APN

Asia-Pacific Network for Global Change Research

Climate and Crop Disease Risk Management: An International Initiative in the Asia-Pacific Region

Final report for APN project: ARCP2007-06CMY-Huda

The following collaborators worked on this project:

Project Leader:

Samsul Huda, University of Western Sydney (UWS), Australia, s.huda@uws.edu.au

Collaborators:

Robert Spooner-Hart, UWS, Australia, r.spooner-hart@uws.edu

Chris Derry, UWS, Australia, c.derry@uws.edu.au

Tamrika Hind-Lanoiselet, formerly NSW DPI, currently Western Australian Department of Agriculture, Australia, tlanoiselet@agric.wa.gov.au

Gordon Murray, NSW DPIF, Australia, gordon.murray@dpi.nsw.gov.au

Holger Meinke, formerly Queensland Department of Primary Industries and Fisheries, QDPIF, Australia, currently Wageningen University, holger.meinke@wur.nl

Jo Luck, Victorian Department of Primary Industries, CRC for National Plant Biosecurity, Jo.Luck@dpi.vic.gov.au

Kep Coughlan, Visiting Fellow UWS, Australia, kepcoughlan@mac.com

Golam Ali Fakir, Bangladesh Science Foundation, Bangladesh, bsf@btcl.net.bd.

M Asaduzzaman, Bangladesh Science Foundation, Bangladesh, masad@agni.com
Preap Visarto, formerly Cambodian Agricultural Research and Development Institute, (CARDI) Cambodia, now Ministry of Agriculture Fisheries and Forestry (MAFF) visarto09@yahoo.com
Y S Ramakrishna, Central Research Institute for Dryland Agriculture (CRIDA), India, ramakrishna.ys@crida.ernet.in (retired)
Suseelendra Desai, CRIDA, India, desai@crida.ernet.in
A V M Subba Rao, CRIDA, India, avmsrao@crida.ernet.in
Ram Thakur, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India, r.thakur@cgiar.org
R Jagannathan, Tamil Nadu Agricultural University, India, jagan@tnau.ac.in
Chirantan Chattopadhyay, National Research Centre for Rapeseed and Mustard (NRCRM), India, chirantan_cha@hotmail.com
Safi Khan, Bidhan Chandra Krishi Viswavidyalaya (BCKV), India, sakhan_bckv@sify.com
Indrabrata Bhattacharya, BCKV, India, indrabratabhattacharya@gmail.com
Saon Banerjee, BCKV, India, sbaner2000@yahoo.com
L S Rathore, National Centre for Medium Range Weather Forecasts (NCMRWF), India, lsrathore@ncmrwf.gov.in
Jim Hansen, Columbia University, USA, jhansen@iri.columbia.edu
Ken Boote, University of Florida, USA, kjboote@ufl.edu
Jerry Hatfield, National Soil Tilth Laboratory, USA, jerry.hatfield@ars.usda.gov
Kees Stigter, Agromet Vision, The Netherlands, cjstigter@usa.net
M Sivakumar, World Meteorological Organization (WMO), Switzerland, msivakumar@wmo.int

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Climate and Crop Disease Risk Management: An international Initiative in the Asia-Pacific Region (Project ARCP2007-06CMY-Huda)

Overview of project work and outcomes

Non-technical summary

This project aimed to integrate a diverse body of knowledge that included agro-meteorological modelling, risk analysis, crop disease impact and community interaction. The activity was timely in terms of the growing importance of climate change and climate variability scenarios to develop a network to examine international relationships for sustained operational support for better forewarning of crop disease occurrence.

Outcomes from the 2006 project scoping workshop included reports on innovative modelling for connecting climate, crop and pest/disease management, coping strategies for agro-meteorological risks, agro-meteorological services, regional data needs, linking short and medium term climate forecasting and institutional and stakeholder collaboration. Some results have appeared in *Managing Weather and Climate Risks in Agriculture*, a Springer publication, under the auspices of the World Meteorological Organisation.

Field experiments and data analyses (carried out in 2006, 2007 and 2008) for peanut, mustard and canola indicated the importance of developing functional relationships between meteorological observatory and crop canopy weather parameters to incorporate into models for weather-based forewarning systems. Results from these field experiments were discussed during the Review and Planning Workshop, 11-14 February 2008 in Dhaka, Bangladesh. This workshop provided the opportunity for project participants to share their ideas and critically evaluate the results. Deliberations in the workshop developed a number of excellent research proposals and strategies to pursue sources of funding, aimed at insuring long-term sustainability and regionalisation of the project.

Objectives

The aim of the project was to develop regional stakeholder and participant capacity, in terms of a risk management approach, for the control of selected climate-sensitive crop diseases. The overall aim was to facilitate people from a group of different disciplines to work together and for all to benefit through co-learning and understanding the requirements of other’s disciplines

The main objectives of the project were to:

1. Develop and adapt predictive models for selected crops and climate-sensitive diseases (late leaf spot in peanut, sclerotinia rot and alternaria blight in canola and mustard), integrating existing climate, crop and epidemiological knowledge
2. Evaluate the predictive performance of crop growth and disease models, using existing data as well as generation of new data
3. Identify and evaluate improved crop disease management strategies based on climate information and predictive models
4. Assess information needs and propose communication strategies (e.g., for climatic and disease risk, and disease forecasts, and advisories)

5. Engage appropriate institutions and policy linkages that are in a position to provide support for climate-sensitive crop disease management in each target country

Amount received and years supported

The project was supported for two years with an unfunded extension of 8 months. Funding from APN was:

2006/07: USD 35, 000

2007/08: USD 35, 000

Activity undertaken

Project year 1 (2006-2007)

- Key role players were identified from universities, government organisations and NGOs in the region for participation in project workshops and research, based on their interests in climate and crop disease risk management.
- A scoping workshop was conducted in Hyderabad, India to identify potential models, their data needs and applicability to the study areas, and to set initial project aims and milestones.
- Predictive models were identified for selected crops and climate sensitive diseases, based on their capacity to include data relating to weather, management, crop data, and disease records. These included the *Cropgro* Model and *Infocrop*.
- A post-workshop session was held to demonstrate the performance capacity of the different models under consideration. Those attending the demonstration included APN project participants and interested stakeholders from the India Coordinated Project on Agrometeorology, who represented a range of States and institutions.
- Meetings with scientists and management at ICRISAT, and visits to related field and laboratory facilities were conducted to discuss modelling and monitoring proposals and to build project participant capacity in the areas of climatic, crop disease and plant protection research.
- Meetings were held between the project leaders and Indian Council of Agricultural Research policy makers.
- Preliminary field data were collected and assessed in order to carry out model adaptation to meet regional needs and requirements.
- Existing data for participant countries were investigated and data deficits of the selected models were identified. Strategies for augmenting available data sets were developed.
- Field experiments were planned for India, Bangladesh and Cambodia to generate additional data, to input into the models or to validate them.

Project year 2 (2007-2008)

- Proceedings from the Hyderabad workshop were published.
- Model outputs were tested and suggestions were made for further development of the models to improve their performance in regions of the project members.
- Inter-sectoral crop disease management strategies were discussed with a view to using information generated by the project in an effective and accountable way, and to build support systems between member countries.
- Links were established between APN and UWS web sites, which facilitated communication of project activities and highlights to a broad audience.
- Project progress was reviewed at the Dhaka workshop. Activities included discussion of the outcomes and implementation of decisions of the Hyderabad workshop, presenting and discussing results from field trials, and developing

future plans and strategies for the network's sustainability, such as identification of new projects and possible funding sources.
- During the workshop field trip participants visited experimental sites at Bangladesh Agricultural University, Mymensingh. They had opportunity to exchange ideas with a wider group of professionals and observe the ongoing research work carried out by the scientists from a number of disciplines related to the network's interests.
- Participants also met with scientists and management at Bangladesh Agricultural Research Institute (BARI) in Ghajipur, and visited related field and laboratory facilities to discuss modelling and monitoring activities, and to build project participant capacity in the area of climatic, crop disease and plant protection research.
- There was an exchange of ideas at the workshop with policy makers and senior officers in key selected organisations including South Asian Association for Regional Cooperation Meteorological Research Centre (SMRC), SAARC Agricultural Information Centre and USDA. Discussions covered future research opportunities and funding options.
- Field experiments, data collection, data analysis, and model evaluation continued

Project year 3 (2008-2009)

This unfunded extension was used to maintain the project team integrity during four important initiatives:

1. To prepare a submission for a CAPaBLE project "Workshop on Climate and agricultural Risk Management, Phnom Penh, 2009". A full proposal has been submitted to APN, and we have responded to Referees' comments.
2. To plan and organize the CAPaBLE workshop and an associated International Symposium "Climate Risk Management in Rural Communities in Developing Countries of the Asia Pacific Region" in Phnom Penh, Cambodia in November 2009, building on our positive project results including network strengths, research outputs and goodwill. The proposed major funder of the symposium is the AusAID International Seminar Support Scheme.
3. To develop an ARCP project proposal, to commence from April 2010, entitled "Identifying the influence of climate change on crop pests and diseases along the Indo-Gangetic Plain".
4. To develop a proposal "Examining the effect of climate change on pest and diseases of major food crops ". This has been submitted to Australia-India Strategic Research Funding.

Results/Major outcomes

1. A viable and active people Network has been built, with effective working relationships encouraging collaboration between scientists and policy makers
2. Intra-network collaborations have developed outside the major project activities, as a result of the network formation. For example, rural development and population health concepts have been incorporated in the capacity building associated with the project
3. An enhanced understanding of the climate-pest-disease pest risk management relationship in different cropping systems has been gained and relevant crop model development carried out to include relevant disease management
4. We have identified, adapted and tested two climate and crop disease models for use by participating countries under the guidance of experienced modellers within the network.

5. A database of relevant information has been collected and stored, in a uniform and consistent manner
6. A regional focus has been provided for research in climate and disease risk management
7. Cambodian scientists have been exposed to the concepts of climate and risk management
8. Simple tools useful to farmers' advisory services have been developed, and an increased awareness of various logistical barriers to achieving the application of scientific products has been achieved
9. Development of ideas and planning for new network activities and research projects has been carried out
10. Publications have been produced, as listed on p 10
11. We have trained two MSc students on project activities, one from Tamil Nadu Agricultural University, India and one from Bangladesh Agricultural University.

Relevance to APN's Science Agenda and objectives

Science Agenda: Our network which has been developed through this project has a primary research focus on climate science (addressing climate variability, climate change scenarios, and downscaling seasonal climate). It is both multi-disciplinary and cross-cutting in that the risk management process is being communicated through the project's findings to researchers, extension workers, farmers and policy makers.

Policy Agenda: The project is improving agricultural decision making through capacity building, co-learning between researchers and decision makers, and by engaging, equipping and transferring ownership to those groups and institutions providing forecast information and support to regional Governments. The long-term aim is to increase collaboration and communication through existing scientific-government-farmer linkages.

Self evaluation

The Project has made a significant contribution to APN goals through improving the integration and communication between disciplines required for decision making in the area of weather risk and crop disease management. The formation of the CARM (Climate and Agricultural Risk Management) Network at our Dhaka workshop formalized the relationship and has set the scene for future strategies in the areas of capacity building, research, and application of weather advisories.

The project team believes that it has made significant progress in all five of the project objectives. However a prime aim of our APN project was to facilitate people from a group of different disciplines to work together and for all to benefit through co-learning and understanding the requirements of other's disciplines. In such a situation no single outcome should dominate as it is a balance in the research that achieves the optimum outcome. For example, if only rainfall is available as a weather parameter, it would not be possible to use integrated crop and disease simulation models in the development of management strategies and Advisories. It is believed that these requirements which relate to achieving a balanced set of intersectoral outcomes, were met in our project.

A brief self-evaluation of our performance within the five project objectives is given below:

1. Develop and adapt predictive models for selected crops and climate-sensitive diseases (late leaf spot in peanut, Sclerotinia rot and Alternaria blight in

canola and mustard), integrating existing climate, crop and epidemiological knowledge

Comment: A consequence of this project is that it encouraged us to pursue funding from agencies in the USA and the state of Florida. These funds will allow us to improve code and test the re-linked *Cropgro*-Peanut-LATESPOT model against new data on leafspot disease progression and consequences of disease on growth processes and yield of leafspot-resistant and susceptible peanut cultivars.

2. Evaluate the predictive performance of crop growth and disease models, using existing data and new data generation

   Comment: Data collected in 2007 and 2008 in participating countries particularly Florida to assess leafspot epidemic and consequences of disease on growth and yield of two peanut cultivars, and is nearly ready to use for model testing.

3. Identify and evaluate improved crop disease management strategies based on climate information and predictive models

   Comment: Examples include forecast products, and the use of crop and disease information in issuing district-wide agro-advisories for peanut and mustard growing regions of India.

4. Assess information needs and propose communication strategies (e.g., for climatic and disease risk, and disease forecasts, and advisories)

   Comment: The work mentioned in point 3 involved multi-disciplinary and multi-institutional activities which involved stakeholders such as agricultural universities, research institutes, and extension branches, NGO, and media agencies. Establishment of an international network CARM and proposals for future work building on our outcomes and outputs are good examples.

5. Engage appropriate institutions and policy linkages that are in a position to provide support for climate-sensitive crop disease management in each target country

   Comment: Officials representing different Government institutions from India, Bangladesh and Cambodia participated in the project workshops held in Hyderabad (2006) and Dhaka (2008). The project team members further discussed with relevant institutions and people from participating countries to promote this field of research and development activity.

The project faced some daunting challenges, particularly given the shifting range of opinions surrounding global change and the dynamic area of suggested interventions. To achieve regional collaboration and general consensus given the controversial nature of the topic which has received heated debate, particularly from an inter-territorial perspective, was one of the outstanding achievements of the workshop. It is believed that the bringing together of different disciplinary and institutional perspectives in the effort further added to the credibility of the process achieved in the field, during institutional visits and at the workshops.

Potential for further work

The CARM (Climate and Agricultural Risk Management) Network formalized during this APN project is coordinating funding applications in the areas of capacity building, development of frameworks for farmer advisories based on weather and climate risk, and climate/crop pest and disease risk research.

The CARM Network is pursuing five specific parallel funding proposals. They are:

1. A CAPaBLE proposal entitled "Integrated climate, crop, disease and pest modelling for improved farm decision-making". The CAPaBLE workshop is planned for Phnom Penh in mid-November 2009, and will focus on capacity building for all network members, but particularly those from Bangladesh, Thailand, Cambodia, and Viet Nam. A full proposal for the project has been submitted to APN, and we are awaiting final advice on project funding.

2. A regional scientific symposium following the CAPaBLE Workshop. The tile of the symposium is "Climate risk management in rural communities in developing countries of the Asia Pacific Region". Activities will include scientific exchange, regional priority setting and preparation of research concept notes. Funding for this activity will be sought through the AusAID International Seminar Support Scheme. Initial contact has been made with relevant AusAID officials.

3. An ARCP proposal entitled "Identifying the influence of climate change on crop pests and diseases along the Indo-Gangetic Plain" has been submitted. The project will involve India, Bangladesh and the Australian Cooperative Research Centre for Plant Biosecurity, and will have a strong Climate Change and Food Security focus.

4. A proposal entitled "Examining the effect of climate change on pest and diseases of major food crops". This has been submitted to the Australia-India Strategic Research Funding body.

5. A project proposal to the Australian-Netherlands Research Collaboration (ANRC) for a workshop entitled "Establishment and management policies of climate field classes in Indonesia to face climate change". The proposed workshop will be held at the University of Indonesia (UI) in Jakarta, from 15-17 March 2010. The aim of this workshop is to examine mechanisms for setting up "Climate Farmer Field Schools" for agronomic risk communications, leading to the establishment of agro-meteorological services for participating farmers.

Publications

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Huda, A.K.S. and Evans, J. 2009. Australian National Drought Policy, Book Chapter resulting from "Workshop on Drought and Extreme Temperatures: Preparedness and Management for Sustainable Agriculture", organised by World Meteorological Organisation as part of Commission on Agricultural Meteorology (CagM) Expert Team presentation (Huda servig as an expert team member), Beijing, China, 16 and 17 February 2009

Huda, A.K.S, Mehrotra, R and Sharma, A. 2009. Mitigation and adaptation strategies in coping with climate change impacts for improved crop health and sustainable food production in South Asia, Springer Book Chapter, resulting form Regional Symposium on Climate Change, Food Security, Sea Level Rise, and Environment in South Asia, held at University of Dhaka, Bangladesh, 25 to 30 August 2008, sponsored by Ohio State of University, the World Meteorological Organization (WMO), the Food and Agriculture Organization (FAO) Regional Office for Asia and the Pacific, and the UN Economic and Social Commission for Asia·and Pacific (ESCAP).

Huda, A.K.S., Desai, S; Derry, C.W., Ramakrishna, Y.S. and Spooner-Hart, R.N. 2007. "Climate and Crop Disease Risk Management: An International Initiative in the Asia-Pacific Region**"** Proceedings of the Scoping Workshop of 6-10 Nov 2006, India: CRIDA. 46p. (ISBN 978-81-904360-1-4).

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Nil

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Technical Report

Preface

The International Workshop on Climate Prediction and Agriculture held at WMO in 2005 suggested the potential for integrating medium-range (3 -10 days) weather forecasting with historically and seasonally based climatic forecasting to facilitate strategic decision making in agriculture.

This project follows up on this recommendation. Research aimed to integrate existing climate, crop, and disease epidemiological research in the development of a regional predictive model for agricultural risk management. One major outcome is potential reductions in use of pesticides. The project aimed to engage appropriate technical and policy institutions that are in a position to provide support for climate-sensitive crop disease management.

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1 - Introduction

Improvements in our knowledge of relationships between weather, crop growth, crop disease development, crop damage and yield reductions require inputs from a number of technical areas. These include agro-meteorological specialists, crop specialists, plant protection specialists, and risk management/decision making experts. Application of the knowledge is also an important area, and it requires close collaboration and co-learning opportunities with a range of stakeholders ranging from land managers to Government policy makers.

The proposed outcome of the project was to develop regional stakeholder and participant capacity in terms of a risk management approach for the control of selected climate-sensitive crop diseases. The major specific aim was to develop a methodology to increase the economic efficiency and environmental friendliness of pesticide applications. Secondary aims refer to use of climate data for making decisions related to insect infestation, health and the environment and climate change scenarios.

The main objectives of the project were to:

1. Develop and adapt predictive models for selected crops and climate-sensitive diseases (late leaf spot in peanut, Sclerotinia rot and Alternaria blight in canola and mustard), integrating existing climate, crop and epidemiological knowledge
2. Evaluate the predictive performance of crop growth and disease models, using existing data as well as generation of new data
3. Identify and evaluate improved crop disease management strategies based on climate information and predictive models
4. Assess information needs and propose communication strategies (e.g., for climatic and disease risk, and disease forecasts, and advisories)
5. Engage appropriate institutions and policy linkages that are in a position to provide support for climate-sensitive crop disease management in each target country

This project provided the opportunity for stakeholders to come together in a structured environment to address this important issue.

2 - Methodology

As mentioned above, making better decisions on the management of crop diseases requires input from a range of technical expertise, integration of their inputs, and generation of new data to establish links across disciplinary areas. APN Project funding was used as a catalyst to allow interaction between important stakeholders, and to fund the collection of additional data that was required to allow development and application of decision-making tools. Most of the data required for this activity was sourced from research outside the APN Project. The majority of the project budget was applied to the running of the two workshops in Hyderabad and Dhaka, and the remainder for testing of simulation models with existing data, and for filling data gaps identified in early project discussions. Crops studied in the different countries were: peanuts and mustard in India; mustard in Bangladesh; peanuts in Cambodia; canola, mustard and peanut data analysis and model refinement in Australia. The USA provided the *Cropgro* peanut model and expertise in its use, expertise in canopy micro-climate, and techniques relating to downscaling of seasonal climate forecasts for crop yield prediction.

In summary, the project can be divided into four important activities:

1. The project-scoping workshop held at Hyderabad in November 2006: The important aims of this workshop were to share information on relevant technical issues, to establish relationships between the scientists from different disciplines, to provide participants with some exposure to the computer simulation models involved, to identify knowledge gaps, and to plan field and other activities to address these knowledge gaps.
2. The period between the two project workshops when the major technical activity was the analysis of existing data (largely from other projects) and filling in the data gaps from both literature review and field experiments, and the development of risk communication methods in extension. During this period it was important to maintain communication channels between project participants, and this was done by means of E-mail correspondence. These activities continued after the Dhaka workshop with attention to remaining data gaps.
3. The Project Review and Planning Workshop in Dhaka in February 2008: Some major aims of this workshop were to review research findings, plan for further data collection to fill knowledge gaps, facilitate improvement in agricultural decision making through capacity building and co-learning between researchers and decision makers, and make plans for future activities and funding.
4. Planning for activities as a follow up to this APN project, including research project submissions, a CAPaBLE capacity building workshop and an international symposium on the subject of Climate and Agricultural Risk Management, to be held in Phnom Penh in November 2009.

3 - Results & Discussion

3.1- Project Framework

A general framework for the project activities is shown in Fig 1 below.

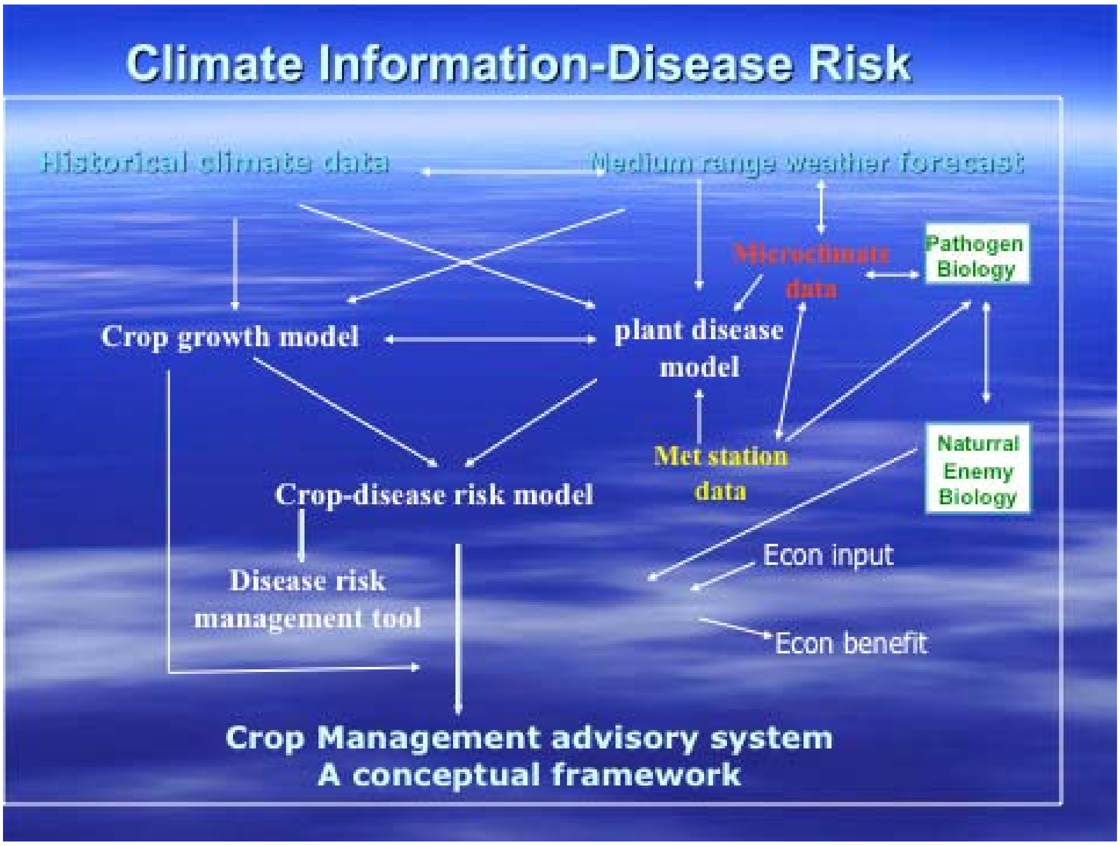


Fig 1: A Conceptual Framework for Management of Crop Diseases

This Framework is best developed in India, where meteorology, plant science, and decision-making are well integrated and packaged as agro-meteorological advisories. At the other end of the spectrum Cambodia has little experience with plant and disease modelling, or use of meteorological information in agricultural decision-making. The project therefore has both scientific aims (to improve the quality of the decision making) and capacity building aims through the exposure of Cambodian and Bangladeshi scientists to knowledge available in India, Australia, the USA and Europe.

The technical reports presented below represent research at different levels of integration and complexity. The ultimate aim is to use sophisticated plant physiology, studies of canopy structure, simulation modelling of crop and disease development, and data on the effect of disease severity on plant yield and economics to make decisions on agronomic activities such as spraying. However, this approach has not reached the application phase, and pragmatic regression approaches to predicting disease severity have allowed the Indian Government to develop weather warnings/advisories for rural communities throughout the country. At the other end of the spectrum, scientists in Cambodia are obtaining preliminary data on pests and diseases in peanuts.

3.2 – Project Workshops

3.2.1 - Project Scoping Workshop, Hyderabad November 2006

The scoping/planning workshop at Hyderabad explored available research information on modelling and epidemiology of selected climate sensitive plant diseases. Workshop participants represented a broad range of disciplines with interests in modelling of climate, crops and diseases, and their applications to crop disease management. Participants came from Australia, Europe, Cambodia, United States, Bangladesh and India. Broad discipline groups were:
a) Climate, crop modelling, risk communication and management and agro-meteorological services (Huda, Ramakrishna, Khan, Jagannathan, Meinke, Hansen, Boote, Stigter, Rathore Coughlan, GGSN Rao, V.U.M. Rao, A.V.M. Subba Rao),
b) Plant protection, epidemiology (Spooner-Hart, Derry, Thakur, Desai, Visarto, Hind-Lanoiselet, Chattopadhyay, Asaduzzaman and Alam).

Researchers also overlapped in their expertise and interest across disciplines particularly in risk analysis and communication.

Days one to three of the workshop comprised a series of presentations, each followed by group discussions to determine a course of action. There was a group tour of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) on 9th November. A final summary meeting was conducted on 10th November.

The outcomes from the workshop were:

- Establishment of an international network of researchers and a collaborative plan for advancing the objectives of the APN project
- An enhanced understanding of the relationships between weather/climate, disease incidence, and reduction in crop yield, which will lead to the development of management interventions
- An inventory of crop models, disease models and data sets which are ready for application to modelling of the targeted crop diseases
- An appreciation of the need to survey the various users of disease forecasts and advisories to inform model development. The consensus was that this requires a bottom up "what do the users want" rather than a top down "what does the modeler want" approach
- Recognition of the need to go beyond modelling diseases and yield losses to managing disease risk as the basis for decision making in this area. The risk management focus will include using historic weather record to quantify risk, and exploring the potential to use seasonal forecasts to anticipate and manage year-to-year shifts in disease risk. This project, and subsequent projects, must also involve the user and assess the economic, social and environmental outcomes of diseases management interventions.
- A list of potential funding agencies for future funding, to build on the APN seed funds

The expected project outputs identified at the workshop were:

- A network of researchers able to collaborate in follow-on projects. This will be achieved through capacity building within the project.

- Results from a set of pilot projects (field trials) in collaborating countries including capacity building in Bangladesh and Cambodia
- Theoretical (from modelling) and actual (farmer survey) economic analysis of disease impact
- Quantification of the impact of diseases on yield

Possible future projects that can be targeted for funding include:

- Development of an ability to assess impacts of climate change on crop diseases and pests
- Development of a crop disease/pest forewarning system for growers and extension personnel
- Development of a framework, including policy supports needed, for capacity building in some of the Asian collaborators countries
- Identification of models and model development for users other than growers and agricultural extension officers. One example is the insurance industry, and this was discussed with NABARD.
- Extension of activities to fruits and vegetables
- Incorporation of policy issues of food security, food safety and environmental issues through reduced chemical usage into models

3.2 2: Project Review and Planning Workshop, Dhaka, February 2008

The general aims of this workshop were information sharing, capacity building, development of integrated crop-climate-disease models, and planning for future group activities, both as part of the project and associated with the project. The project team and the mix of disciplines attending the Dhaka Workshop were largely the same as those represented at the Scoping Workshop in Hyderabad, but there was a greater representation of policy makers in Dhaka.

Some specific objectives of this workshop were:

- To review research findings and plan research to fill knowledge gaps
- To share model validation results from a number of sites to ensure efficient application at regional level,
- To facilitate improvement in agricultural decision making through capacity building and co-learning between researchers and decision makers.
- To plan for future group activities both as part of the project and associated with the project

Following the technical presentations and discussions, the group examined remaining project needs and objectives and plans for the future.

Workshop participants felt that we should continue the existing APN Network, with the possible addition of Nepal and countries from the Mekong Basin. The group resolved to apply for both ARCP and CAPaBLE funding for 2009. It was suggested that the CAPaBLE workshop should be held in Phnom Penh, Cambodia to maximise capacity building on crop modelling and use of meteorological data in that country. A number of potential research projects were considered including:

- Climate/drought and aflatoxin.
- Enhancing nutrient efficiency in response to climate variability for improved plant health and productivity.

- An overarching program on climate change and food security (yield and quality).
- Developing strategies for securing a healthy community food supply when confronted with climate change in the AP region (there was a suggestion that "sustainability" might cover both of these projects)
- A Case study, highly integrated, on vegetables, wheat, mustard, rice in West Bengal-Bangladesh
- Australia greenhouse project and Hawkesbury forest project

The Workshop then broke into two small groups to develop project concept notes, one on decision making at a farm level and the other on long term pest and disease, security, and health under climate change. Discussion followed on possible sources of funding for the projects, and a strategy for maximizing the chances of success of funding applications

After re-visiting and refining the list of project outputs and outcomes originally developed at the Hyderabad Workshop, participants drew up a set of formal recommendations from the Dhaka workshop and the project. These were:

1-The Climate and Crop Disease Management Network (CCDMN) membership should continue with the addition of countries with similar interests in the Asia Pacific Region, such as Nepal and countries in the Mekong Basin.
2-The network should identify sources of short-term bridging funding to take the initiative to 2009, and make application for such funds
3-The Network should identify sources of longer-term funding for 2009 and beyond, including applying for APN capacity building funds (CAPaBLE).
4-The Network should strengthen community engagement and participatory management of future network activity
5-The network should build on its success in disease management to broaden its sphere of activity to Integrated Crop Management (ICM).
6-To reflect this broadened focus the CCDMN should change its name to the CARM (Climate and Agricultural Risk Management) Network
7-The network should accommodate a crop-related, population health component in its activities, and to seek funding in this domain.
8-The Dhaka workshop identified and endorsed one major area of program development, and recommended that the network pursue the development of projects within the program. The program focuses on both irrigated and rain-fed cropping systems in Asia, and on decision-making for crop pests, disease, nutrient management, and crop-related human health. Activity would include interest in simulation of response to extreme events under a climate change scenario.
10-Mechanisms for network survival during the inter-funding period should be investigated, including website, e-mail, and sponsoring an international conference (see point 11 below)
11-The CARM network should examine mechanisms for sponsoring an international conference in 2009 in Cambodia on a subject to be determined to maintain and extend the activities of the network.

3.2.3: Mustard Modelling Workshop, Hyderabad, June 2008.

A group of six scientists assembled at CRIDA, Hyderabad, India during 21-22 Jun 2008 to review current and past mustard data to adapt and test *Infocrop*-mustard, share model validation results to ensure application at regional level, and to discuss the relevant issues in completing the final report and publications to ensure dissemination of research findings to a wide audience of scientists and policy makers. The scientists were Dr S.A. Khan (BCKV, Kalyani, India); Dr Saon Banerjee (BCKV, Kalyani, India); Prof G.A. Fakir (BSF, Bangladesh); Dr C. Chattopadhyay (NRCRM, Bharatpur, India); Dr AVM Subba Rao (CRIDA, Hyderabad, India) and Dr M. Asaduzzaman (BSF, Bangladesh)

The workshop consisted of:

- Training on the *Infocrop* program, ways and means to run the program, and its features.
- Input data required for the model were identified, entered and converted.
- Processing of multi-location data using *Infocrop* program to estimate the yield under disease-free and blighted condition.
- Presentation of results in MS Excel sheet form
- Preparation of the workshop report.

The data processing was restricted to three locations, viz., BCKV Kalyani (WB, India), IARI New Delhi (India) and BARI Pabna (Bangladesh). Each location was unique for the difference in the agro-climatic features and the crop tested.

At all the locations there was a wide gap between the simulated and actual yields for most test dates and varieties (crops). Due to this gap, the simulated effect of Alternaria leaf blight on yield was estimated only for the dates where the gap between the actual and simulated yields was minimal. We concluded from these simulations that the program *Infocrop* is unable to simulate the yield accurately under both disease-free and blighted conditions at the tested locations for the varieties tested.

The Workshop recommended the following future activities:

- The *Infocrop* model needs to be refined to enable it to simulate the yields for oilseed Brassicas (*B. juncea, B. rapa*) under disease-free and blighted conditions.
- The program needs to include Alternaria pod blight (only Alternaria leaf blight is included) and also Sclerotinia rot features during improvement for proper validation.

3.3 – Weather and Climate Prediction

Medium-range weather forecasts and seasonal climate forecasts are required as inputs to models for tactical (short-term) and strategic (long-term) decision-making on disease management. For this project, the major input was made by the National Research Centre for Medium Range Weather Forecasting (NCMRWF) of the India Meteorological Department (IMD). The IMD provided information for Indian districts and to some extent Bangladesh, based on data from West Bengal.
The IMD has issued quantitative district level (612 districts) weather forecast up to 5 days since 1st June, 2008. The products comprise quantitative forecasts for 7 weather parameters viz., rainfall, maximum and minimum temperatures, wind speed and direction, relative humidity and cloudiness. In addition, weekly cumulative rainfall forecast is also provided. IMD, New Delhi will generate these products based on a Multi Model

Ensemble technique using forecast products available from a number of models of India and other countries. These include: T-254 model of NCMRWF, T-799 model of European Centre for Medium Range Weather Forecasting (ECMWF); United Kingdom Met Office (UKMO), National Centre for Environmental Prediction (NCEP), USA and Japan Meteorological Agency (JMA).

The products are disseminated to Regional Meteorological Centres and Meteorological Centres of IMD located in different states. These offices undertake value addition to these products and communicate to 130 AgroMet Field Units (AMFUs) located with State Agriculture Universities (SAUs) and institutes of the Indian Council of Agriculture Research (ICAR).

3.4 - Crop and Disease Modelling for Groundnut/Peanut.

Peanut suffers from the fungal disease late leafspot (*Phaeoisariopsis personata*), which together with rust (*Puccinia arachidis)* can cause yield losses of 15-50% in India. The occurrence of Leafspot is very climate sensitive, so weather data is a very important input to any prediction.

The *Cropgro*-Peanut model developed in the USA is being linked to algorithms for the prediction of climate sensitive plant diseases. Pathogen modelling involves a number of facets including disease incidence and severity, the onset, progression and termination of sporulation, spore movement and economics.

3.4.1 - Relationships between meteorological observations and canopy microclimate

It is well known that in rain-dependent production systems standard meteorological observations (even if measured close by) do not adequately reflect the weather at the crop canopy level.

Some work was carried out at the National Soil Tilth Laboratory, Ames, Iowa to use meteorological variables collected adjacent to the field area to develop a relationship to estimate the different phonological stages of Canola. Observations are also collected of canopy reflectance using an eight-band radiometer that covers the visible and near-infrared wavelengths. These data are being used to develop vegetative indices to estimate different phenological stages in canola along with biomass and yield estimation. The weather conditions for the three growing seasons studied have been different in terms of the occurrence of rainfall events and this has impacted on the growth and yield of the crop. These experiments will continue and data are being assembled to evaluate the occurrence of climate risk factors, in particular, occurrence of extended dry periods and temperature extremes.

In India, studies on the relationship between observatory and groundnut canopy meteorological conditions were carried out at the Central Research Institute for Dryland Agriculture (CRIDA) at Hyderabad. For disease development, weather at canopy level is more important. However, often it is not possible to collect this data due to non-availability of infrastructure. Hence, an attempt was made to establish a functional relationship between weather from observatory and the weather at canopy level. Field trials were laid out during the *kharif* (rainy) season in 2005 and 2006 with groundnut cv.

JL 24. The crop was sown at a spacing of 45x10 cm. A sensor with datalogger was placed in the field at canopy level to record temperature and relative humidity. The height of the sensors was adjusted with the growth of the crop to position them in foliage region. The field was artificially inoculated with late leafspot pathogen by randomly transplanting the infected plants across the field. Randomly selected 100-plant groups were tagged and late leafspot progression was recorded at regular interval up to harvest.

Both maximum- and minimum-temperature (shown in Fig 2) followed a typical sigmoidal relationship

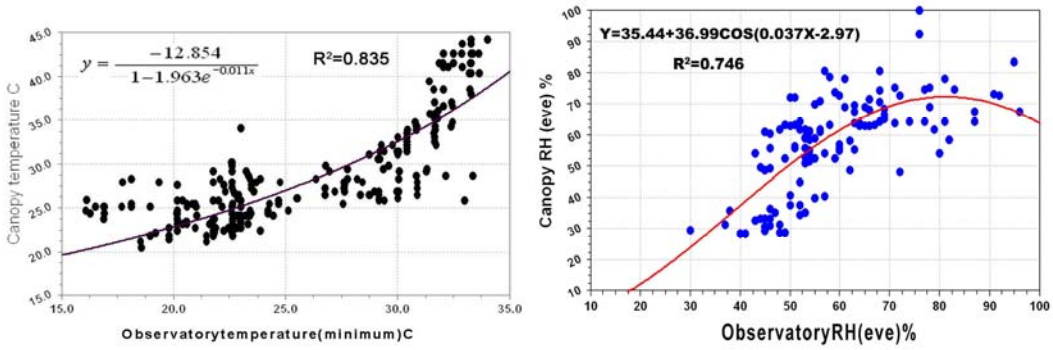


Fig 2. Relationship between observatory and canopy weather data for minimum temperature and evening relative humidity for 2005

The R^2 was highly significant. However, for morning- and evening-relative humidity (see Fig 2), there was a variation in relationship between *kharif* 2005 (shown in Fig 2) and *kharif* 2006. While an exponential relationship was observed in *kharif* 2005 for both parameters, during *kharif* 2006 a sinusoidal relationship was observed. A study of the reasons for this relationship could give a scope to develop more meaningful disease forewarning systems. These functional relationships for temperatures could be used for developing weather based forewarning systems. The conversions will serve as a correction factor to the observatory data.

3.4.2 – USA Studies linking crop and diseases simulation models

The University of Florida made the *Cropgro*-peanut model available to the APN-project for coupling the effects of disease on plant growth and yield. Training was provided on the model at APN work sessions and symposia, during which the data requirements to use this model (weather, soil, management, and disease recording) was outlined, and typical model outputs discussed. The potential use of baseline data developed from the USAID-Africa project towards the improvement of fungal disease prediction was also described. Model performance against prior existing data showed the potential for predicting late leafspot (*Phaeoisariopsis personata*) disease epidemics on full-season groundnut cultivars grown in the USA, and for predicting the consequences of infection on leaf abscission and on canopy assimilation, and subsequently on crop growth and pod yield. This model predicts leafspot infection and disease processes on individual leaf cohorts (Figure 3). The disease processes include infection, latent phase, lesion expansion, and sporulation, leading to polycyclic epidemic progression. During this project, we identified potential data sets for testing this coupled model, to include four data sets on Florunner peanut in Florida (1983, 1985, 1986, and 1987) and several in Ghana (1999, 2000, 2001) where sprayed and unsprayed treatments were present. Particularly for the Ghana data, we discovered the need to translate disease from the widely-used, but simple ICRISAT score for leafspot assessment into actual percent defoliation and percent leaf necrosis on remaining leaves, for purposes of comparison to simulated model outputs. Traditional main stem defoliation estimates by pathologists tended to overestimate the amount of leafspot disease damage.

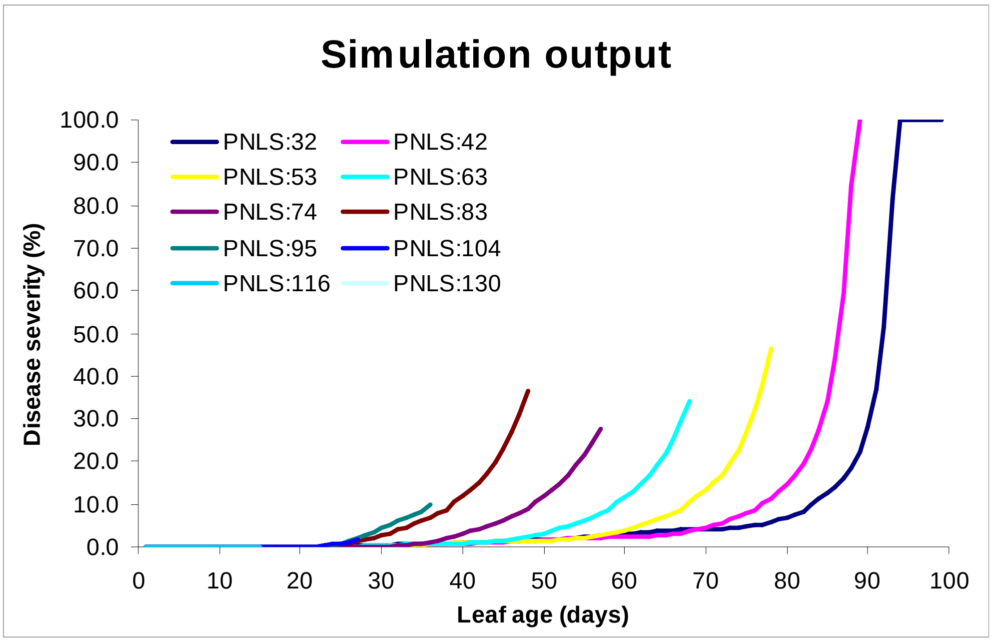


Figure 3. Simulated leafspot disease progression over time on individual leaf cohorts (formed at 32, 42, 53, 63, 74, 83, 95 days after sowing) for unsprayed Florunner in 1983 in Florida, using *Cropgro*-peanut-LATESPOT model. Cohorts 104, 116, and 130 were not formed in simulations. Leaflets normally abscise at 20-30% disease, so cohorts 32 and 42 are not represented correctly.

Re-evaluation of capabilities of the existing *Cropgro* peanut-LATESPOT model indicated a need to improve certain aspects of the model, because of new disease process knowledge gained since the LATESPOT model was written in 1989. In addition, structural problems in the *Cropgro* model required that we develop the leaf-cohort structure within the crop model, rather than in the disease module, to obtain better predictions of leaf abscission from other causes (leaf aging, canopy self-shading, water deficit, etc) in addition to and in interaction with leafspot-induced abscission. This coding change is underway, and will be completed by summer 2009. In addition, leafspot disease also causes pod abscission and this process needs to be modelled better to account for leafspot disease effects on harvestable pod yield, because pod abscission differs by cultivar type (Spanish versus Runner type). The leafspot epidemic model needs improvement and further testing to account for differences in groundnut cultivar resistance to leafspot diseases, especially in terms of effects on infection, latent phase, lesion expansion, and rate of sporulation. New knowledge on efficacy of newer fungicides on components of leafspot disease development on groundnut exists, but more data is needed. An experiment in Florida was conducted in 2008 to measure leafspot development on single-leaf cohorts and consequences of a given percent necrosis over time, on leaf photosynthesis for a resistant versus a leafspot-susceptible cultivar. Canopy assimilation, crop growth, pod growth, and final yield were also measured. These data are nearly ready to be used in a new independent test of the coupled

Cropgro-peanut-leafspot simulator, and a second year of data collection in 2009 is planned. With the improved crop-leafspot model, we will evaluate yield losses from leafspot disease under sprayed and unsprayed conditions in USA and West Africa and compare simulated to observed growth and yield losses in those studies.

Research to integrate weather, crop and disease models is still at the research stage, so has not progressed to the stage reflected in Objective 3 of our project, that is "To identify and evaluate improved crop disease management strategies based on climate information and predictive models".

3.4 3 – Indian studies predicting severity of Late Leafspot in Peanut

The major components of model development in India have involved the following steps:

1. Collection and compilation of historical databases on climate, crop pests and diseases
2. Conducting field experiments with special emphasis on pest-disease data collection
3. Development of statistical regression models to predict pest-disease incidence from weather data
4. Validation of models in farmers' fields
5. Integration of seasonal and medium-range weather forecasts with models for real-time forewarning

ICAR has been developing a crop-weather-pest database since 1990. Field trials have been carried out at CRIDA, TNAU and ICRISAT on late leafspot and rust. At CRIDA, the trials were focused on establishing relationships between macro and micro-weather parameters in relation to late leafspot incidence and intensity (see section 3.4.1). At TNAU, studies on late leafspot and rust and crop microclimate interactions with five planting dates coupled with 3 levels of potash were carried out.

Further work was carried out to refine the decision support system for Late Leafspot based on statistical regression models. Detailed analysis of variability in apparent infection rates ('r') of late leafspot of groundnut across locations was done. Significant variability in percent disease index, apparent infection rate ('r') and area under disease was noticed across locations and over years. Across the locations and over years the apparent infection rate ('r) varied considerably, which in turn influenced disease development. At Aliyarnagar, the mean 'r' values were 0.044, 0.156, and 0.066 for 2002, 2003 and 2005, respectively. At Vriddhachalam, the mean 'r' values were 0.066, 0.089 and 0.030 for 2001, 2002 and 2003, respectively. The weather during 2001, 2002 and 2003 varied considerably resulting in varied mean 'r' over years. At Coimbatore, mean 'r' value for 2001 was 0.057. The 'r' values within the crop season also varied for different dates of observation. This viability within the season could be attributed to variable weather conditions as the other two requirements for epidemic development viz. susceptible host and initial inoculum, were satisfied.

A close observation of disease initiation and disease progression reveals that early initiation of disease during the crop season is not always translated into faster development of epidemic resulting in more disease intensity. This variability will be accounted for in the decision support system by incorporating location-wise 'r' as an additional input and also by adding a screen to choose locations to improve predictability of disease occurrence.

An example of the fieldwork carried out is described below. The research was done as part of a Thesis for a Master of Science in Agricultural Meteorology degree program at TNAU, Coimbatore. A field experiment was conducted at the Coconut Research Station from July 2007 to December 2007 to develop forewarning of late (*tikka*) leaf spot disease in groundnut. The experiment was conducted in a Factorial Randomized Block Design with three replication employing two factors. The factors include five dates of sowing (the first sowing date was selected during last week of July followed by subsequent four sowings with the last sowing in the second week of September) while the other factor was three levels of potassium (75, 100 and 125 per cent recommended dose (54 kg K_2O/ha)).

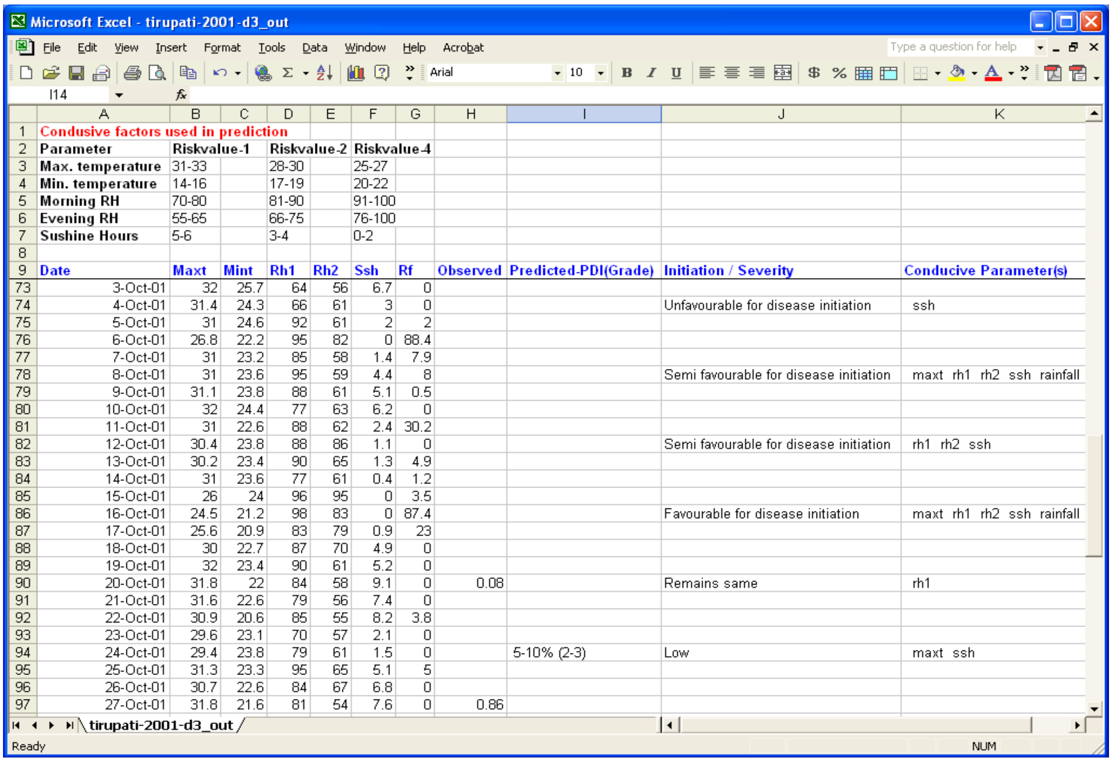
The result revealed that the disease incidence was found to decrease with increased potassium fertilization in all sowing dates. The first appearance of *tikka* leaf spot disease was earlier in the late sowings *i.e.* fifth and fourth sowings as compared to earlier sowings. Stepwise multiple regression analysis was used to identify those weather variables useful to explain variation in groundnut late (*tikka*) leaf spot (*Phaeoisariopsis personata*) disease severities. Disease incidence estimates (Y), maximum temperature (°C), minimum temperature (°C), RH [morning and evening] (%), rainfall (mm), wetness duration (hrs), wind speed (km hr^{-1}), Growing Degree Days (°C), Relative Temperature Disparity, Relative Humidity Disparity, Photo Thermal Unit and Helio-Thermal Unit were used as variables. Among the 12 independent variables taken for study the evening RH, wetness duration and HTU had significant correlations with percent Disease Incidence.

The early sowings *viz.*, July last week and August second week sowings favourably increased the leaf area index, dry matter production, matured pods per plant, hundred pod and kernel weights and yield of groundnut. The highest level of potassium (125 per cent) during earlier sowings reduced the tikka leaf spot disease and was found to increase the disease resistance in groundnut. Regression equations were developed for each of the sowings. They all had R-squared > 80 per cent accuracy using five weather variables (Table 1).

Table 1: Relationships between severity of Late Leafspot and weather parameters for five sowing dates for peanut.

Date of sowing	**Prediction equation**
First sowing	(PDI) $Y= 19.27 + 2.36_{[\text{wetness duration (hrs)}]} + 0.212_{[\text{HTU}]}$
Second sowing	(PDI) $Y= 91.720 + 0.547_{[\text{wetness duration (hrs)}]} + 2.116_{[\text{evening RH(\%)}]} - 0.197_{[\text{HTU}]}$
Third sowing	(PDI) $Y= 117.116+ 0.577_{[\text{wetness duration (hrs)}]} + 0.984_{[\text{evening RH (\%)}]} - 0.257_{[\text{HTU}]}$
Fourth sowing	(PDI) $Y= 91.935 + 0.452_{[\text{wetness duration (hrs)}]} + 69.917_{[\text{GDD}]} - 5.993_{[\text{PTU}]}$
Fifth sowing	(PDI) $Y= 100.95 - 3.283_{[\text{GDD}]} + 0.326_{[\text{HTU}]}$

For the predictive model developed from the regional fieldwork described above, daily weather inputs are maximum temperature, minimum temperature, morning RH, afternoon RH, sunshine hours and rainfall. Crop data includes date of sowing, present crop age in weeks, and present status of the disease (No/Low/Moderate). Multiple or stepwise regression equations predicting days to first disease incidence, days to highest disease incidence, disease duration, and percent disease incidence are developed using the above inputs. An example of model outputs is shown in Fig 4 below.



Microsoft Excel - tirupati-2001-d3_out

	A	B	C	D	E	F	G
1	Condusive factors used in prediction						
2	Parameter	Riskvalue-1		Riskvalue-2		Riskvalue-4	
3	Max. temperature	31-33		28-30		25-27	
4	Min. temperature	14-16		17-19		20-22	
5	Morning RH	70-80		81-90		91-100	
6	Evening RH	55-65		66-75		76-100	
7	Sushine Hours	5-6		3-4		0-2	

9	Date	Maxt	Mint	Rh1	Rh2	Ssh	Rf	Observed	Predicted-PDI(Grade)	Initiation / Severity	Conducive Parameter(s)
73	3-Oct-01	32	25.7	64	56	6.7	0				
74	4-Oct-01	31.4	24.3	66	61	3	0			Unfavourable for disease initiation	ssh
75	5-Oct-01	31	24.6	92	61	2	2				
76	6-Oct-01	26.8	22.2	95	82	0	88.4				
77	7-Oct-01	31	23.2	85	58	1.4	7.9				
78	8-Oct-01	31	23.6	95	59	4.4	8			Semi favourable for disease initiation	maxt rh1 rh2 ssh rainfall
79	9-Oct-01	31.1	23.8	88	61	5.1	0.5				
80	10-Oct-01	32	24.4	77	63	6.2	0				
81	11-Oct-01	31	22.6	88	62	2.4	30.2				
82	12-Oct-01	30.4	23.8	88	86	1.1	0			Semi favourable for disease initiation	rh1 rh2 ssh
83	13-Oct-01	30.2	23.4	90	65	1.3	4.9				
84	14-Oct-01	31	23.6	77	61	0.4	1.2				
85	15-Oct-01	26	24	96	95	0	3.5				
86	16-Oct-01	24.5	21.2	98	83	0	87.4			Favourable for disease initiation	maxt rh1 rh2 ssh rainfall
87	17-Oct-01	25.6	20.9	83	79	0.9	23				
88	18-Oct-01	30	22.7	87	70	4.9	0				
89	19-Oct-01	32	23.4	90	61	5.2	0				
90	20-Oct-01	31.8	22	84	58	9.1	0	0.08		Remains same	rh1
91	21-Oct-01	31.6	22.6	79	56	7.4	0				
92	22-Oct-01	30.9	20.6	85	55	8.2	3.8				
93	23-Oct-01	29.6	23.1	70	57	2.1	0				
94	24-Oct-01	29.4	23.8	79	61	1.5	0		5-10% (2-3)	Low	maxt ssh
95	25-Oct-01	31.3	23.3	95	65	5.1	5				
96	26-Oct-01	30.7	22.6	84	67	6.8	0				
97	27-Oct-01	31.8	21.6	81	54	7.6	0	0.86			

tirupati-2001-d3_out

Fig 4: Microsoft Excel Worksheet showing weather parameters used in disease assessment, Risk Values, daily data and assessments for a field trial at CRIDA

3.4 4 - Cambodian scoping studies on pests and diseases in Peanut:

Since modelling activities are not well established as a research tool in Cambodia, field research was confined to initial data gathering on peanut crop growth and occurrence of pests and diseases. The study was designed to evaluate peanut varieties for resistance to major/important pests and diseases and its relationship to climate factors, with a view to identifying varieties best suited in the Cambodian upland ecosystem.

We conducted trials in three locations: Kampong Cham, Battambang and CARDI research station during the early wet season (March-June) of 2007. Six varieties were studied-three from Thailand and three from Cambodia. Twenty-four 5 m2 plots were laid out at each site, and seeding and fertilizer application was at recommended rates. The plots were maintained weed-free by hand weeding, but no pesticides were applied to control insects and diseases.

Observations of pest and disease occurrence were made throughout the growing season on five occasions, ranging from 25 days after emergence (20 April) to the mature pod stage (30 June). Damage rating scales were used for both insect pests (ratings 0-5) and diseases (ratings 0-9). For the common diseases, the ratings were related to varietal resistance (0 = Highly Resistant and 9 = Highly Susceptible). Meteorological data was recorded only at CARDI research station. Daily temperature, humidity and rainfall were recorded as these factors are closely related to fungal disease development.

Ten insect species were observed attacking the peanut crops. Leaf feeder (*Spodoptera litura*) produced major damage across all varieties tested, while Groundnut leaf miner

(*Aproaerema modicella*), *Aphis craccivora* Koch, Jassids (*Empoasca kerri* Pruthi), and Green vegetable bug (*Sroeung san dek)* caused moderate damage.

At all study sites we observed three major diseases- Early leafspot, (*Cercospora arachidicola*), Late leafspot, (*Cercosporidium personatum*) and Rust, (*Puccinia arachidis)*. However, the degree of infection of those three diseases was very different for the six varieties. Weather factors (temperature, air humidity and rainfall) during the cropping season were optimum for these three diseases. The average of temperature varied from 29 to 32 degrees C and the air humidity were around 60-70%.

The three varieties from Thailand (KKUNo.1, KKU No.40 & KKU No. 72-1) were tolerant varieties according the Standard Evaluation System. They received a score of three (out of 9) while the three traditional varieties from Cambodia were badly affected by both early leafspot and late leafspot (with ratings of 5-7-see Fig 5). All varieties were tolerant to rust except for one of the local varieties Kroab chrounh, which was moderately susceptible to the rust.

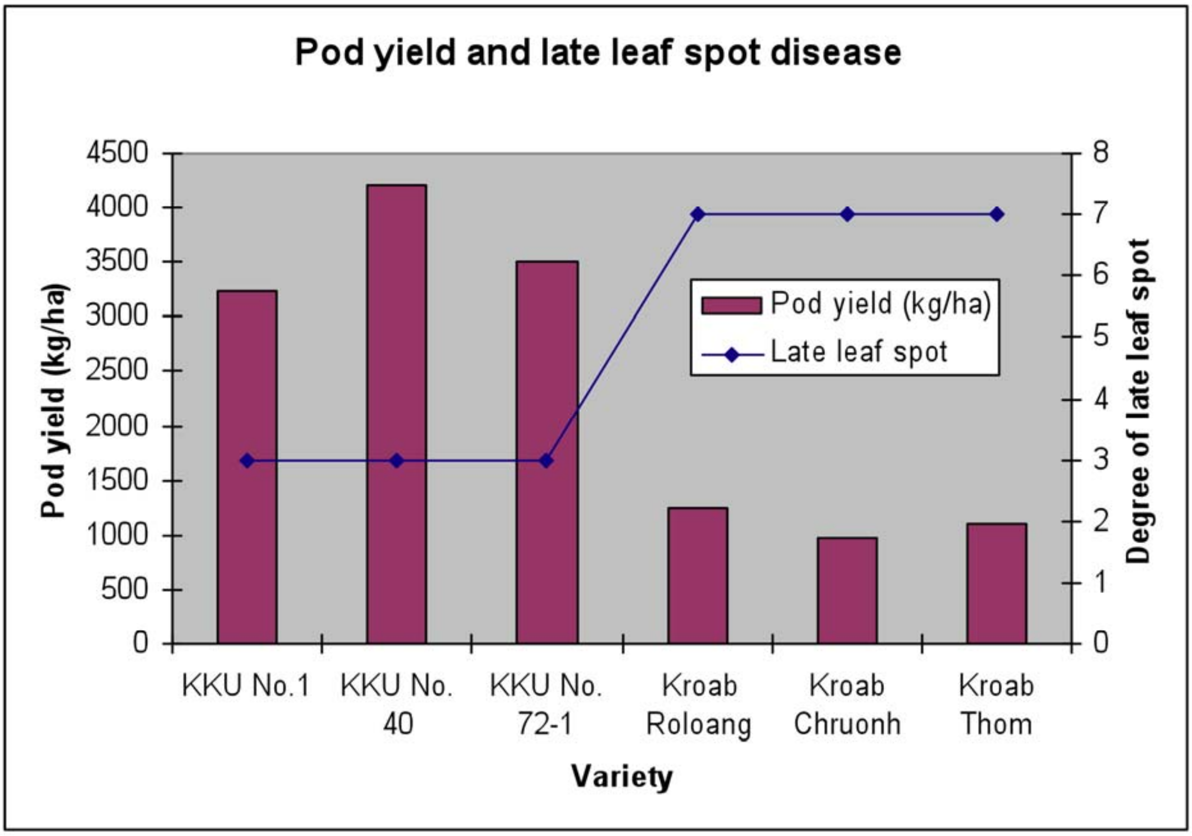


Fig 5: The relationship between peanut pond yield and Late Leafspot rating, Cambodia.

The yields of the three varieties from Thailand were much higher than those of the traditional Cambodian varieties. Pod yields for the Thai varieties varied from 3200-4300 kg/ha, while those of the Cambodian varieties varied from 1000-1300 kg/ha. The yield figures were inversely related to the ratings for Early and Late Leafspot, as described earlier.

Two conclusions can be made from this study:

1. Thai varieties perform vastly better than traditional varieties in the uplands of Cambodia if no pesticides are applied
2. If the low yield of the traditional varieties is due to disease damage (there are no differences in insect damage ratings across the varieties) rather than limited yield potential, the data provide some guidance on the degree of disease damage that can be accepted without pesticide application. A score of 3 does not appear to have a large effect on yield, while a score of 7 may be very detrimental. This conclusion needs to be validated through further trials with and without pesticide treatment.

3.5 – Crop and Disease Modelling for Mustard and Canola

India-based crop simulation modelling for Mustard was based on *Infocrop* (see sections 3.2.3 and 3.8). In Australia, a locally developed Canola model was used in the economic calculations reported in section 3.6. Mustard suffers a number of climate-sensitive diseases, the most serious of which is the foliar disease Alternaria blight (*Alternaria brassicae*) which causes yield loss of up to 35% in India. In Australia, Alternaria blight and Sclerotinia rot (*Sclerotinia sclerotiorum*) present a serious problem for Canola.

3.5 1 – Fungal Diseases of Mustard in India

In West Bengal, productivity of mustard is hampered due to infestation of Alternaria blight and downy mildew. The infestation of these diseases is very much associated with weather conditions during the growing season of crop. Since infections of these diseases are dependent upon weather factors, suitable disease weather relationships can be developed to forecast the risk of these diseases and can be used in farmers' advisory systems.
Research was carried out at Mymensingh during the winter of 2007-08 with three dates of sowing – 27 October, 6 November, and 22 November (Table 2).

Table 2: Severity of Alternaria blight at different dates of sowing at Mymensingh during 2007-08 cropping seasons for the variety BARI Sharisha 9

Sowing date	**Percent Alternaria blight severity (PDI)**								**Yield (Kg/ha)**
	30 DAS	37 DAS	44 DAS	51 DAS	58 DAS	65 DAS	72 DAS	79 DAS	
27 Oct 07	2.8	4.9	10.4	15.8	21.7	27.4	37.8	42.1	910 a
6 Nov 07	4.8	7.9	13.3	20.9	25.4	31.5	45.8	52.1	845 b
22 Nov 07	9.8	15.2	25.3	29.3	32	42.2	50.3	61.2	710 c
Average	5.8	9.3	16.3	22	26.3	33.7	44.6	51.8	

Highest maximum infestation is for crops sown in mid-November. It was concluded that the peak downy mildew intensity was observed when Maximum temperature was greater than 27 degrees C, Minimum temperature was greater than 10 degrees C, and relative humidity (RH) was around 100% in the morning and 50% in the afternoon

The effect of dates of sowing on percent disease index of Alternaria blight of different varieties of rape and mustard was also evaluated. It was observed that the percent disease index (PDI) of Alternaria blight was highest in the crop sown 8 November and with delay in sowing beyond this date, the PDI decreased. The highest PDI for all varieties was observed between 26 January and 7 February. Intensity of Alternaria blight appears to occur when RH is high and minimum temperature is around 10 degrees C.

The National Research Centre on Rapeseed-Mustard (NRCRM) has developed a regression model for predicting Alternaria Blight on Mustard leaves. The model predicts crop age at first disease appearance, age of crop at maximum severity, and highest Alternaria blight severity. The model is based on three years fieldwork at Bharatpur, and model parameters are maximum and minimum temperature and relative humidity in morning and afternoon.

3.5 2 – Studies of Alternaria Leaf Blight in Mustard in Bangladesh:

In Bangladesh, a number of management practices are used to minimize the occurrence of Alternaria Blight in mustard include: More tolerant varieties, Use of Clean seed, Date of sowing, Seed and plant fungicide treatments, and Destruction of crop residues. Major climatic factors studied in the research program include RH, air temperature, rainfall, fog occurrence, sunshine, and wind velocity and direction

Research has been carried out to develop a suitable model for Alternaria Leaf Blight of Mustard. The study was conducted with two mustard varieties (BARI Sharisha 6 and BARI Sharisha 9) at two locations (Pabna and Mymensingh) representing two different Agro-Ecological Zones for two consecutive years with three dates of sowing in October-November. Percent Disease Severity is based on a scale from 0-5 estimated from % leaf or pod area diseased. Daily weather data – minimum and maximum temperature, rainfall (mm), minimum and maximum RH (%), and solar intensity/ sunshine hours- were measured for the growing period of the crop

Results revealed that Alternaria blight severity increased with the advance of sowing time for both varieties at both the locations. Late sowing resulted more disease compared to early sowings. Yield decreased with the increase in disease severity. Among the weather parameters measured, rainfall (mm) and sunshine have marked influence on disease severity and yield. Higher relative humidity (%) during the rainy days and foggy (zero sunshine hours or less sunshine) weather also had significant effects on disease development. No marked influence of temperature was observed.

The findings of the study indicate that more comprehensive weather based data will be needed for development of a sound model of Alternaria leaf blight.

3.6 –Framework/Advisories for Management of Crop Diseases in India and Australia

Based on the above research, forecast products and the crop information available in India, the AMFUs prepare district-wise agro-advisories for all the Peanut and Mustard growing regions of India. It is multi-disciplinary and multi-institutional project, which involves all stake holders such as State agricultural Universities (SAUs), Indian Council for Agriculture Research (ICAR), *Krishi Vigyan Kendras* (KVK), Department of Agriculture & Cooperation, State Departments of Agriculture/ Horticulture/ Animal Husbandry/ Forestry (Up to District level offices), NGOs, Media Agencies, etc. This project is being operated through five-tier structure to set up different components of the service spectrum. It includes meteorological (weather observing & forecasting), agricultural (identifying weather sensitive stress & preparing suitable advisory using weather forecast), extension (two way communication with user) and information dissemination (Media, Information Technology, Telecom) agencies. A general format for the development of Agromet Advisories is shown in Fig 6.

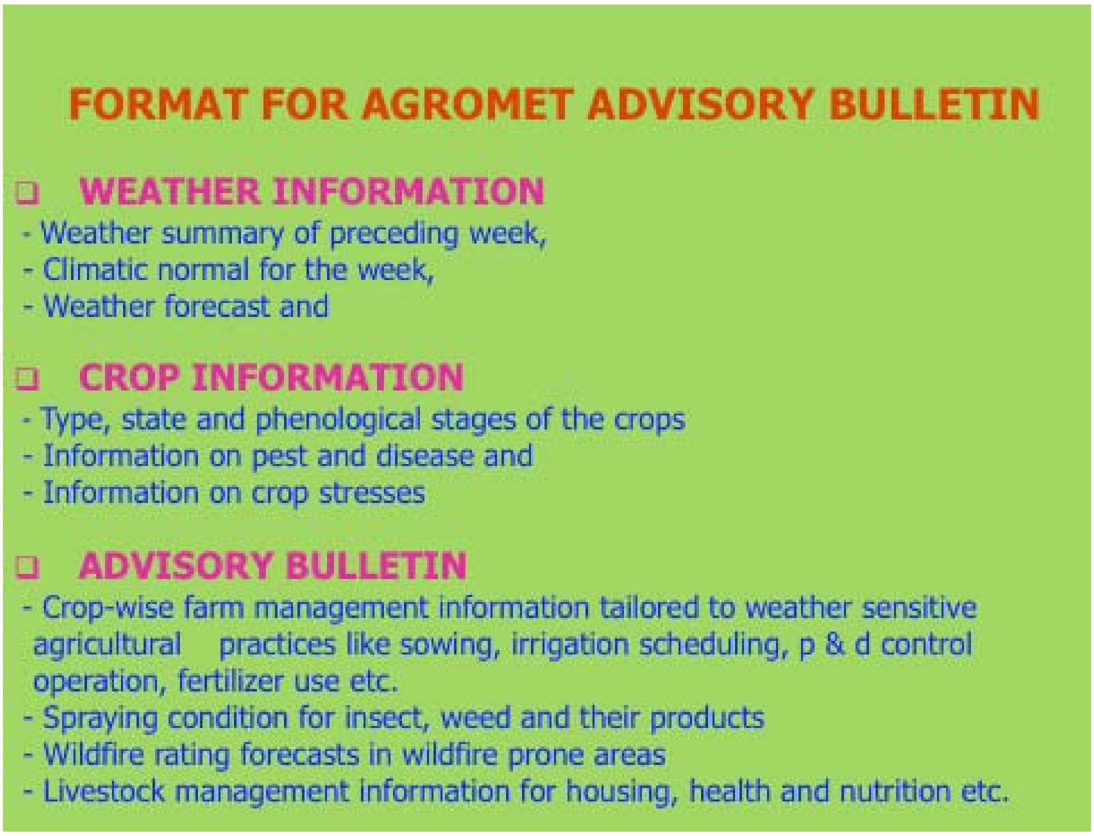


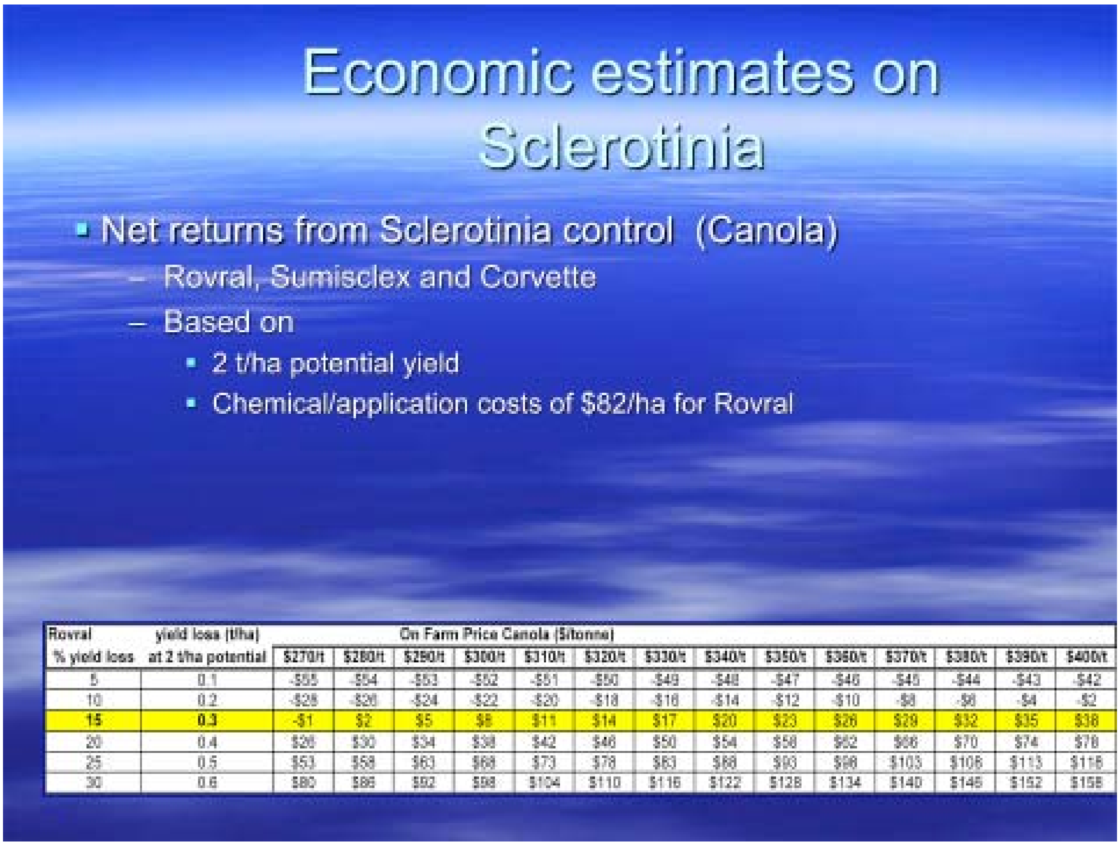
Fig 6: A Format for Weather Warnings and Agromet Advisories in India

In Australia, a framework has been developed to allow extension specialists to advise farmers on the feasibility and economics of pesticide spraying. The aim is to increase the efficiency of pesticide application and reduce environmental effects of their use.

Since most fungicides are reasonably rainfast, spraying could proceed if rainfall is not imminent. If there is a high probability of rain in the next three days this would increase the probability of disease development. If there is no visual evidence of crop disease, the decision to spray will depend on the disease. For a disease like stripe rust spraying could be deferred. The agronomist would look for the hot spots then start spraying to protect emergent leaves/uninfected plants as the disease goes through several lifecycles (polycyclic) in the crop. However, for a disease like Sclerotinia which is monocyclic there is only one chance for control, and that is before the disease develops. So data must be available to know if weather conditions have been favourable for disease development and are going to be favourable for disease development.

For a polycyclic disease there are certain disease thresholds when it is too late for treatment. For example when the wheat flag leaf is severely affected with active/alive stripe rust the agronomist would probably advise the farmer to cut the crop for hay as grain filling will be limited. For monocyclic diseases once it is present there is nothing much you can do for that year's crop. The nature of the inputs to a decision described above emphasise the importance of forewarnings of disease occurrence based on crop, disease and weather factors.

Added to this is the concept of an economic threshold for spraying. A farmer (with the assistance of an agronomist) will decide not to spray if the economics are not good. This decision will be based on the expected market price of the product and the cost of spraying. An example of such an economic decision for Sclerotinia on Canola is given in Fig 7.



Rovral	yield loss (t/ha)	On Farm Price Canola ($/tonne)													
% yield loss	at 2 t/ha potential	$270/t	$280/t	$290/t	$300/t	$310/t	$320/t	$330/t	$340/t	$350/t	$360/t	$370/t	$380/t	$390/t	$400/t
5	0.1	-$55	-$54	-$53	-$52	-$51	-$50	-$49	-$48	-$47	-$46	-$45	-$44	-$43	-$42
10	0.2	-$28	-$26	-$24	-$22	-$20	-$18	-$16	-$14	-$12	-$10	-$8	-$6	-$4	-$2
15	0.3	-$1	$2	$5	$8	$11	$14	$17	$20	$23	$26	$29	$32	$35	$38
20	0.4	$26	$30	$34	$38	$42	$46	$50	$54	$58	$62	$66	$70	$74	$78
25	0.5	$53	$58	$63	$68	$73	$78	$83	$88	$93	$98	$103	$108	$113	$118
30	0.6	$80	$86	$92	$98	$104	$110	$116	$122	$128	$134	$140	$146	$152	$158

Fig 7: An economic evaluation of spraying for the control of *Sclerotinia* on Canola in NSW, Australia.

3.7 – Application of Advisories in Rural Communities.

The Decision Framework described in section 3.6 is based largely on technical issues and factors related to the farm business. However, particularly for resource-poor farmers in Developing Countries there may be a range of social, cultural and political issues that provide further barriers to decision making. Therefore it is important to involve farmer groups and rural communities in developing decision frameworks.
These issues were also considered as part of our APN project.

At this stage, application of advisories based on weather warnings is confined to India. An extract from the Web page of the Diseases Forecast Service is shown in Fig 8. In Bangladesh and Cambodian Farmer Field Schools have been confined to subjects such as Integrated Pest Management.

Fig 8: A Disease Forecast Service for Rural communities in India.

In India, these weather-based advisories are being disseminated to the farmers through mass media, Internet etc as well as through district level intermediaries. The advisories are communicated through multi-channel dissemination system including All India Radio (AIR), Doordarshan, private television channels, FM radio, print media (newspapers), Internet (web pages of IMD, SAUs etc). It is planned to disseminate the advisories through community service centres (CSC) of the Ministry of Information Technology, Cell Phone-SMS, *Krishi Vigyan Kendra*s (KVKs)/ District Agricultural Offices (DAO), Kisan Call Centres, NGOs etc. Extension is carried out at the lowest administrative level since these are most directly accountable to the local community. A mechanism has also been developed to obtain feedback from the farmers on quality of weather forecast, relevance and content of agromet advisories and effectiveness of information dissemination system, including accessibility to information and experts.

Most warning systems have not made the transition from scientific validation to real world application as agrometeorological service.The use of weather warnings by farmers is faced with a number of logistical barriers to their application including inconvenience, complexity of the technical decision, added costs and labour (despite the projected return), and the difficulty of timely response, unsuitable weather data (air temperature, rainfall, relative humidity, leaf wetness duration in particular); unsuitable weather forecasts; and the need for geographic interpolation of results. To these barriers may be added for our APN developing countries the problem of non-existing or unsuitable communication channels

During the project, two strategies were tested:

1. Firstly, project participants were asked to identify potential farming systems and user groups (within those farming systems) of the products identified by our Hyderabad workshop, and for the crops discussed there and in the project document. Farming systems in which the diseases occur (or bear relevance to) and existing advisory services (or their absence) to such farming systems had to be identified. This is required to serve our objectives to "identify risk communication needs of local stakeholders" and "developing risk communication strategies through engagement with local stakeholders". The aim here is to bring model results to those users in an appropriate form and language for use as decision support.
2. The second strategy was the "Development of a strategy towards agro-meteorological services in developing countries" as an outcome of our APN exercise, with indications where the bottlenecks are in the communications between product generators and users? "Even with only rainfall (as is the case for Cambodia) there might be disease risk "advisories" possible to farmers, from where we can work towards "services".

Feedback from Cambodia and Bangladesh emphasizes that these country have a long way to advance in the area of use of weather data for risk management:

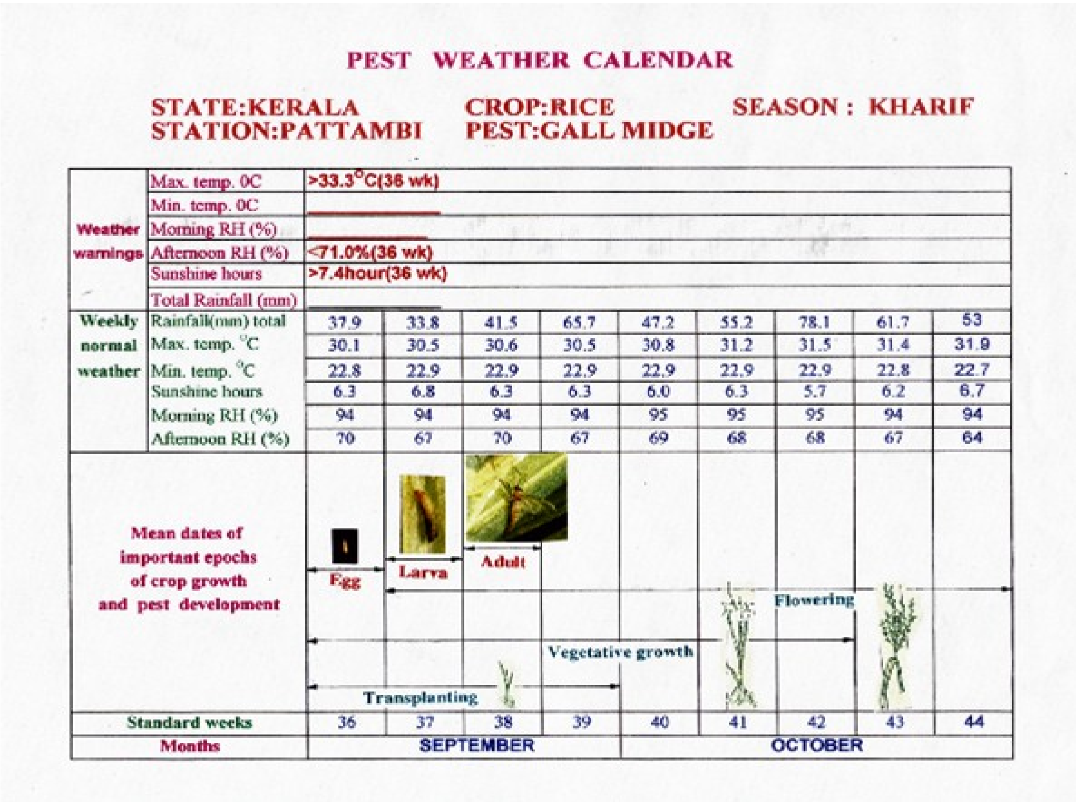
"Compared to other countries such as Australia, India or Indonesia, Cambodia is still far away from implementing weather for crop risk assessment. However, the APN project is a step in the right direction. Research has begun in Cambodia, but only one of the sites is suitable for peanut production, and only rainfall is available at that site", and

"In Bangladesh there are Farmer Field Schools for Integrated Pest Management under the Department of Agricultural Extension. Through these schools more than 30 thousand farmers have been trained on IPM. These trainings have been particularly useful in controlling pests and diseases of rice and vegetables".

Knowledge in this area has been increased through capacity building exercises as part of our past and proposed workshops.

It was only in India that the agricultural and meteorological systems were sophisticated and integrated enough to allow any progress in these areas of "Application of predictive capacity in terms of climate, weather, disease and production capacity in combination". There is a list of weather based pest and disease models and their use is exemplified by a pest weather calendar for “Gall midge” in rice, shown in Fig 9.

In the calendar, conditions for weather warnings are given together with weekly normal weather conditions for September and October and the mean dates of important epochs of crop growth and pest development. This way, moments for action can be determined. At present sporadic experiments are being conducted at research centres and agricultural universities to further develop and apply weather-based pest and disease forewarning models. It is planned to carry out such experiments in more organized manner at all 127 Agricultural Meteorology Forecasting Units for developing pest and disease weather models for important pests and diseases for major crops.



PEST WEATHER CALENDAR

STATE:KERALA CROP:RICE SEASON : KHARIF
STATION:PATTAMBI PEST:GALL MIDGE

Weather warnings	Max. temp. 0C	>33.3°C(36 wk)								
	Min. temp. 0C									
	Morning RH (%)									
	Afternoon RH (%)	<71.0%(36 wk)								
	Sunshine hours	>7.4hour(36 wk)								
	Total Rainfall (mm)									
Weekly normal weather	Rainfall(mm) total	37.9	33.8	41.5	65.7	47.2	55.2	78.1	61.7	53
	Max. temp. °C	30.1	30.5	30.6	30.5	30.8	31.2	31.5	31.4	31.9
	Min. temp. °C	22.8	22.9	22.9	22.9	22.9	22.9	22.9	22.8	22.7
	Sunshine hours	6.3	6.8	6.3	6.3	6.0	6.3	5.7	6.2	6.7
	Morning RH (%)	94	94	94	94	95	95	95	94	94
	Afternoon RH (%)	70	67	70	67	69	68	68	67	64
Mean dates of important epochs of crop growth and pest development										
Standard weeks		36	37	38	39	40	41	42	43	44
Months		SEPTEMBER				OCTOBER				

Fig 9: A Typical Pest Weather Calendar in India

The major aim for the future is to develop a model of government-organized “Farmer/Climate Field Schools” in which extension intermediaries sit with farmers to discuss risk communications of agro-meteorological services and “what communications should be made and how” to serve them best. The concept of Climate Field Schools is discussed further in section 5.

3.8 – Studies related to Climate Change and Pests, Diseases and Human Health

Reports on a number of secondary aims of this project were presented at the Dhaka workshop (see section 3.2.2). These included:

- Studies on Entomology, Weather and Climate Change at the University of Western Sydney. Effects of climate change considered included climate uncertainty, elevated temperature, elevated CO_2 and combinations of these factors. A large experiment has been established at UWS to examine effects of elevated CO_2 on plant growth, nutrient uptake, and change in plant host susceptibility to arthropod pests and diseases.

- Inputs by UWS to World Health organisation (WHO) studies of the potential impacts of climate change on human diseases such as Diarrhoea, Malaria and protein-energy malnutrition. The APN project has allowed preliminary interaction with India, Cambodia and Bangladesh on these issues, leading to the presentation of a concept paper at the Dhaka workshop by Derry and Huda titled *Climate Change, Agriculture and Health*. In this paper the fragility of the human species to survive extremes of climate when protective economic and infrastructural environment are under threat was outlined, and the resultant need to predict short to medium term climatic extremes, such as flood or drought, emphasised. The WHO approach is to regard both climate and health as trans-boundary phenomena requiring both medium to long-range planning effectively coupled to local environmental preparedness and action, if morbidity and mortality are to be reduced to the lowest possible level. Through the workshop UWS added additional links to its existing network with health agencies in China sustained through its campus-based WHO Collaborating Centre for Environmental Health Development. WHO's interest in this area is underscored by the statement: "Climate-sensitive diseases are among the largest global killers. Diarrhoea, malaria and protein-energy malnutrition alone caused more than 3.3 million deaths globally in 2002" (WHO Fact Sheet No 266 August 2007, WHO, Geneva). Aggravating environmental factors outlined in the paper were the increase in endemic disease susceptibility in malnourished populations where sustainable crop yield was poor, the aggravating effect of particulate pollution on acute respiratory infections where thermal atmospheric inversions and cool katabatic flows coupled to crop burning severely impacted on air quality, and the fact that half of the World's population lives within 60 km of the sea, rendering small changes in ocean level important in terms of cropping considerations and hence local nutritional status. It is hoped that visits to the Centre by Asia-Pacific participants will increase in 2009 leading to exchange of ideas in this area of interest.
- Work carried out by the Australian Cooperative Research Centre for Plant Biosecurity. One study simulated changes in the geographic distribution of plant diseases under a climate change scenario between 1990 and 2070. A second study provides empirical field data on the effect of elevated CO_2 on plant pathogens. A scoping study is studying Wheat Stripe Rust (*Puccinia striiformis*) and Crown Rot (*Fusarium pseudograminerarum*).
- Studies of Effect of Climate Change on Crop Growth, BCKV West Bengal:
  Climate change is one of the major threats to almost all sectors including agriculture during past few decades. In the next decade, the mean temperature in South Asia is projected to increase by 0.3^0C to 0.7^0C, which will affect the growth and yield of different crops including rapeseed and mustard. Keeping this view in mind, a study was carried out to observe the probable impact of climate change on crop performance. To achieve the objective, one crop growth model (namely *Infocrop*) was validated for one of the most popular mustard varieties (B_9). Soil, crop phenology, growth and yield for six years (2001-02 to 2006-07) were collected from secondary sources along with weather data from Kalyani observatory as inputs to the validation exercise. After model validation, it was run for a changed temperature scenario (1^0C and 2^0C temperature rise over the normal) to observe the impact of climate change. It was observed that the yield

decrease in B_9 variety of mustard due to temperature increase by 1^oC (both maximum and minimum) is in the order of 300 kg/ha against the normal value of 1417 kg/ha. If the temperature is increased by 2^oC, the potential yield may be reduced to about 978 kg/ha. The biomass production is also reduced considerably. These decreases may be due to the fact that the crop matures earlier for temperature increase, thus the biomass production declines and ultimately the yield is also reduced. Suitable plant variety, agronomic and other management options must be developed to reduce the yield gap.

4 - Conclusions

The overall aim of the project was to develop regional stakeholder and participant capacity, in terms of a risk management approach, for the control of selected climate-sensitive crop diseases.

The main objectives of the project were to:

1. Develop and adapt predictive models for selected crops and climate-sensitive diseases (late leaf spot in peanut, Sclerotinia rot and Alternaria blight in canola and mustard), integrating existing climate, crop and epidemiological knowledge
2. Evaluate the predictive performance of crop growth and disease models, using existing data as well as generation of new data
3. Identify and evaluate improved crop disease management strategies based on climate information and predictive models
4. Assess information needs and propose communication strategies (e.g., for climatic and disease risk, and disease forecasts, and advisories)
5. Engage appropriate institutions and policy linkages that are in a position to provide support for climate-sensitive crop disease management in each target country

Main outcomes of the project based on these objectives are:

- A network of researchers able and willing to collaborate in research and application in the area of weather-crop-disease modelling and Advisories
- Strengthening of regional collaboration for proactive crop management
- Initiation of a new set of experiments for testing predictions of leafspot disease epidemic and consequences on growth and yield of peanut, to include new efforts to improve model code and structure.
- A system for validation of existing/future models using local index crops (eg; *Cropgro* crop and disease model, *Infocrop*, or simplified user-friendly model versions for local use),
- Generation of data on crop growth and disease occurrence from a set of pilot projects (field trials) in collaborating countries. This process has enabled capacity building in Bangladesh and Cambodia.
- Elucidation of the relationship between data obtained from meteorological stations and microclimatic conditions in nearby crop fields.
- Quantification of the impact of certain diseases on crop yield, and the relationship between weather and disease incidence.
- Involvement of stakeholders and national policy makers in managing the outcomes of the research

5 - Future Directions

At the Dhaka workshop in February 2008, it was agreed that the project group should build on its success in disease management and broaden its sphere of activity to Integrated Crop Management (ICM), including decisions such as fertilizer application, planting, and other agronomic decisions, and its geographic focus to incorporate more countries within the Mekong Basin. To reflect this broadened focus and to aid the integration of disciplines within the project group, we proposed the formation of the CARM (Climate and Agricultural Risk Management) Network. It was also agreed that the network should accommodate a crop-related, population health component in its activities, and to seek funding in this domain.

The CARM Network is pursuing five funding proposals to further its objectives. They are:

1. We have worked with Dr Preap Visarto, our collaborator from Cambodia to prepare relevant documents for a new CAPaBLE proposal entitled "Integrated Climate, Crop, Disease and Pests Modelling for Improved Farm Decision-Making". The CAPaBLE workshop is planned for Phnom Penh in mid-November 2009, and will focus on capacity building for all network members, but particularly those from Bangladesh, Thailand, Cambodia, and Viet Nam. One outcome from this workshop will be a framework for extension of Indian methodologies and modelling expertise to other Asian collaborators. A full proposal for the project has been submitted to APN, and we are awaiting final advice on project funding.
2. If we are successful in obtaining the APN funding, we intend to value-add to the training activity by holding a regional scientific symposium following the CAPaBLE Workshop. The tile of the symposium will be "Climate Risk Management in Rural Communities in Developing Countries of the Asia Pacific Region". The symposium will involve a wider range of scientific interests, and participants from the South Pacific and Indonesia. Activities will include scientific exchange, regional priority setting and preparation of research concept notes. Funding for this activity will be sought through the AusAID International Seminar Support Scheme.
3. An ARCP proposal has been submitted to APN for a research project to start in April 2010. The title of the two-year project is "Identifying the influence of climate change on crop pests and diseases along the Indo-Gangetic Plain". The project will involve Indian and Bangladeshi members of the network collaborating with the Australian Cooperative Research Centre for Plant Biosecurity through its flagship project "investigating the impacts of climate change on plant biosecurity". The project will have a strong Climate Change and Food Security focus.
4. A proposal entitled "Examining the effect of climate change on pest and diseases of major food crops ". This has been submitted to the Australia-India Strategic Research Funding.
5. We are presently preparing a project proposal to be submitted to the Australian-Netherlands Research Collaboration (ANRC) for a workshop entitled "Establishment and Management Policies of Climate Field Classes in Indonesia to face Climate Change". The Workshop will be held at the University of Indonesia (UI) in Jakarta, from 15 till 17 March 2010.

This workshop is the logical follow-up to project activities described in section 3.7. The aim is to examine mechanisms for setting up "Climate Farmer Field Schools" for agronomic risk communications, leading to the establishment of agro-meteorological services for participating farmers. There has been some success in the use of Climate Field Classes for various problems in Indonesia (e.g. rice planting date, in-field water management, coffee plantation surface management). Risk communication strategies should be based on: (i) improved needs assessments; (ii) the related products discussed by others in our present APN project; and (iii) getting rid of the logistical barriers to use of products.

References

Nil

Appendices

Appendix 1: Conferences/Symposia/Workshops

The Project conducted two major workshops and one small workshop on use of *Infocrop* for modeling growth of Mustard. These workshops are described in summary in Section 3.2. References to the two major workshops are:

- Huda, A.K.S., Desai, S; Derry, C.W., Ramakrishna, Y.S. and Spooner-Hart, R.N. 2007. "Climate and Crop Disease Risk Management: An International Initiative in the Asia-Pacific Region" Proceedings of the Scoping Workshop of 6-10 Nov 2006, India: CRIDA. 46p. (ISBN 978-81-904360-1-4).

and

- Coughlan, K.J, Huda, A.K.S., Derry, C.W. and Asaduzzaman, M. 2009. "Climate and Crop Disease Risk Management: An International Initiative in the Asia-Pacific Region" Proceedings of the Project Review and Planning Workshop, 11-14 February 2008, BSF, Dhaka, Bangladesh.

Full reports on these workshops are given in Appendix 4, and these reports contain details such as Agenda/Program (title, date and venue) Participants list (comprising contact details of each participant, including organisation and email address)

A small Mustard Modelling Workshop was held at CRIDA, Hyderabad, India during 21-22 Jun 2008. Participants were Dr S.A. Khan (BCKV, Kalyani, India); Dr Saon Banerjee (BCKV, Kalyani, India); Prof G.A. Fakir (BSF, Bangladesh); Dr C. Chattopadhyay (NRCRM, Bharatpur, India); Dr AVM Subba Rao (CRIDA, Hyderabad, India) and Dr M. Asaduzzaman (BSF, Bangladesh)

The workshop program consisted of:

- Training on the *Infocrop* program, ways and means to run the program, and its features.
- Input data required for the model were identified, entered and converted.
- Processing of multi-location data using *Infocrop* program to estimate the yield under disease-free and blighted condition.
- Presentation of results in MS Excel sheet form
- Preparation of the workshop report.

Contact details for participants are available from the other project reports.

Appendix 2: Funding sources outside the APN

- Australia-India Council
- World Meteorological Organisation
- Participating institutions including University of Western Sydney (UWS), Cambodian Agricultural Research and Development Institute (CARDI), Bangladesh Science Foundation (BSF), Indian Council of Agricultural Research (ICAR)

Appendix 3: Glossary of Terms

AusAID	Australian International Aid Agency
AIC	Australia India Council
AMFU	AgroMet Field Units
ANRC	Australian-Netherlands Research Collaboration
BARI	Bangladesh Agricultural Research Institute
BCKV	Bidhan Chandra Krishi Viswavidyalaya
BSF	Bangladesh Science Foundation
CARDI	Cambodian Agricultural Research and Development Institute
CARM	(Climate and Agricultural Risk Management) Network
CCCDM	Climate and Crop Disease Management Network
CRIDA	Central Research Institute for Dryland Agriculture
IARI	Indian Agricultural Research Institute
ICRISAT	International Crop Research Institute for the Semi-arid Tropics
NABARD	National Bank for Agricultural Research and Development, India
NCMRWF	National Research Centre for Medium Range Weather Forecasting
NRCRM	National Research Centre on Rapeseed-Mustard
IMD	Indian Meteorological Department
SAU	State Agricultural University
TNAU	Tamil Nadu Agricultural University
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
WHO	World Health Organisation
WMO	World Meteorological Organisation

Appendix 4: Workshop Reports and Power Point Slides

Abstracts, Power Point Slides of conference/symposia/workshop presentations
Conference/symposium/workshop reports
This is included in a separte CD.