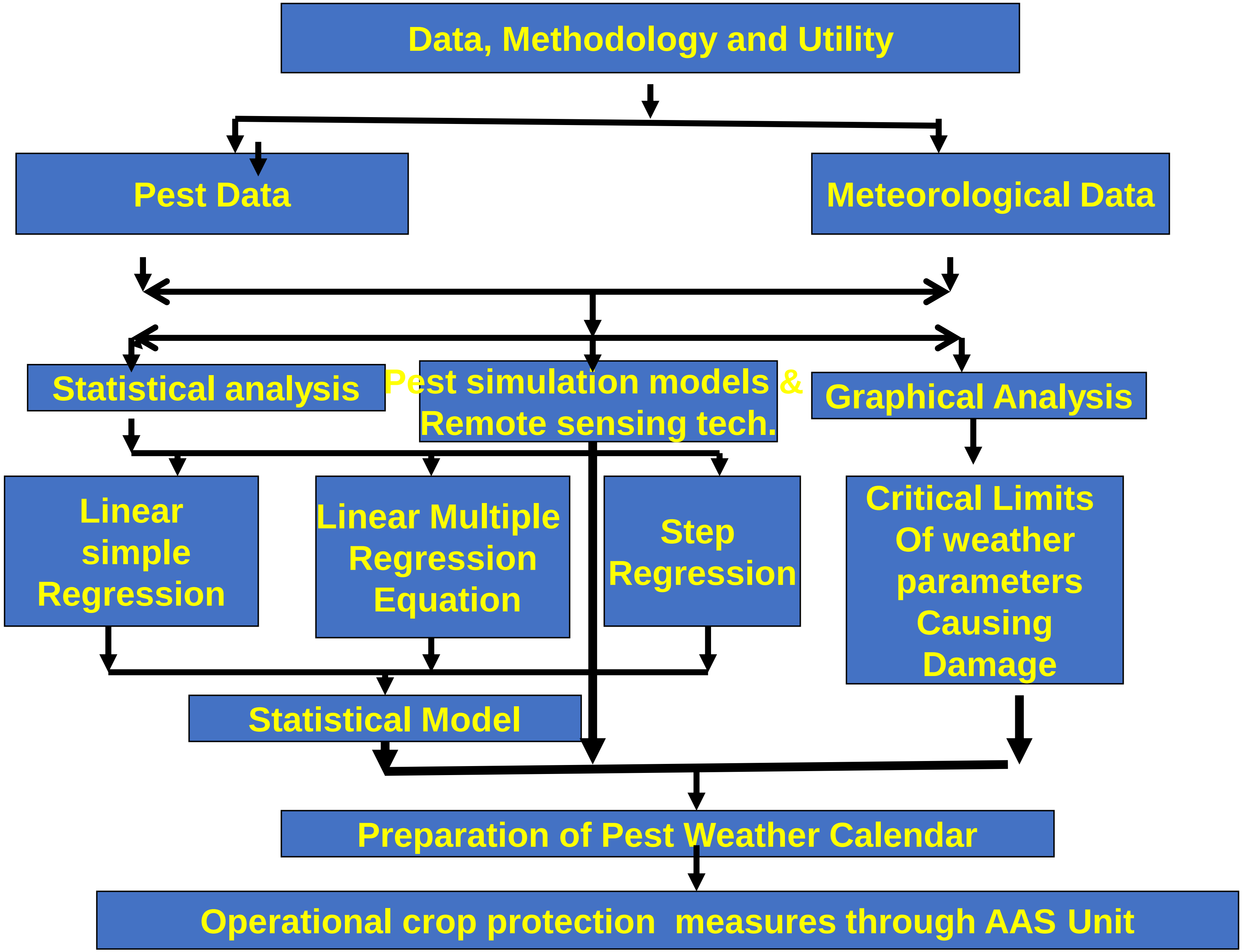
$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k$$

Just like linear regression, when you fit a multiple regression to data, the terms in the model equation are *statistics* not *parameters*.

A multiple regression model using statistical notation looks like...

$$\hat{y} = B_0 + B_1 x_1 + B_2 x_2 + \ldots + B_k x_k$$

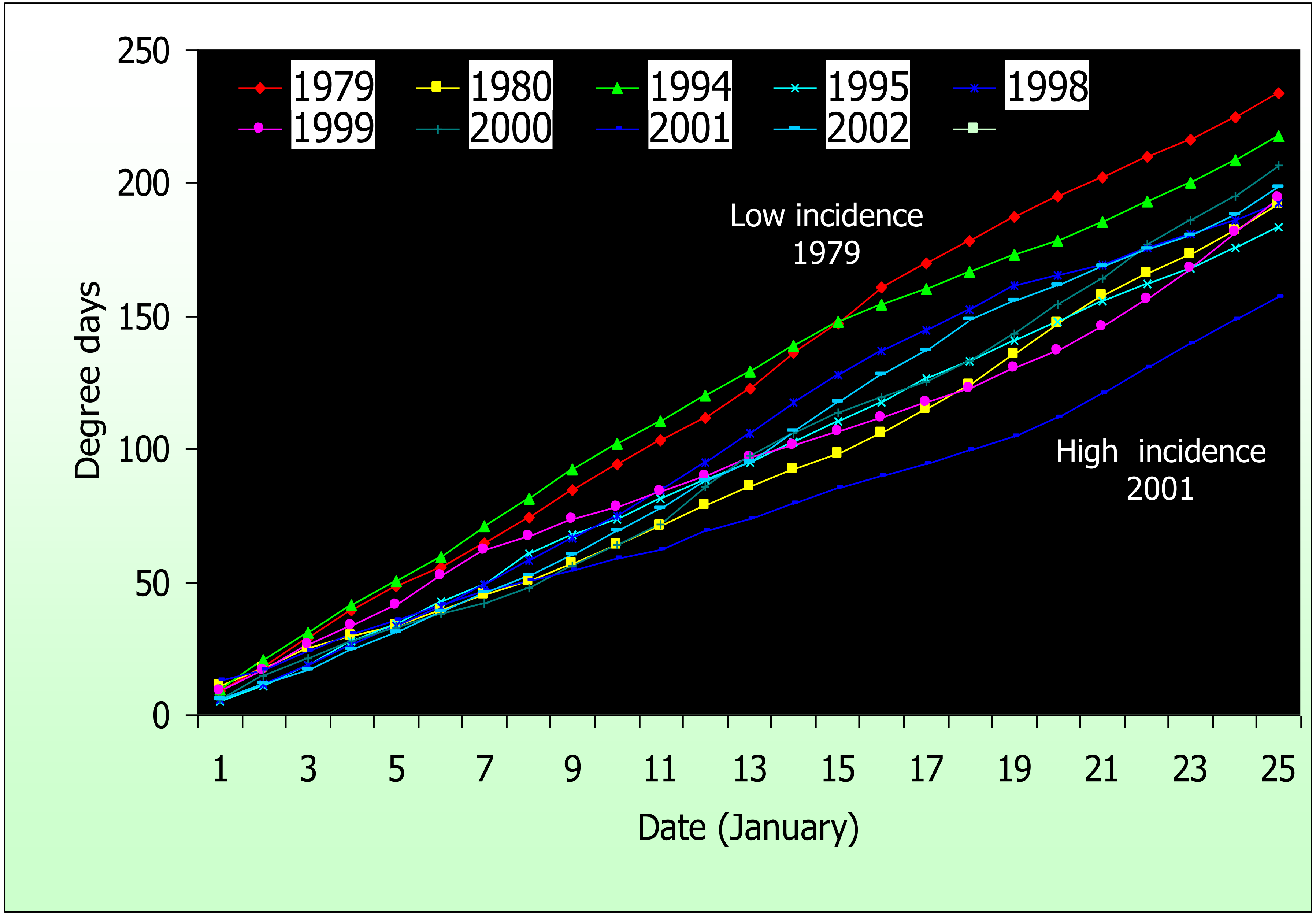
where k is the number of independent variables.


Data, Methodology and Utility
Pest Data
Meteorological Data
Statistical analysis
Pest simulation models & Remote sensing tech.
Graphical Analysis
Linear simple Regression
Linear Multiple Regression Equation
Step Regression
Critical Limits Of weather parameters Causing Damage
Statistical Model
Preparation of Pest Weather Calendar
Operational crop protection measures through AAS Unit

Temperature and Rainfall interplay – the case of cotton pests

Dry spells (High temp, low RF)	Wet spells	Intermittent dry and wet spells	Low temperature & high humidity
Aphids Thrips Mealy bug Whitefly	Jassids Bacterial leaf blight	*Spodoptera* *Helicoverpa*	Aphids (mustard)

Developments in Mustard: Degree-day approach for mustard aphid



Pest Weather Calendar:

Usually a pest weather calendar is prepared based on results emerged from the different studies for operational crop protection measure during the peak infestation period.

From this calendar, it is possible to assess the infestation of pest based on real time data of meteorological parameters.

It is concentric circle where the important epochs of crop growth, corresponding standard weeks, dates and critical values of the meteorological parameters causing the pest infestation are included.

This calendar along with the real time information on population density of pest and current weather would help agrometeorologists / agricultural scientists to forewarn the farmers about the possible attack of the pest on the crop.

PEST WEATHER CALENDAR

STATE: KERALA CROP:RICE SEASON:SUMMER RICE

STATION:PATTAMBI PEST:STEM BORER

weather warnings	Max. temp. °C				32.7 to 34.5°C (48wk)						32.7 to 34.5°C (2wk)					
	Min. temp. °C				19.1 to 22.4°C (48wk)						19.1 to 22.4°C (2wk)					
	Morning RH%															
	Afternoon RH%				31 to 48% (48wk)						31 to 48 % (2wk)					
	Sunshine hours				9.8 to 9.1 hours (48wk)						9.8 to 9.1 hours (2wk)					
	Total rainfall															
Weekly normal weather	Total rainfall(mm)	51	39.5	28	10.8	12.5	8.3	0.8	3.8	0	0	0	0.1	0.2	1.3	0.7
	Max. temp. °C	32.1	32.4	32.2	32.5	32.6	32.6	32.8	33	33.1	33.5	33.8	34	34.6	35.2	35.4
	Min. temp. °C	22.4	22.2	21.9	21.7	21.4	21.1	20.9	20.8	20.4	20.5	20.5	20.8	20.9	21.2	20.8
	Sunshine hours	7.5	7.7	7.7	8.1	8.1	8.6	9.1	8.9	9.4	9.5	9.8	9.6	9.7	9.9	9.9
	Morning RH%	90	89	87	85	83	84	79	81	78	78	76	78	80	80	80
	Afternoon RH%	59	57	57	51	50	48	45	44	39	38	35	35	35	33	33
Mean dates of important epochs of crop growth and developement		 LARVA		  ADULT	 EGG	LARVA				  ADULT  EGG		LARVA 			  ADULT	
STANDARD WEEKS		45	46	47	48	49	50	51	52	1	2	3	4	5	6	7
MONTHS		NOVEMBER				DECEMBER				JANUARY					FEBRUARY	

Sugarcane pest weather calendar

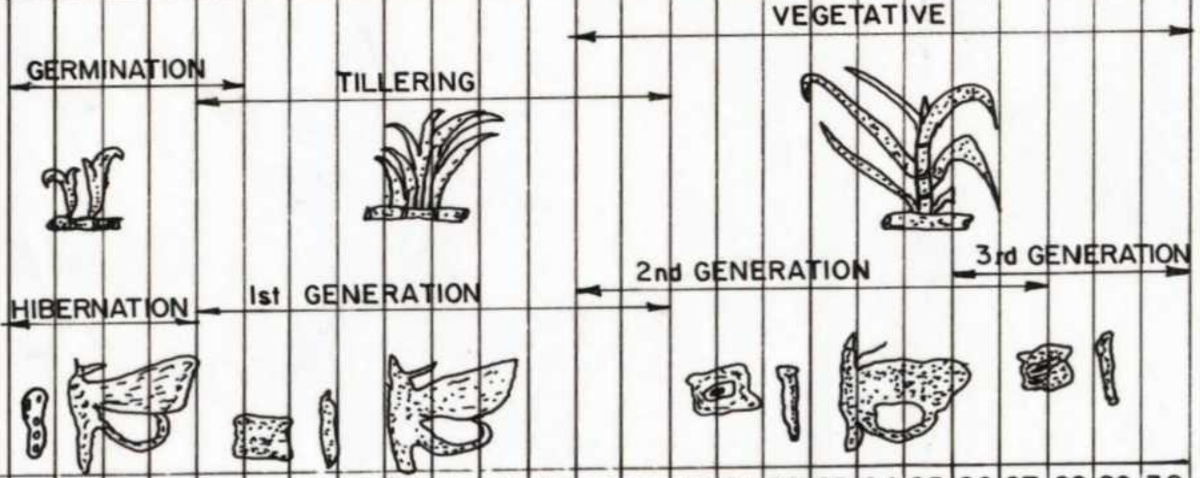
STATE : WEST UTTAR PRADESH

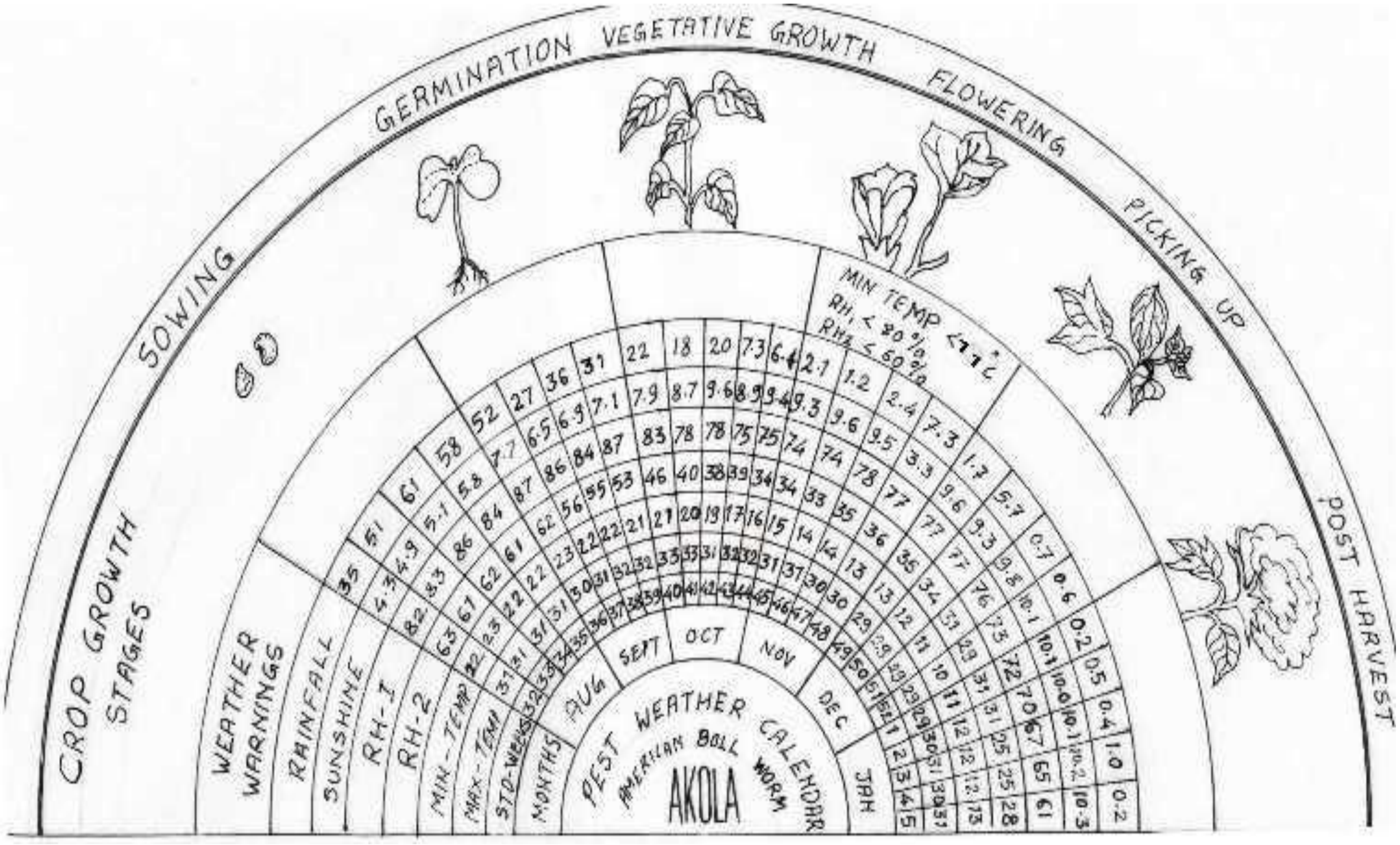
DISTRICT : SAHARANPUR

CROP: SUGARCANE

IRRIGATED

WEATHER WARNINGS	MAX. TEMP.	> 19.7 °C AT 1st STD WEEK	> 38.3°C AT 24th STD WEEK
	MIN. TEMP.	< 7.4°C AT 6th STD WEEK	< 19.9 °C AT 18th STD WEEK
	MORNING RH.	< 75.8% AT 13 STD WEEK	< 65.1% AT 24th STD WEEK
	AFTERNOON RH.	< 38.4% AT 10th STD WEEK	< 39.9 % AT 24th STD WEEK
	SUNSHINE HOURS	< 8.1 Hrs AT 49th STD WEEK	> 7.1 Hrs AT 27th STD WEEK

WEEKLY NORMAL WEATHER	RAINFALL(mm) TOTAL	7.3	12.9	10.9	5.9	6.6	10.6	5.8	5.3	1.4	2.3	1.8	1.4	0.6	5.0	3.8	7.3	8.3	17.9	17.0	23.2	64.4	77.4	105	81.9	74.7
	MAX. TEMP. °C	21.9	22.9	24.5	26.0	26.7	28.9	29.3	31.1	32.6	35.2	33.7	37.0	38.3	38.1	38.7	39.4	39.2	39.1	38.2	37.6	35.5	34.6	37.2	32.8	32.7
	MIN. TEMP. °C	7.1	8.3	8.8	10.1	10.8	12.6	13.2	14.5	15.4	16.9	18.4	19.6	20.2	21.1	21.5	22.6	23.6	24.6	25.9	26.0	26.7	25.2	24.9	25.3	25.4
	SUNSHINE HOURS	7.9	8.0	8.9	8.8	8.5	8.6	8.4	8.8	9.1	9.4	9.9	10.3	10.3	10.3	10.4	10.4	10.4	9.6	8.5	8.3	7.5	7.4	5.8	6.3	6.4
	MORNING RH.	87	87	86	84	81	78	76	71	64	57	51	50	47	49	47	47	48	56	60	67	77	80	87	87	85
	AFTERNOON RH.	39	40	36	35	36	32	32	26	22	21	19	21	19	22	21	24	26	31	36	43	56	62	71	69	72
LIFE HISTORY AND MEAN DATES OF IMPORTANT EPOCHS OF CROP GROWTH AND PEST DEVELOPMENT																										
STANDARD WEEKS		6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
MONTHS		FEB				MAR				APR				MAY				JUN				JUL				



- American bollworm appeared maximum in November.
- Decrease in minimum temperature below 11^{0}C and morning relative humidity below 80 % and afternoon relative humidity below 40 % at 46th to 48th week.

Control strategies

Thus, method or control strategies should be adopted to restrict the loss up to an economically acceptable level. The processes are as follows.

A. Victim protection or preventive or prophylactic control:

b**2. Reduction of the effects of contacts between the pest and victim.**

(a) **B. Pest destruction, curative or palliative control**

Mechanical and physical control:

2. Cultural current:

Ecological control:

4. **Biological control:**

5. Pesticidal Control:

a. Chemical pesticides:

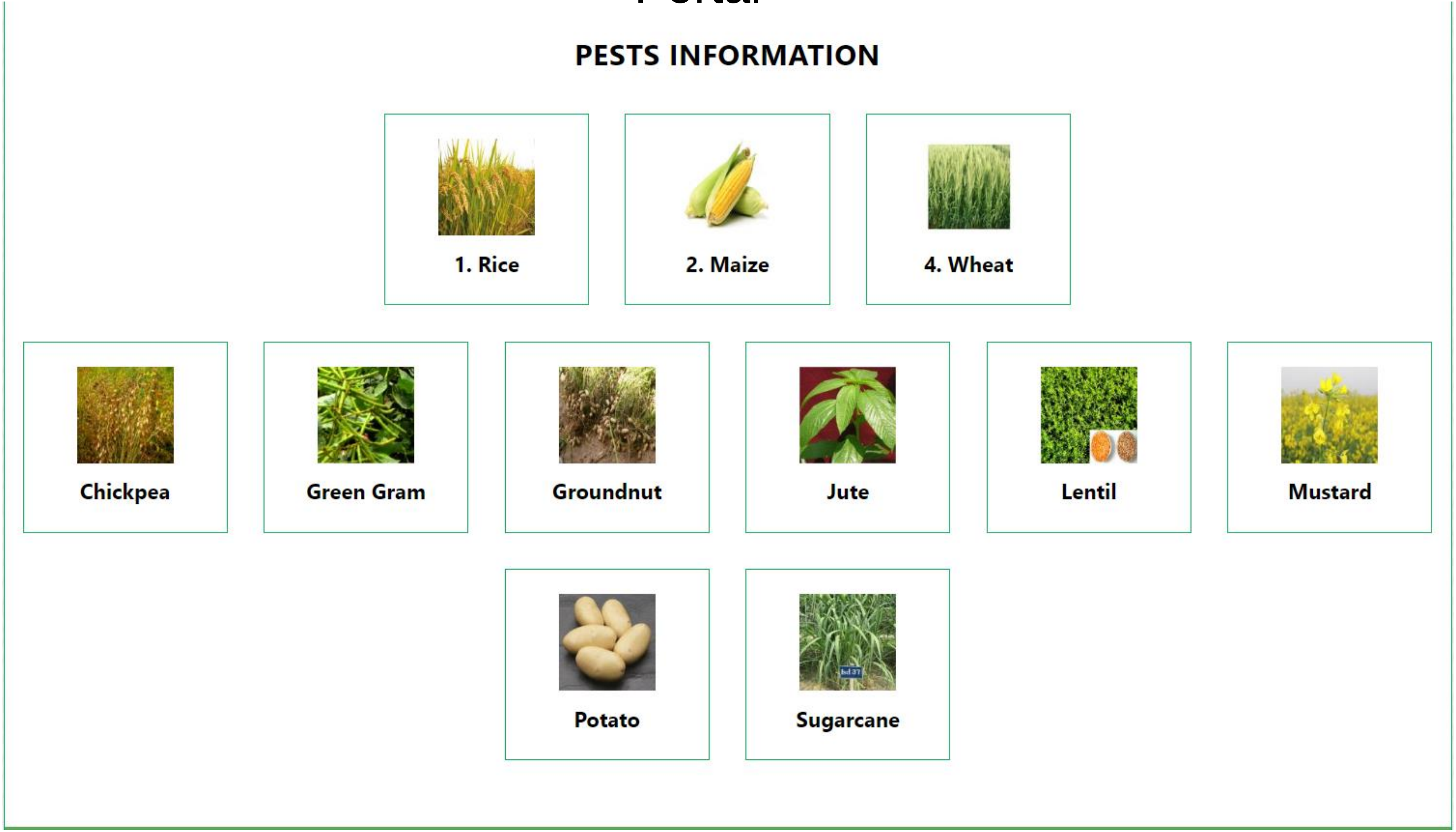
Biological control:.

5. Pesticidal Control:

a. Chemical pesticides:

b. Physical pesticides:

Available Information on Pests & their Management in BAMIS Portal



Yellow Stem borer of Paddy

Favorable weather	Minimum Temperature above 20.3 ^{0}C, Maximum Temperature: 29.5-34.7^{0}C, Optimum temperature: 24-29^{0}C, Higher morning Relative Humidity above 84%, Afternoon Relative Humidity above 38.7% and dry weather	
Control Measure	Common name	Trade name
	Carbofuran @10kg per ha.	Brifur 5G/Razfuran 5G/ Carbotaf 5G/ Curater 5G/Foreafuran5G
	Cartap @14kg per ha	Care 50 SP/Cartap 50 SP/Cikotap 50 SP/ Kadan 50 SP/ Forwatap 50 SP
	Fipronil @ 1ml. per litre of water	Focus 50 SC/ Goolee 50 SC/ Regent 50 SC/Nema 50SC/Envoy 50 SC
	Diazinon @ 17kg per ha.	Razdan 10 G/ Basudin 10G/ Diazinon 10 G/ Dianon 10 G/Sabion 10 G
Infestation stage	Early tillering to flowering	

Cut warm in Mustard

Favorable weather	Dry Weather &sandy-loam soil	
Control measure	Common name and dose	Trade name
	Sray of Carbofuran @ 20 kg/ha or Chlorpyrifos @ 5ml/L water at 15 days interval.	Furadan 5G/ Razfuran 5G/ Carbotaf 5G/ Curater 5G/ Chlorpyrifos 20EC /Dursban 20 EC/Classic 20 EC/Cyren 20 EC/ Lithal 20 EC
Infestation stage	Germination	

Merit of Disease Forecasting

- **Prediction of disease appearance does not always help in control but does enable farmers to reduce their losses in other way.**
- **Forecast of wheat leaf rust issued early in the season allows farmers to plough up there wheat and plans some other crop or pasture their fields if serious out-break is indicated.**
- **Thus they can recover at least part of their season investment.**
- **Agrometeorological forecasting as a tool to reduce the cost of pest and disease control operations by reducing their frequency and spraying only when the risk and vulnerability are high.**

Disease Triangle

- **The first step in resolving problems caused by plant disease is to study their interaction with plant hosts and the environment and to determine relationships which man can influence and modify without its effects on the environment. The complexity of this relationship can be represented as a triangle**

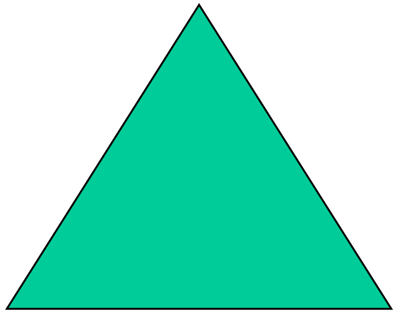
Schematic representation of interaction between the host (H), Pathogen (P) and environment (E). There are three conditions for disease to occur

Host

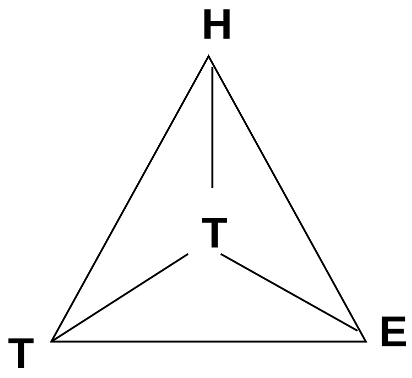
Pathogen

Environment

This is called disease triangle or disease triode.



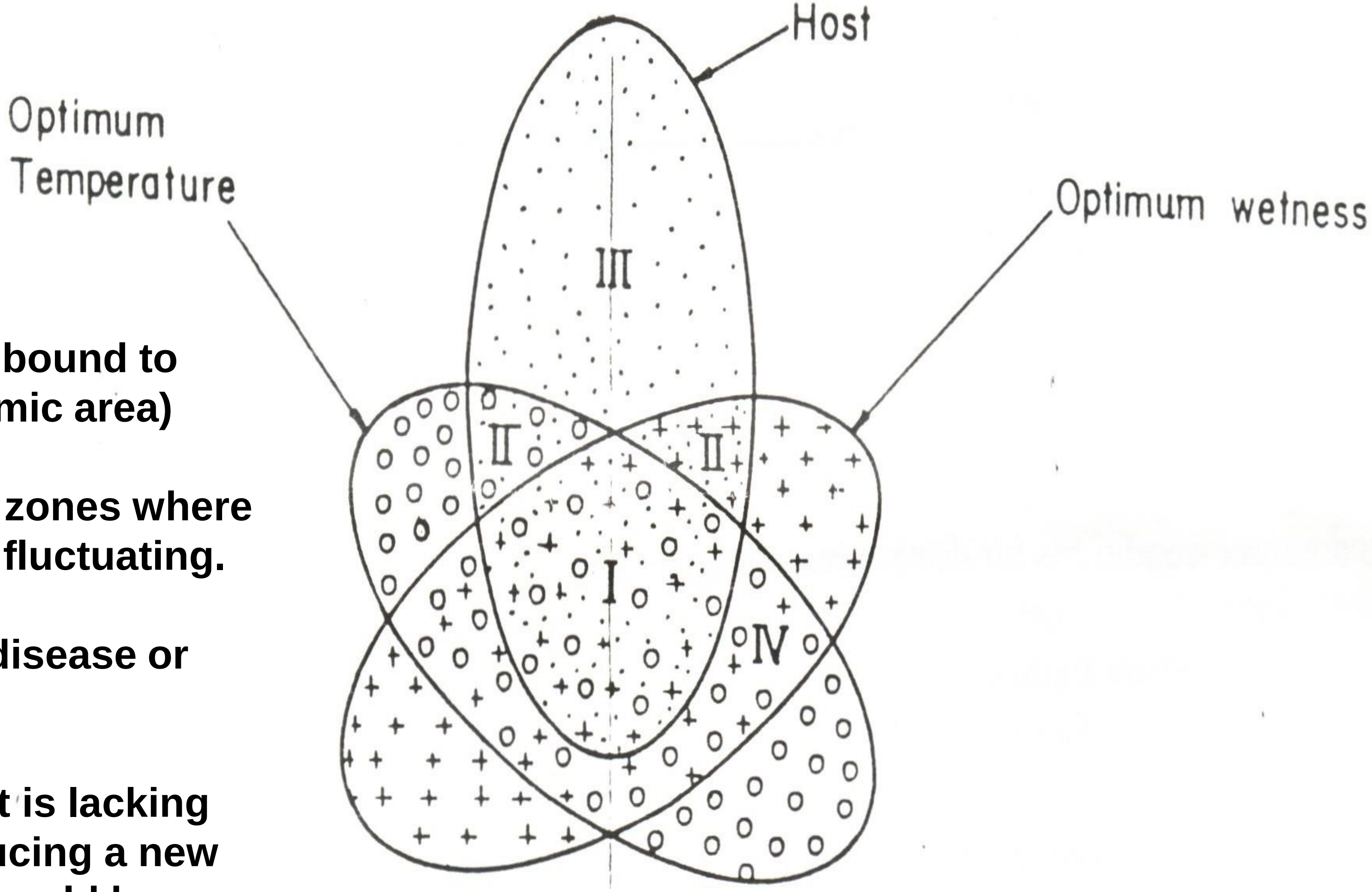
Time dimension model for disease is like that



Under favorable weather conditions four combinations for disease to occur

- **H (Unfavorable) P (Unfavorable) Disease is unlikely**
- **H (Favorable) P (Favorable) Disease will occur**
- **H (Unfavorable) P (Favorable) Diseases are bound to occur (intensity will be more)**
- **H (Favorable) P (Unfavorable) No diseases.**

Role of environment in distribution of plant disease



I=Disease is bound to occur (Endemic area)

II = Marginal zones where the attack is fluctuating.

III = No disease or sometimes.

IV = Host is lacking (here introducing a new variety we should be careful).

Minimum information required for disease forecasting

- Crop should be widely cultivated and should be of economic importance to the nation

- Disease should cause severe loss under optimum condition.

- The pathogen should be aggressive under wide range of climate and environmental condition

Condition of disease development

- Susceptible plant must be in a vulnerable state.

- Parasite causes the disease should in an infective stage.

- Environmental condition must be favorable.

Establishment
of
interrelationship of disease to the weather parameters thorough models

Plant disease models

- A plant disease model is a mathematical description of the interaction between environmental, host, and pathogen variables that can result in disease.

- A model can be presented as a simple rule, an equation, a graph, or a table.

- The output of a model can be a numerical index of disease risk, predicted disease incidence or severity, and/or predicted inoculum development.

Continued

- **Plant disease models typically are developed in specific climates and regions around the world.**

- **Before using a model not field tested or validated for a specific location, test the model for one or more seasons under local conditions to verify that it will work in this location.**

- **Models may contain assumptions about site specific conditions that might not apply for all areas.**

- **Input variables and/or other parameters, such as timing of model initiation, may need adjustment due to pathogen biology, host phenology, and variety in a specific area**

Model description

- The mathematical relationship that describes the interaction between the environment, host, and pathogen variables, and disease.

- The model can be presented as an equation, a graph, a table, or a simple rule. The output of a model can be a numerical index of disease risk.

Action threshold

- Describes the level of disease above which significant economic loss is predicted.

- A treatment advisory is issued when this threshold is exceeded.

- Some models present the user with several levels of disease risk, to allow the user to decide the amount of risk that is tolerable.

Model development

- **Plant disease models typically are developed from laboratory and/or field studies by researchers cooperating with extension personnel.**
- **The goal is to predict the risk of disease and/or development of inoculum, based on monitoring key environmental, host, and pathogen variables.**
- **Based on management options and goals, action thresholds can be incorporated into the model to provide advice on fungicide treatments.**
- **Models should be evaluated in the field, and actual disease compared to predicted disease.**

Model validation & Evaluation

- **"Validation" means testing of the model in the field over several cropping seasons and/or locations to evaluate the ability of a model to assess or predict disease. Typically a researcher will fine-tune and re-test a model several times.**

- **"Evaluation" means testing the model under local conditions, generally by someone other than the original researcher.**

- **To ensure widespread applicability, these descriptive models must be validated across a variety of microclimates over a number of years by researchers and extension personnel cooperating with pest control advisors and growers.**

- **Models are tested to see how well they predict disease incidence, and then are revised and refined based on these findings.**

- **Frequently, disease incidence of plants treated according to the model is compared to disease managed by traditional spray schedules, as well as unsprayed plots.**

- **Models developed in one area are frequently validated by researchers in other areas. Under such circumstances, the models may need region-specific modifications.**

Model implementation

- **After being found to predict disease or inoculum levels adequately, models can be used with microscale weather data obtained through the use of on-site, user-friendly electronic weather stations that monitor microclimate variables such as air temperature, relative humidity, hours of free moisture, and precipitation.**

- **These new technologies can be transferred through public and private means.**

- **Growers and pest control advisors can use disease risk indices for on-farm disease management.**

- **Frequently, local implementation efforts are supported by extension personnel and researchers through demonstrations and other outreach activities**
- **The use of the model to guide the timing of fungicide applications.**

Description of database contents

- Disease model information was first assembled from published literature, as well as written documents supplied by the researchers, and then presented in a standard format.

- When several models are available for a disease, they are listed in reverse chronological order, by date of publication.

- When information is incomplete, the field is left blank, or termed "in progress" or "unspecified

Fields of the database

- **Crop:** A crop of economic importance
- **Disease:** A disease of economic importance
- **Pathogen:** The scientific name of the pathogen that causes the disease
- **Model developer and citation:** The citation(s) of the published model. When models have been modified by either the original researcher or another researcher, the most recent model is listed first. The original model also is listed separately from the modified model

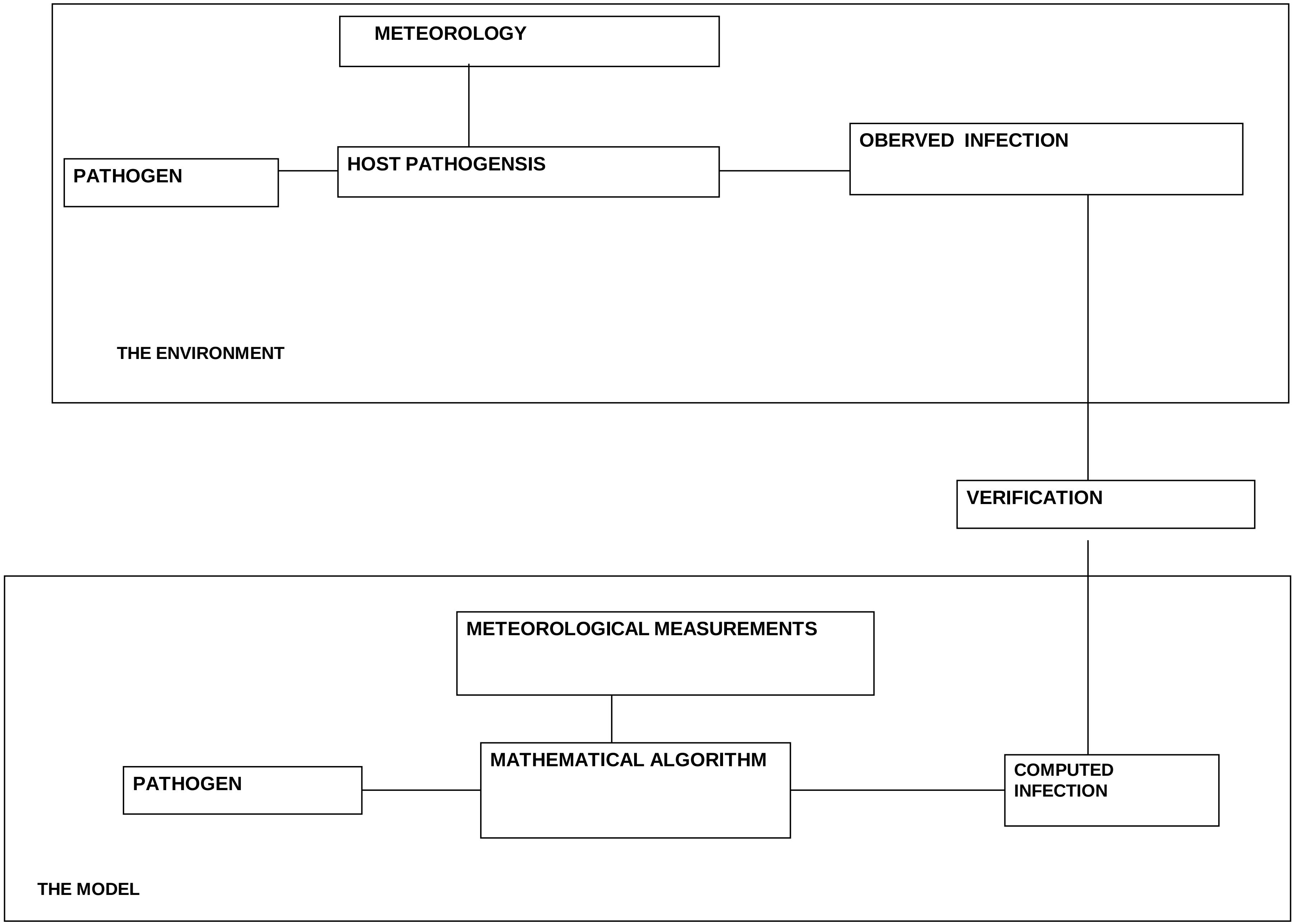
What Data and What models

- **Historical data**
- **Model parameters from lab experiments**
- **Current field experimental data, pest / disease distribution data; crop data**
- **Qualitative data / knowledge / assumptions**

- **Differential equations**
- **Multivariate analysis**
- **Population dynamics modeling**
  - Quantitative / size
- **Simulation modeling**
  - **Timing of attack**
  - **Stochastic**
    - **Simple probabilistic**
    - **Complex**

Simulation model

- **The plant disease simulator (figure below) is, in fact a computer programme which attempts to mimic all aspects of plant disease cycle concurrently and gives the disease potential induced by different sets of environmental condition.**
- **The construction of simulator often reveals large gaps in our knowledge, which must be incorporated either through direct experimentation or by inserting in to the model, and assumption that can be verified later on.**
- **The greatest advantage of plant disease simulators lies in their propensity to determine disease potential.**
- **The possibilities for disease prediction and subsequent recommendation of control measures either singly or integrally may be compared under different sets of environmental conditions and degree of control can be determined**



Schematic diagram of a plant disease simulator.

Developments in Disease Management

- Simple prediction rules
- Crop-Disease-weather relationships (correlation and regression)
- Weather based advisories
- Effect of weather variables on insect development
- Life tables
- Degree-day approach
- Data mining and neural network techniques
- Remote sensing techniques

Disease Forecasting

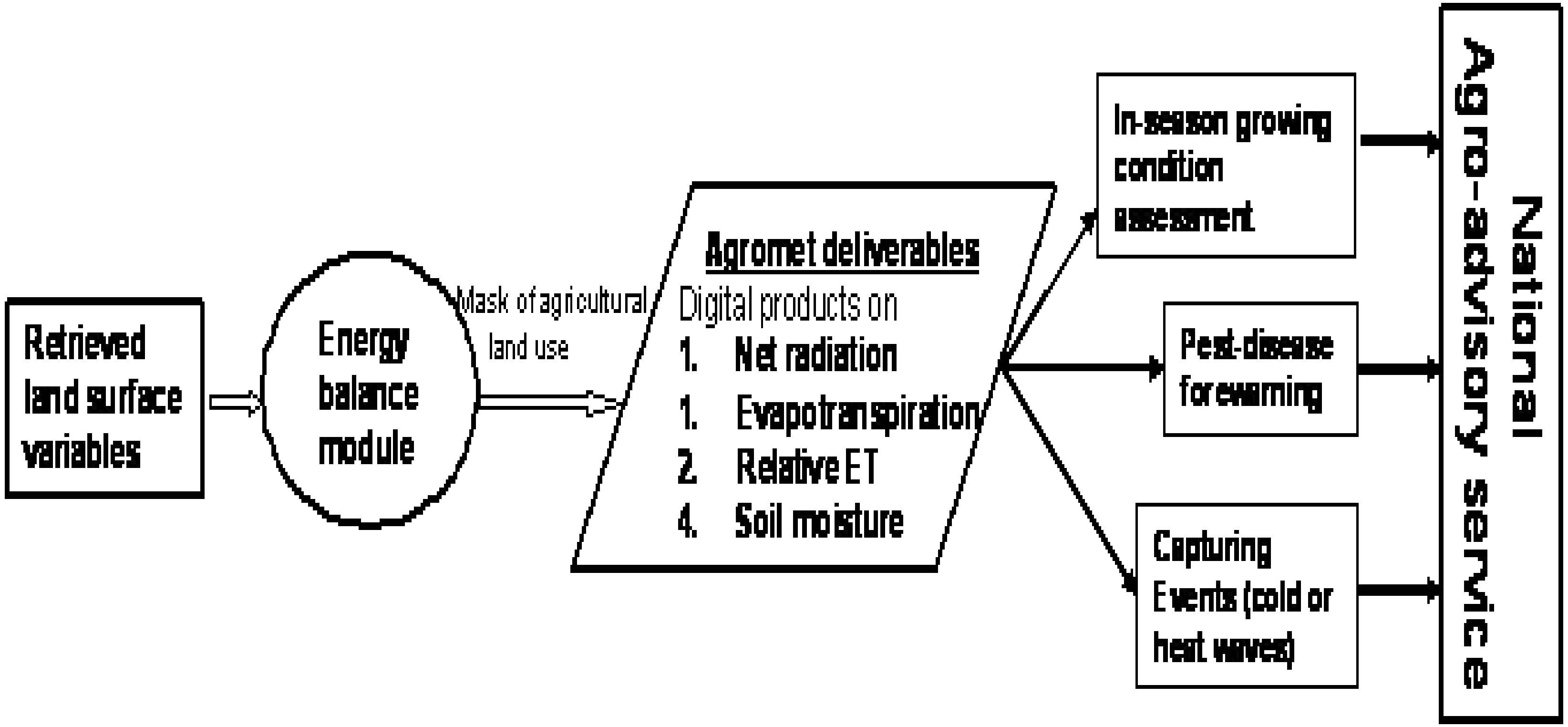
- **Prediction can never be entirely right. This is also true for disease forecasting also.**

- **The possible accuracy depends on how complicated the critical periods are and on how far in advance they operate.**

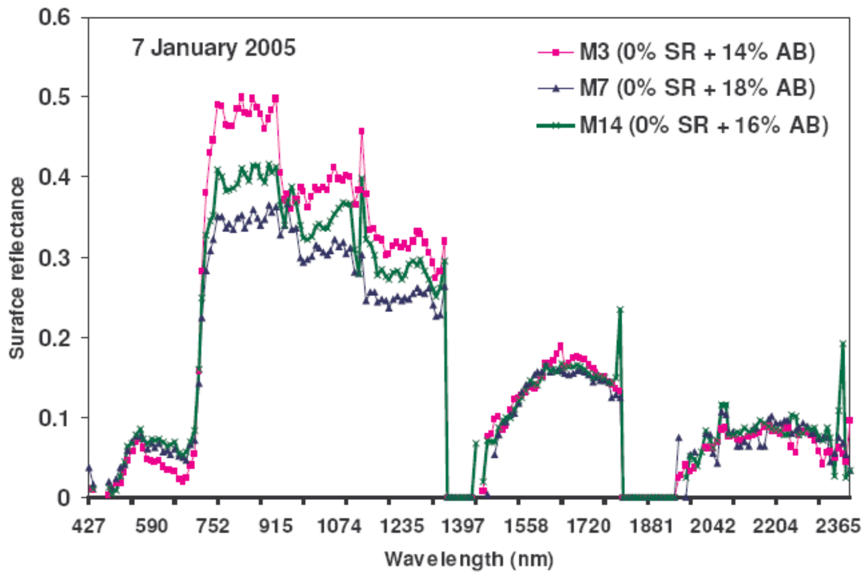
- **For instance, if winter temperature by itself determines the amounts of the disease for the following seasons, a prediction is a simple matter of calculation and can be made with practically complete certainty that it will be right.**

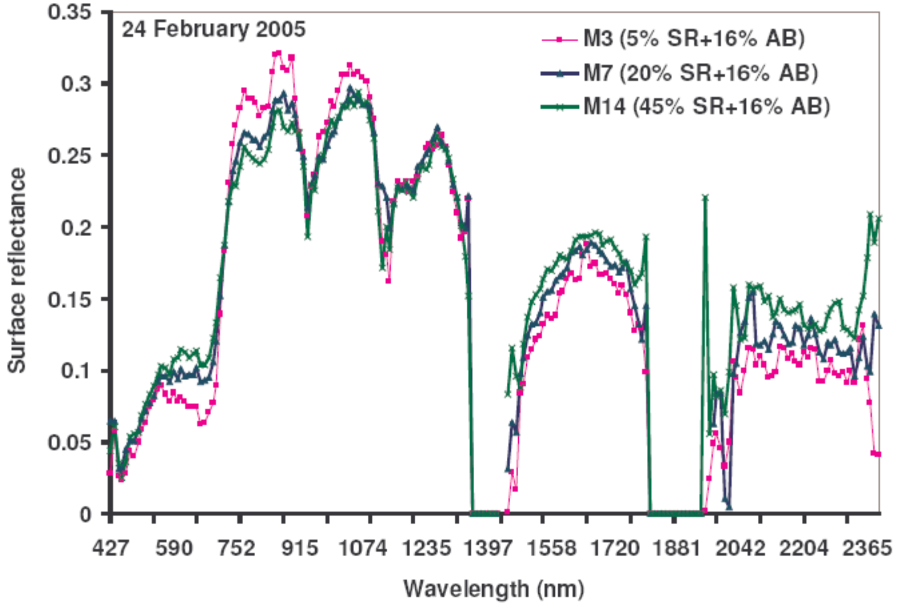
- **In contrast, if the pathogen can cause disease at any time that its temperature or moisture demands or both are met, both disease and weather must be watched throughout the season and frequently revised short-term forecasts re necessary.**

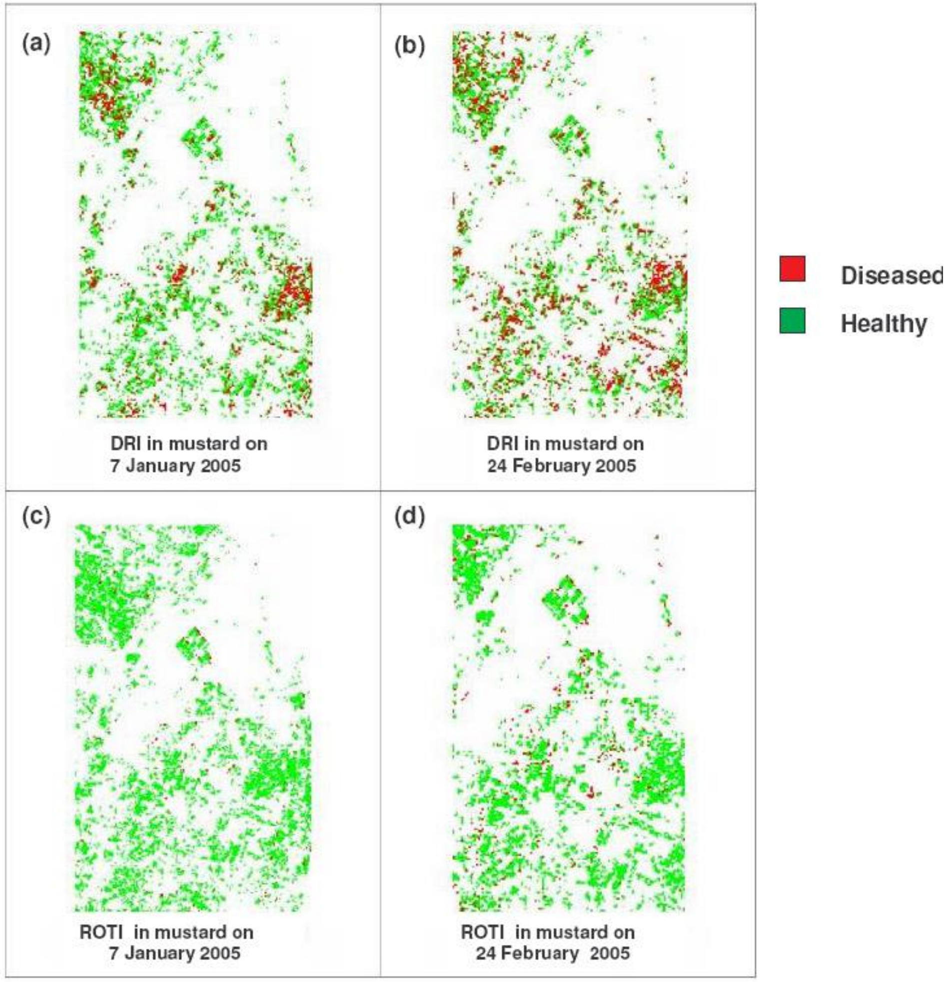
Use of space data in AAS



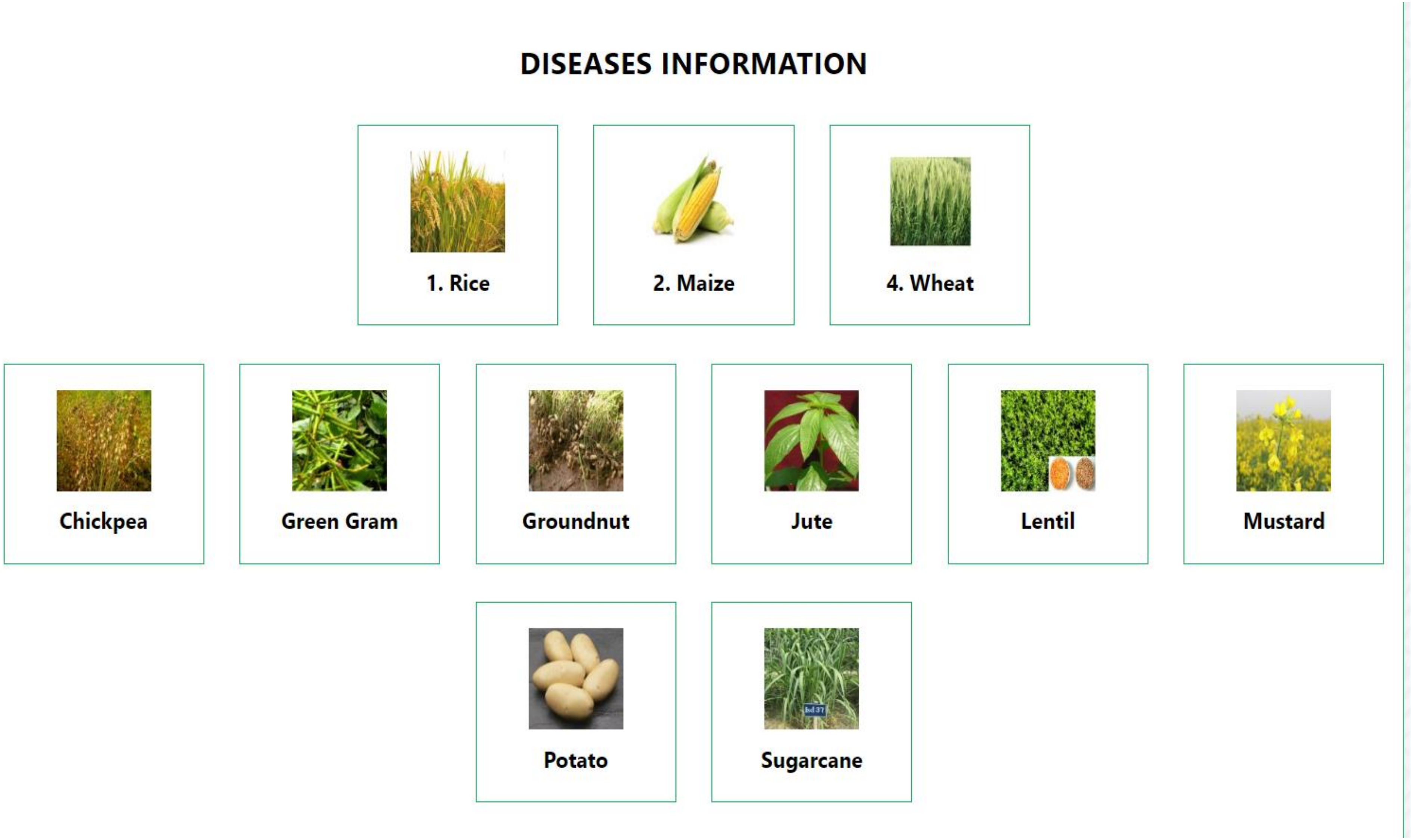
Mustard sclerotinia rot detection using hyperspectral data







Available Information on Diseases & their Management in BAMIS Portal



Wheat Blast

Favorable weather	Continuous rains and average temperatures between 18-20^{o}C during the flowering stage of the crop followed by sunny weather and humid days. highest blast intensity at 30^{o}C which increased with duration of wetting period. lowest at 25^{o}C with a wetting period of less than 10h. However, with increasing wetting period of 40h at 25^{o}C blast intensity of 85% observed
Control measure	Nativo 75 WG 6 gm/desimal or Seed treatment with Noen 2-3 gm/Kg.
Infestation stage	All stages

Late Blight of Potato

Favorable weather	Temperature 16-20°C. Cold and humid weather is congenial for spreading the disease. Low night temperature and high humidity associated with drizzling, fog and accumulation of dew on leaves. If this situation occurs, the disease becomes epidemic.	
Control measure	Common name and dose	Trade name
	Spray of Mancozeb @2gm/L water.	Dithane M 45/Indofil M 45/Haymancozeb 80 WP/ Mcozeb 80 WP
Infestation stage	Seedling to Maturity	

THANK YOU