CROP PROTECTION PROGRAMME

Ecology and management of rice hispa (*Dicladispa armigera*) in Bangladesh

R No 7891 (ZA 0445)

FINAL TECHNICAL REPORT

1 November 2000 – 31 January 2005

Project Leader: Dr. S.T. Murphy

CABI Bioscience (A Division of CAB INTERNATIONAL)
Date FTR completed March 2005

"This publication is an output from a research project funded by the United Kingdom Department for International Development for the benefit of developing countries. The views expressed are not necessarily those of DFID."

Crop Protection Programme, RF7891

EXECUTIVE SUMMARY

The rice hispa, *Dicladispa armigera,* (Colecoptera: Chrysomelidae) is a serious pest of rice in Bangladesh and other rice-growing countries in tropical Asia, in Bangladesh yield losses can be 40-50%. The specific objectives were to: (1) understand the socioeconomic factors associated with the pest, current controls and the natural mortality factors affecting populations of the insect in endemic and outbreak areas; (2) to use this information to develop recommendations for Extension support and farmers to improve the sustainable control of the pest in Bangladesh.

Through socioeconomic studies, it has been confirmed that farmers rate insects as the worst production problem; hispa is only second to stem borer as a constraint. The current IPM efforts by farmers promoted by the Department of Agricultural Extension (DAE) are generally sound and that the DAE IPM training programme for farmers (under the DAE Strengthening Plant Protection Project – SPPS) is providing a good basis for equipping farmers with the right knowledge. In general, insecticides are the most popular tool but there is no evidence of abuse in current use; but mycopseticides might provide an alternative (see below). But the economic basis of some of the cultural controls are questionable (and this ties in with farmer perceptions), so DAE need to factor this in, in the development of the training programme. Farmers have also strongly support current State interventions, e.g. provision of sprayers and sweep nets etc.

The project has provided some new key research information (see outputs 4, 5, 6 and 7) and most of this does have several implications for hispa management.

Studies on historical hispa data have shown good relations between hispa numbers and some abiotic parameters, particularly the previous winter humidity values. It has been agreed that this work should be continued as a priority with the aim of developing better monitoring schemes and also to develop forecasting models.

Surveys have shown that hispa is present throughout most of the lowland rice area at very low incidence and this means that all these areas are probably at risk from locally based outbreaks as well as outbreaks from remote areas; thus greater vigilance is needed in areas *outside* the southern region of Bangladesh – currently assumed to be the winter endemic range. Simple GIS models have been explored to predict hispa risk areas on a more local basis; this is complementary to the forcasting work above.

Other research has indicated the wide range of ages rice that can be used for feeding and also reproduction; it has been confirmed that hispa can reproduce on a number of common weed species. But field observations suggest that the host plant is not a major limiting factor to hispa population growth. IPM training will now highlight the significance of alternative hosts.

Life table studies have shown that insect natural enemies do have an important impact and one species appears to be density dependent. Also the studies confirmed the importance of winter relative humidity and also of river flooding as mortality factors. Thus the need for the conservation of natural enemies takes on significance and needs to be built into IPM training; but the episotic nature of the outbreaks makes

augmentation technologies difficult to implement. But there are good possibilities for the development of a mycopesticide (e.g. based on *Beauvaria bassiana*) and by linking with more advanced research in India. This is only viable alternative to insecticides.

A national workshop consolidated the project outputs into an agreed plan that will build on the current IPM effort in Bangladesh. Actions will be to develop IPM for farmers by factoring in the project results; other actions will be further State level support to IPM through building monitoring and forecasting and developing mycopesticide capability.

CONTENTS

ACRONYMS

AAU	**-**	**Assam Agricultural University (India)**
BRRI -	**-**	**Bangladesh Rice Research Institute**
CABI	**-**	**CAB INTERNATIONAL**
CARE	**-**	**(CARE is an international NGO that focuses on poverty)**
DAE	**-**	**Department of Agricultural Extension (Bangladesh)**
DAE, SPPS	**-**	**Strengthening of Plant Protection Services (DAE project)**
IC	**-**	**Imperial College, University of London, UK.**
IRRI	**-**	**International Rice Research Institute**
NRI	**-**	**Natural Resources Institute, UK.**
PETRA	**-**	**Poverty Elimination Through Rice Research Assistance**

PROJECT STAFF AND ACKNOWLEDGEMENTS

The project activites were undertaken by a coordinated team effort involving the following scientist and extension staff:

CABI

Dr. S.T. Murphy

IC

Dr. J.M. Stonehouse

NRI

Dr. J. Holt
Dr. J. Venn

BRRI

Dr. N.Q. Kamal
Mr. M.F. Rabbi
Mr. P. Sarker
Mr. S. Haque
Dr. D.A. Monsur Choudhury
Mr. M.N. Bari
Mr. M.A. Samad Azad
Mr. M. Mosaddeque Hossain
Ms. S. Nasrin
Dr. D.N.R. Paul

DAE

Mr. Md Hasanul Haque

IRRI

Dr. G. Jahn
D. B. Barrion

Biometric advice was given by Dr. N.R. Paul, Head of BRRI Statistics Division, and by Drs. J. Holt, NRI, and S.T. Murphy, CABI, as these project staff have statistical training.

The project staff would like to acknowledge inputs into the project from a wide range of people, in particular:

Many DAE extension staff working in the Districts of Bangladesh

Technical staff of BRRI

CARE, Bangladesh

IRRI office, Bangladesh

BACKGROUND

1. Researchable Constraint Addressed

Rice production is crucial to the Bangladesh economy. Approximately 75% of the cropped areas and 83% of the total irrigated area are devoted to rice cultivation and an estimated 60-70% of the agricultural labour force is employed in rice production, processing, marketing and its distribution. Rice yields are low and there is much potential for yield gains. The land area available for rice production is declining and large gains in productivity will be needed to sustain domestic production at an adequate level to cope with the annual rate of population growth of approximately 1.7%. Improved techniques for sustainable rice production should increase yields and the returns of resource-poor of farmers while protecting the resource base.

The need for sustainable intensification in production methods presents a considerable challenge as under the current situation, low-input systems may not be able to deliver the required yields increases, while on the other hand high input intensification often lead to cropping systems that are neither sustainable nor stable. This is particularly true for rice agro-systems where intensification through the introduction of high yielding varieties and the use of insecticides has led to widespread rice pest outbreaks and the emergence of secondary pest in South East Asia. These outbreaks are now understood to be induced by the removal of generalist predators from the system through the application of insecticides (Settle *et al,* 1996)

Losses due to insect pests have been identified as one of the key constraints to increasing production in Bangladesh (Alam 1967). The challenge for researchers is to develop, demonstrate and identify appropriate uptake pathways for improved low-input crop protection methods which will increase rice yields, and which are appropriate for resource-poor low-input rice cropping systems.

The rice hispa (*Dicladispa armigera*) (Coleoptera, Chrysomelidae) is an increasingly important outbreak pest in rice cropping systems in Bangladesh and one which appears to be associated with intensification of production. An understanding of its population dynamics, natural mortality factors and socioeconomic aspects of control options will allow the development and adoption appropriate sustainable control measures within the context of an integrated rice pest management strategy in Bangladesh (Karim, 1986).

While this project is focused in Bangladesh, rice hispa as an increasingly important pest in South Asia and China.

2. Demand

In an analysis of rice research priorities in Bangladesh in 1996, rice hispa was identified as one of the key insect pests by agricultural extension officers and farmers; this was in both rainfed and irrigated rice systems (BRRI, pers. comm.). At a CPP/BRRI/IRRI workshop in Bangladesh in April 1999, management of hispa was identified as a priority crop protection topic in Bangladeshi rice systems because management options were either inadequate or unavailable. Rice hispa has a long history of sporadic outbreaks in Bangladesh and India. Estimates suggest a wide variation in yield losses between 10 and 65% (average 20%) in affected areas. In Bangladesh yield losses have been estimated as 40-50% and the problem is intensifying. The reasons for this are poorly understood and there is little information about pest ecology, dispersal and its interaction with natural enemies. Several options for cultural control of pest exist, but the extent to which, these are acceptable and used by farmers is unclear. The socio-economic importance of the pest, and of the control options, require further study.

3. Summary of Previous Research

Socio-economics and contol

The rice hispa is a major pest of rice in Bangladesh and parts of India, Nepal, Myanmar and southern China. It has a long record of sporadic outbreaks in Bangladesh and India. Damage caused by the rice hispa reduces plant height, tiller number, grain per panicle, and ultimately, grain yield. Affected deep-water rice plants become vulnerable to rising flood water level (Karim 1986; Islam 1997, 1999). More recent studies by Haque *et al.* (2000) indicate that under high densities of rice hispa, the leaf growth of younger plants (with greater than 20% leaf damage) is severely retarded. Under such conditions, grain yields in the t. aman are affected but not in the aus. Estimates suggest a wide variation in yield losses between 10 and 65%; with an average of 20% in affected areas (Islam, 1973; Karim 1986; Islam 1999). In Bangladesh yield losses have been estimated as 40-50% (Islam, 1973). The intensity of outbreaks seems to increase following the large-scale adoption of high-yielding rice varieties and their associated production technologies.

Rice hispa attacks all four rice crops: aus (summer rice), transplanted aman (monsoon rice), deepwater rice, and boro (winter rice) in Bangladesh. Sporadic outbreaks of rice hispa occur almost throughout Bangladesh, but large areas have been affected by outbreaks of a higher intensity in the south-western parts of the country in the past. In India, both rice crops, kharif and rabi, are subjected to sporadic outbreaks of *D. armigera* and may be severely attacked (Karim 1986).

Currently rice hispa is principally controlled principally with insecticides. However, a range of cultural control methods have been developed for hispa which address different life stages. Early planting can avoid peaks of oviposition, and the avoidance of early-season fertiliser applications slows population growth. Mechanical removal of the egg stage is possible by cutting off the leaf tips where eggs are laid (Sen, 1921; Alam, 1967; Prakasa Rao, 1977; Rawat *et al*., 1980; Karim, 1986; Khan, 1989). Trapping adults in sweep nets have been shown to reduce damage at high outbreak levels if it is done correctly (CABI 1999). Technical evaluation of these needs to be carried out, but in addition, a socio-economic evaluation of constraints to their adoption will be necessary.

Ecology

Several authors (Karim, 1986, Islam, 1997) have summerized the basic information that has been collected on the life cycle, life history and phenology of the rice hispa. The rice hispa passes through four stages: egg, larva (four instars), pupa and adult. Adult rice hispa feed externally on leaf tissue and the larvae mine into the leaf. Both the adult beetle and larvae damage a rice plant by eating the green tissue of the leaf and severely infested leaves dry up. From a distance, severely damaged fields look burnt. In the intensive rice-cropping areas of Bangladesh and India, the rice hispa can have 6-7 generations. During the crop-free period, the rice hispa can breed on rice ratoons or wild grasses, or diapause as adults. Rice hispa is a highly dispersive species. After emergence, adults mate and often disperse in large numbers. Adult beetles can fly long distances from one crop to another. The flight capacity of the rice hispa has not been determined but there is speculation that it may fly more than 25 km/day (Islam 1999).

There is a general notion, reflected in the literature (e.g. Karim, 1986; Johnsen *et al.*, 1997) that the rice hispa has an endemic winter range on ratoons, wild rice etc. in the southern Districts of Bangladesh; but Johnsen *et al*. (1997) found no evidence that the rice hispa retreats to overwinter on wild rice and other plants in the Sunderbans. Many factors have been reported to influence the incidence and abundance of the rice hispa in rice fields but there is little quantitative data; Johnsen *et al.* (1997), using historical data on hispa abundnace could find no correlation between hispa numbers and major abiotic parameters such as rainfall but the analaysis was very basic. Grasses and weed hosts play a role in the survival of the rice hispa in low numbers during the off-season, and in their initial multiplication at the beginning of the crop season but crops raised early in the season may escape or suffer negligible damage. Continuous, heavy rain has a negative effect on adult feeding and egg laying. Egg hatching and the survival of larvae are greatly affected by moisture and they suffer heavy mortality in dry conditions but on the other hand, high temperatures and high humidity are conductive to the build-up of rice hispa populations (Islam, 1999). Karim (1986) suggested the warmer winter conditions of the south is a principal factor driving outbreaks.

Most workers seem to agree that natural enemies do have a moderate impact on adult rice hispa. There is some evidence that predation by reduviid bugs and spiders is a significant natural mortality (Karim, 1986, Sahu *et al*., 1996), and this might be expected given the role of general predators in suppressing other rice pests like rice leaffolder (De Kraker, 1997) and brown planthopper (Settle, *et al.*, 1996).

With respect to the immature stages of rice hispa, Karim (1986) thought that insect parasitoids play a ‘supressive’ role at low densities of hispa, whereas Johnsen *et al*. (1997) felt that this group of natural enemies is key in the regulation of rice hispa populations. The impact of parasitoids in India and Bangladesh, has been measured as ‘percentage parasitism’, but the estimates have been highly variable; figures range from 9 to 82% (Khan and Murthy, 1954; Sharma and Parshad, 1961; Prakasa Rao, 1977; Karim 1986; Razzaque *et al*., 1989).

Some of the parasitoid natural enemies in Bangladesh included a yet undescribed egg parasitoid (*Trichogramma* sp.) and braconid larval parasitoid, *Scutibracon hispa* and an eulophid *Neochrysocharis* (Dr. A. Polaszek pers. comm.). Studies reported by BRRI (2001) indicate that the larval parasitoids will attack and develop in all larval instars but *S. hispae* prefers later instars and *Neochrysocharis* sp. prefers the younger instars. It is quite likely, based on experience with other trichogrammatid and the leafminer parasitoids, that pesticides will cause disruption of natural control and, if this control is important, resurgence of pest populations will result. Deuteromycete fungi, including *Beauveria bassiana*, have been recorded on rice hispa (Puzari and Hazarika, 1991, 1992) and may be valuable, where augmented, to control adults populations. Prospects for this method, or parasitoid augmentation, require studies on hispa life tables and biology of the natural enemies.

PROJECT PURPOSE

This programme output is: integrated rice pest management strategy implemented in one floodplan area. The specific research objectives of this project were:

1. To develop an understanding of the natural mortality factors affecting the rice hispa in endemic and outbreak areas of rice affected by the pest in Bangladesh, and of the socio-economic factors associated with the pest and its control.
2. To use this information to develop recommendations for extension workers and farmers to improve the sustainable control of the pest in rice cropping systems.

The project purpose was addressed through nine outputs in the original project proposal. The order they are presented in this report is slightly different from the original order as the new order provides a more logical sequence of the different research components. The new order is indicated below; the number in brackets refer to the original output number:

1. (1) Farmer Interviews

2. (2) Economic assessment of the pest and control options

3. (3) The development of socio-economically sound options for control

4. (5 part & 6) Analysis of historical hispa outbreaks and the development of forecasting models

5. (5 part) Studies on the endemic range of rice hispa

6. (4 part) Influence of host plants on rice hispa oviposition and survival

7. (4 part) Field studies on rice hispa survival and mortality

8. (7 &9) Recommendations for IPM technologies

9. (8) Publications

Thus, the general theme of the research programme was as follows:

- A socio-economic evaluation was made of the problem and of the current control methods being used; the latter was conducted at the farmer and institutional levels. The information from the evaluation provided the baseline on which the new research in the project would build, as appropriate.

- Research in the project focused on:

  (1) Understanding the broad patterns of rice hispa distribution, abundance, and survival using historical data and information from current geographical surveys.

(2) Studies of some key factors affecting natality and mortality. The studies took a broad geographical and seasonal approach given the regional nature of the rice hispa problem.

- The implications of the new research for rice hispa control at the farmer and institutional levels - this was addressed through a workshop and through consultations with key institutions. Uptake pathways for the new information were also addressed.

Additional literature, relevant to particular research topics, is mentioned in the relevant sections.

Finally, CARE Bangladesh offered very useful advice during the course of the project but did not actively take part in the project activities (due to a policy change within CARE midway through the project). Their activities were taken on by BRRI.

RESEARCH ACTIVITIES

1. Farmer Perceptions of Hispa and Controls

1.1. Introduction

This work assessed the perception by Bangladeshi farmers of the rice hispa, in terms of particular characteristics:

A – Perception of hispa, relative to other pests and problems - its gravity, characteristics and amenability to controls.

B - What farmers do, and are prepared to do, to combat hispa, and how these may differ from other pests.

C - What dictates choices of different alternative control technologies – their perceived advantages and limitations, as practical, effective and economic - and action thresholds at which controls are brought into use.

D - Views on Government support to the management of hispa and other pests.

1.2. Materials and methods

The work comprised two studies. The first was an informal interview survey, seeking qualitative information to identify characteristics of farmer decision-making - criteria, priorities, rationales etc. It was also intended to pre-test possible questionnaire and other questions, to gauge farmers' readiness to answer them. The second was a formal interview survey using a questionnaire, making use of the findings of the informal survey, to assess in a more formal way farmer reactions to hispa, and the reasons behind the actions taken to combat it.

1.2.1. Informal survey

Talks were in Semi-Structured Interviews (SSIs) in which a basic list of core questions was asked to guide the conversations to answering a few specific questions, but at the same time maximum attention was given to exploiting interesting or unexpected remarks, to allow the exploration of perceptions and opinions on a wide range of relevant topics (Rhoades, 1982). Attention was paid to the reasoning, logic and other thought processes directing perception and behaviour. Farmers were given freedom to talk. Elicitive contrasts (Gladwin and Christina, 1983) were used to explore the perception of pests and control technologies by contrasting them with others. Conversations were recorded in notes and typed up.

The first survey was of farmers met during the insect sampling survey of February-March 2001, which visited 40 sites and entailed conversation with about 100 farmers in the Southern Districts of Khulna and Barisal; the second was of 30 sites in the Northern Districts of Sylhet and Moulvibazar in March 2002; a final validation session was conducted at a group meeting with 17 farmers in Barisal in January 2004.

The core question list comprised the following:-

A - Hispa
- level, nature and impact of damage
- differences from other pests (gravity, attack, controls etc)
- local history and seasonality of attack development
- knowledge of life cycle, biology and overwintering sites

B - Hispa control options
- whether ever tried, and if so with what result
- if tried, reasons why (dis)continued
- if untried, why not
- source of information - whence and what opinion of quality

C - Institutional frameworks
- experience and opinion of Government support activities
- access to and opinion of extension services, NGOs etc
- market provision - pesticides, equipment, sprayers (hired/owned/borrowed)

The readiness of farmers to answer questions for a system of wealth ranking or categorisation, to understand how resources influence actions and to delineate recommendation domains, was also explored. The findings of an earlier nationwide wealth ranking exercise (PETRRA, 2000) are summarised in Appendix 1.1. This found that two important variables were farm size and the number of months in each year the family can subsist on its own harvest before resorting to off-farm work (the Rice Provisioning Ability or RPA). These correlated with other characteristics such as house quality (e.g. use of thatch, tin or cement), access to credit and the hiring out of labour. These two variables were similarly studied in this research, and their validity assessed by the statistical testing of the strength of the association between them. Productive land area was assessed by asking farmers the size of their farmland, asked in "decimals" (0.01 acres), as the standard local unit, the "bigha", varies between places, and given as acres for comparability with other research in Bangladesh, where it is the common unit of measurement. To accommodate differences in the quality of land, the area of plots in full-time private crop production was distinguished from that of other plots - such as flooding (beel) and sharecropped land - and the area of the latter divided by two to reflect its reduced productivity, before all areas were added up to obtain a "Weighted Productive Area" (WPA). Family provisioning was assessed by asking farmers how many months they subsisted on their own harvests, the "Rice Provisioning Ability" (RPA) and this was multiplied by the number of family members to obtain a "Monthly per Capita Provision" (MCP).

1.2.2. Formal survey

The study took the form of a questionnaire survey among 120 farmers in the hispa-prone areas of Sylhet and Moulvibazar districts of Bangladesh, in September and October of 2004. In each district two different upazillas were selected, and in each upazilla 30 respondents were interviewed. The questionnaire was designed after conclusion of the informal survey, and aimed to quantify some of its particular findings. One of these was the perception of hispa as characteristically "lumpy" in the time-distribution of its attacks. Another was, following from this, the preference for controlling it by remedial, threshold-triggered pesticide sprays, instead of more regularly-used, suppressive measures such as "IPM" technologies. Another was, thanks to its perception as arising in widespread and catastrophic "outbreaks", its perceived need for receiving Government assistance for its control. In many of these characteristics hispa was contrasted with the rice stem borer or "masra" - a generic local term for borers such as *Scirpophaga incertulas* and *Sesamia inferens*.

The questionnaire is given in Appendix 1.2. It was divided into the following sections:-

A - Basic descriptors of the farmer and farm, such as wealth and age
B - Ranking and scoring of agricultural production problems
C - Hispa perception as a pest
C1.Cx - Listing of options for hispa management, with criteria for decisions as to their use
D - Masra perception as a pest
D1.Dx - Listing of options for masra management, with criteria for decisions as to their use

Discussion opened without disclosing the interest of the researchers in hispa, in the hope that the ranking of problems would not emphasise this problem to favour the interest of the interviewer. Subsequently, respondents were shown photographs of adult and larval hispa infestation, to confirm the identity of the pest under discussion, as shown in Figure 1.1.

Figure 1.1. Photographs of hispa adult (left) and larval (right) infestation, used for identification in farmer interviews (photos: M Mosaddeque Hossain).

2. Economic Costs and Benefits of Hispa Management Options

2.1. Introduction

This work aimed to analyse and compare the economic costs and benefits of the various hispa management strategy options available at both farm and government levels. The studies at these two levels are treated separately.

2.1.1. Farm-level returns

The objective of this study was to quantify the economic returns at farm level of different hispa management options.

Study of the returns to hispa controls encounters the difficulties that, as a foliage pest, hispa causes damage to yield as an indirect function of infestation or leaf damage, and that as a result the functional relationship connecting infestation, damage and yield is complex and not fully known. The response of yield to hispa damage (and the calculation thereby of economic injury levels) have been studied in the past as follows. Nath and Dutta (1997a,b) found 33.72g/plant with 5% "infestation" (undefined) and 3.50g/plant with 70%, and a linear regression relationship of [Yield=35.2-0.466.Infestation] (or, with an assumed spacing of 8"x6" (32.3 plants/sqm) of [Yield (MT/Ha)=11.37-0.1505.Infestation]). Chatterjee and Bera (1990) found yield in g/sqm in a linear relationship with percentage leaf area damaged of [Yield (MT/Ha)=6.044-0.045.Infestation]. It is not clear how reliable the assumption of a linear relationship between infestation (however measured) and loss may be, however, as the y-intercepts for these two (respectively 11 and 6MT/Ha) are more than the "good yield" values (typically about 4) discussed in Section 1.

Economic injury level has been reported by Nath and Dutta (1997b) as 4 adults/hill in a crop protected to mid-tillering, 2 in a crop protected from maximum tillering. Anon (2003) recommended 5 adults/hill or 5 larvae/tiller or 35% leaf damage over the field. (2004 current BRRI recommendation is 4 adults/hill).

A wide variety of control methods have been assessed against hispa, but overall it has shown itself resilient against many natural and biological methods of control.

Resistance by rice plants has been found at useful but not decisive levels, and has tended to favour traditional varieties rather than the modern hybrids which, as higher yielders, have often been promoted to replace them. Dhaliwal et al (1980) found numbers of damaged leaves per plant significantly less in Basmati and PR476 varieties (respectively 7 and 10) than in PR484, PR274 and PR437 (respectively 13, 13 an6 16). Sontakke and Rath (1998) found leaf damage of 15.9% in a local variety and 32.4% in a hybrid. Budhraja and Rawat (1980b) found varieties differed in their ability to recover from hispa attack after "rescue" by insecticides as (in yield in MT/Ha, respectively unprotected/"rescued"): Anupama 0.9/2.0; Chatri 1.5/2.0; Numgi 1.2/1.8; Ratna 0.7/5.0. Dutta and Hazarika (1994) screened 50 varieties and found none suffered less than 10% damaged leaves (the best being 13% and the worst 100%). Dhaliwal (1980) found none resistant among 334 cultivars tested. Chand and Tomar

(1984) screened 64 cultivars and found none with less than 20% damage and most over 50%. Shajahan and Taludker (1995) examined the effects on two rice varieties of four pests, with the results in Table 2.1: it appeared the two varieties differed in vulnerability to hispa less than that to the other pests. There is little current evidence that plant resistance does or will play more than a helpful minor role in hispa management.

Table 2.1. Infestation of two varieties of paddy rice by four pests - hispa, the stem borers ("masra") Scirpophaga incertulas and Sesamia inferens, green leafhopper (GLH) Nephotettix spp. and rice swarming caterpillar (RSC) Spodoptera litura (Shajahan and Taludker, 1995), with means and the ratio between the two varieties calculated from the data (masra data as percentage of dead hearts, for other pests data are numbers caught in ten sweepnet strokes).

Variety	DAT	Hispa	Masra	GLH	RSC
	30	2.1	1.5	53	8.6
(A) Nizersail	50	6.8	3.8	99	19.3
	Mean	4.45	2.65	76	13.95
	30	1.6	0.9	33	8.4
(B) IR20	50	7.4	2.8	101	26.6
	Mean	4.5	1.85	67	17.5
Ratio A/B		0.99	1.43	1.13	0.80

Predators and parasitoids have not been reported as significantly reducing hispa populations (see literature review in this report). Rao (1964) found very few parasitoids on hispa, in comparison with "very large numbers" on stemborer. Khan and Murthy (1954) found one instance of 82% parasitism by a '*Bracon'* species. A study of predation on paddy pests by fish, mostly Nile tilapia and common carp (Deka et al., 1994), confirmed they consumed weeds, algae and some insect pests but did not have much impact on hispa or leaf-folder, as indicated in Table 2.2. It is thought that natural enemies will play only a minor role in hispa management, although the need to consider the safety of natural enemies of masra is implied.

Table 2.2. Numbers of pests, as counts per hill (and scoring "<1" for "negligible"), with and without Nile tilapia and common carp, among two varieties ("Ahu" and "Sali") of paddy rice (Deka et al., 1994).

	Hispa		Masra		Case-Worm		Leaf-Folder	
Fish	Ahu	Sali	Ahu	Sali	Ahu	Sali	Ahu	Sali
Absent	5-7	<1	-	8-16	3-4	<1	2-9	3-4
Present	3-8	-	0	0	0	0	7-30	<1

No hispa pheromones or lures have been found with a useful level of attraction (Deka and Hazarika, 1998).

Leafclipping, alongside sweepnetting the principal nonpesticidal recommended hispa control, was evaluated by Rawat *et al.* (1980) with the results summarised in Table 2.3. This indicates a substantial level of protection.

Table 2.3. Effects of clipping of rice leaves for hispa protection, as infestation and effects on unprotected plots and those cut 30cm from tips at 34DAT (Rawat et al., 1980; N=10). The percentage increase attributable to clipping was (2.14-1.47)/1.47x100=45%.

Data	Unclipped	Clipped
Hispa adults/hill	7.5	5.0
% damaged leaves	100	89
Yield (MT/Ha)	1.47	2.14

Chemical insecticides have been widely and successfully evaluated against hispa. Budhraja *et al.* (1980) found all granular insecticides obtained positive economic returns in controlling hispa, with Carbofuran (obtaining a yield of 2.3MT/Ha), Thiodemeton (obtaining 2.2MT/Ha), Quinalphos (2.0MT/Ha), Phorate (2.0) and Disulfoton (1.9) all obtaining significantly higher yields than an unprotected crop (1.4). Subbratnam and Perraju (1976) found all tested granule and spray insecticides effective and without causing damage, and Biswas and Mandal (1992) obtained satisfactory control with phosphamidon, chlorpyriphos, endosulfan, quinalphos and monocrotophos. Nath and Dutta (1997a,b) evaluated the returns to control of hispa by one, two or three monocrotophos sprays, with the results summarised in Table 2.4, indicating percentage increases in yield obtained of, respectively, 5, 31 and 38%.

Table 2.4. Responses of a paddy crop to hispa control by one, two and three fortnightly sprays of monocrotophos 36WSC at 0.07%, after 30DAT (N=4) (Nath and Dutta, 1997).

Sprays	0	1	2	3
Panicles/hill	7	10	11	12
Spikelets/panicle	418	445	515	685
Yield/plant (g)	9.5	10.2	13.2	14.1
Yield (MT/Ha)	1.81	1.90	2.38	2.50

The entomopathogenic fungus *Beauvaria bassiana* has been reported as effective in the laboratory (Hazarika and Puzari, 1995) and superior to neem oil and equivalent to monocrotophos in field trials (Hazarika and Puzari, 1997). It offers opportunities for mass-rearing (Mazumder *et al*, 1995), but Bangladeshi assessments have not yet shown clear promise.

The most widely-used nonpesticidal “IPM” technique used against hispa is sweepnetting. This study of the literature found no published quantification of the effects of sweepnetting on hispa populations and loss.

This study assessed the reduction in hispa infestation and loss attributable to control by the two methods most widely used by Bangladeshi farmers – insecticide cover sprays and sweepnetting.

2.1.2. Government-level returns

The main options open to the State for hispa management assistance are training, the donation of sweepnets to farmers, the bounty offered for adult hispa collected during outbreaks, the provision of subsidised pesticide assistance in the form of donated insecticide and sprayers used by locally-recruited sprayteams, and aerial sprays. There has been no formal cost-benefit assessment of these, as the mix has been developed by evolving to the satisfaction of stakeholders. This section considers the possible cost/benefit returns to some of these options.

2.2. Materials and methods

2.2.1. Farm-level returns

Sweepnetting and cover sprays of insecticide were assessed in farmers' rice fields in 2004. Farm plots were selected and access negotiated, and each was divided into three – an unprotected area (as small as possible), an area sweepnetted against hispa adults, and an area sprayed with insecticide – in a complete randomised block design with each farm serving as a block. Sweepnet and insecticide applications followed local practice, and were carried out at frequencies and times at the discretion of the local DAE block supervisor. Host farmers were assured that if a heavy infestation developed the entire plot would be sprayed. Assessment of the effects of controls was by two methods.

The first of these was the quantification of yields and economic inputs and outputs, by the local DAE staff in conversation with the farmer. A one-page data sheet was developed for DAE staff to use, listing the values to be collected in terms of numbers of control operations, costs of insecticide and other inputs, yields and prices for each of the three treatments on each plot. Data were gathered per plot, and converted to values per unit area of a hectare. Returns to control were calculated as the per-unit-area yield in each controlled plot, minus the per-unit-area yield in the uncontrolled plot, multiplied by a price value obtained from the farmer. Chemical costs were asked directly. Labour inputs were costed at the local rate, including the calculation of notional costs for those farms using family labour. Similarly, sprayer hire costs per spray were calculated as the number of man-days per spray per hectare, multiplied by the daily hire cost of the sprayer, even for those farmers who owned sprayers. Costs of labour, chemical and sprayer were converted from per-operation to per-harvest by multiplication by the number of operations. The data sheet for DAE colleagues was accompanied by an exemplar sheet filled in with fictitious values as a dummy, to illustrate how data were to be entered, to facilitate their task, and this is reproduced in Appendix 2.1. It was accompanied by a one-page briefing document, also reproduced in Appendix 2.1, explaining the experiment's purpose, aims and methodology, and setting out precisely the Project's undertakings to host farmers to compensate losses and/or permit spraying of the entire plot, to ensure their crops would not suffer in a heavy attack.

The second assessment was as the quantification of production and pest infestation, undertaken by BRRI staff visiting the field plots at intervals. Data were gathered with the aid of a visual scoring card to simplify and facilitate the gathering of infestation data as visual estimates, reproduced as Figure 2.1, and on a standard one-page data sheet. A copy of this data sheet was also provided filled in with dummy values to illustrate how to fill it in, and a copy of this is given in Appendix 2.1. In each plot, data were recorded on twenty hills, using a suite of estimation methods aimed to be carried out quickly and simply while standing in the field.

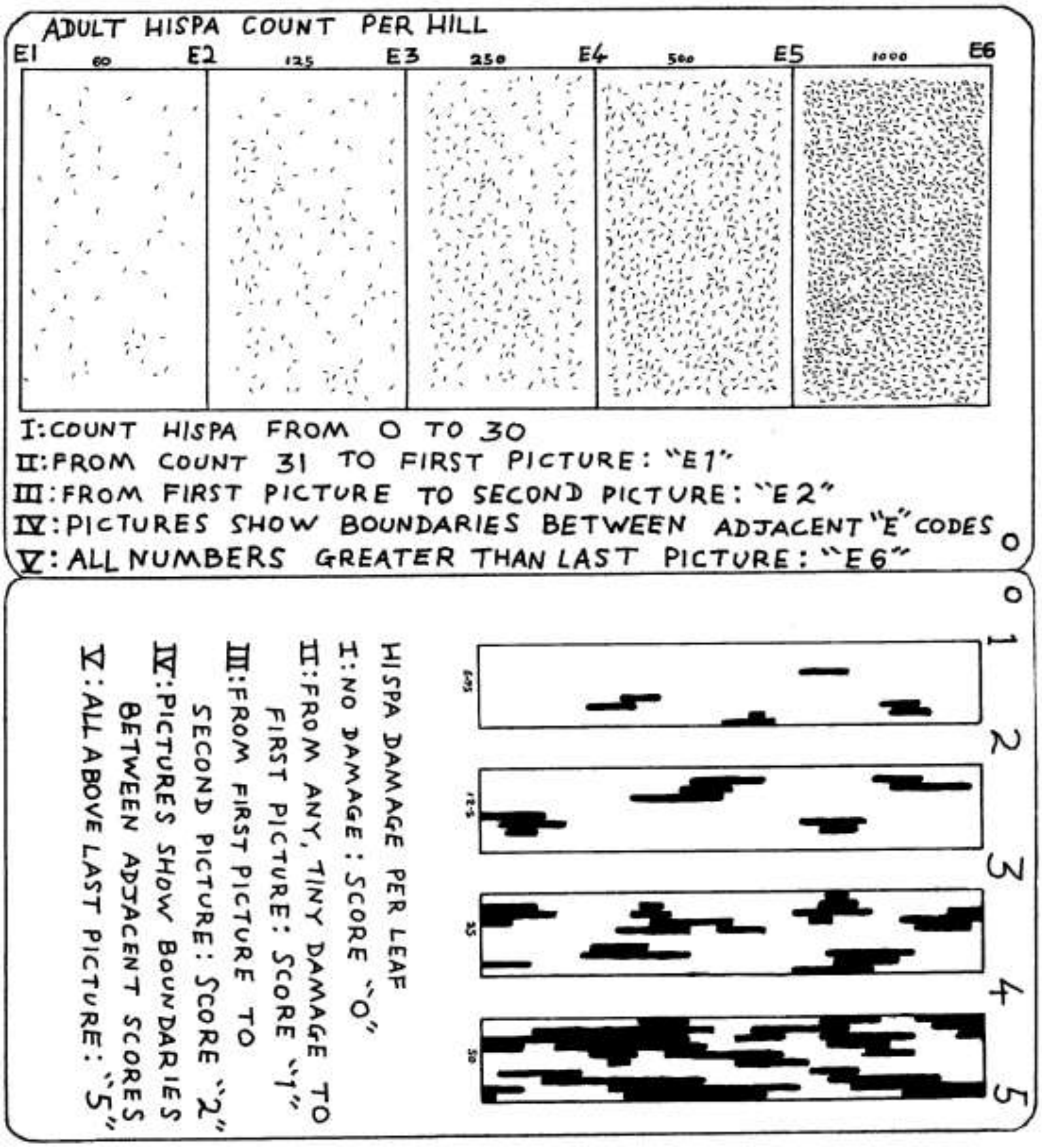


Figure 2.1. Visual comparison card developed for the scoring estimation of hispa infestation.

i. First, counts were made of hispa adults and brown planthoppers (BPH) on the hill (taken first as adults may move away on seeing the investigator). Insects were counted up to a maximum of thirty and then, if numbering more than this, estimated with reference to the card.
ii. Second, counts were made of the tillers on the hill, and of those which contained dead hearts or white heads (to allow fractional destruction of tillers by stemborers to be calculated directly).
iii. Third, the median growth stage of rice plants on the hill was recorded.
iv. Fourth, the number of leaves per tiller was counted on three tillers.
v. Finally, the percentage of leaf damage by hispa was estimated on eight leaves, assessed visually by reference to the card.

Visual scoring categories for the card were selected as increasing exponentially, because scales of intensity, as pictures, when sorted into categories which appear natural to the eye, are typically on an exponential scale, according to the Weber-

Fechner law of the logarithmic relationship of visual perception to stimulus intensity (Horsfall and Barrett, 1945). As the classes rose on an exponential scale, each datum was converted to a percentage as the geometric mean of the upper and lower limits of its class. Assigning a test estimate to a category using a visual key is typically easier when the key shows not the central value in an assignment class but the border between each class and its neighbours (Stonehouse, 1994). Adults were counted up to a maximum of 30 per hill, and then estimated by reference to the card, with the scores and intervals in Table 2.5. Leaf damage scores were therefore awarded as "0" for no infestation, and then with the scores and intervals in Table 2.6.

Table 2.5. Scores used for the visual assessment of adult hispa numbers, with the upper and lower limits of each from the pictorial card shown in Figure 2.1, and the mean value used in conversion of scores to adult count data.

Score	Count	1	2	3	4	5	6
Lower limit	0	31	61	126	251	501	1001
Upper limit	30	60	125	250	500	1000	Inf.
Value	Number	43	87	175	352	710	1432

Table 2.6. Scores used for the visual assessment of hispa damage, with the upper and lower limits of each from the pictorial card shown in Figure 2.1, and the mean value used in conversion of scores to percentage leaf area loss data.

Score	0	1	2	3	4	5
Lower limit	0	0	6.75	12.5	25	50
Upper limit	0	6.75	12.5	25	50	100
Value	0.0	4.6	9.2	17.7	35.4	70.7

The estimate of the percentage of leaf loss (v), allowed the comparison of hispa control methods; additionally, the percentage of leaf not lost (1-v), multiplied by the number of leaves per tiller (iv) and number of tillers per hill (ii) allowed the estimation of the area of photosynthetic leaf per unit area (assuming valid estimates of (a) the area of an individual leaf and (b) the number of tillers per unit area) for comparison with records of information of eventual crop yield.

Working in flooded paddy fields, data recording was most conveniently done by assessors working in pairs, with one in the field calling out estimates to be recorded by the other on data sheets or a laptop computer (computer entry of the data later on was also more efficiently done by pairs, one reading the numbers out and checking entries as the other typed them in). Visual impressions of coverage in relation to keys are notoriously inaccurate and prone to bias (Courshee and Ireson, 1961; Kranz, 1988; Lindow, 1983; Sherwood et al., 1983; Stonehouse, 1994) and so the assessment of different treatment plots was not assigned to separate assessors, but all treatment plots in one block were assessed by the same assessor (so that differences between assessors were subsumed into between-blocks variance) or, when assessors worked in pairs, each did half of each treatment plot, swapping roles after ten of the twenty hills.

2.2.6. Government-level returns

Information regarding costs of options were obtained from informants at the Government Ministry of Agriculture Department of Agricultureal Extensioon (DAE), and from literature issued by the DAE/DANIDA SPPS project.

Return data were taken from the farm-level trial, the literature, and the estimates and opinions of farmers as the responses to the formal survey.

3. Options for Institutional Frameworks for Implementing Hispa Control

3.1. Introduction

This work assessed the options available to the Government of Bangladesh and other agents for the management of rice hispa. It comprised two components.

The first was a study of newspaper reports of pest outbreaks in Bangladesh rice, to assess the perception and pressure from the media and public opinion in terms of pest outbreaks and expectation of action from Government and other agencies. It also assessed how perceptions of hispa and other pests by the media may differ from, or resemble, those by farmers and policy-makers.

The second was an interview study, composed of conversations with policy-makers, Government workers, NGOs and others. This study aimed to provide a qualitative assessment of the options available for Government policy and action to support the management of hispa.

3.2. Material and methods

3.2.1. Newspaper study

A collection was made of articles mentioning insect pests of rice, in eight different publications going from 2004 back to 1997 inclusive. Newspapers searched were all national dailies, as follows.

- A: Bangla-language
    - *Daily Prothomalo*
    - *Daily Jugantor*
    - *Daily Ittefaque*
    - *Daily Inquilab*
    - *Daily Dinkal*
- B: English-language
    - *Daily Star*
    - *Bangladesh Observer*
    - *Independent*

Bangla-language reports were translated into English. The reports were collated by date and language, and assessed for content, tone and alignment with a particular policy position.

3.2.2. Interview study

Semi-structured interviews were conducted with a wide range of institutions dealing with hispa, including Government agency offices both centrally and in the provinces, international institutions in Bangladesh and the UK, and NGOs and cooperatives dealing with farmers and their problems.

Use was also made of the farmer interviews presented and discussed elsewhere.

4. Analysis of Historical Hispa Data and the Development of Forecasting Models

The following activities were covened in this component

- Gathering and preliminary analysis of existing DAE survey data on hispa pest status and distribution
- Analysis of the historical data
- Development of a population model of rice hispa

Along with those for a variety of other rice pests, records of rice hispa abundance have been collected over a number of years by the DAE in Bangladesh. Records exist on a district by district basis, and sometimes also for the within-district administrative units, upazillas.

A number of approaches were taken to the analysis and modelling of those data which could be accessed during the lifetime of the project. The objective of these analyses was to look for relationships which could provide explanation or prediction of hispa population dynamics and so the occurrence of outbreaks. In addition, protocols were put in place to computerize future data collection as well as the backlog of paper records.

The description of the work has been divided into the following, each contributing several project activities:

- Patterns of hispa abundance were first investigated in a data set comprising 18 of the districts in Bangladesh thought to be most hispa-prone (All activities).
- Cropping pattern was then examined on a country-wide basis to search for any associations between the geography of hispa abundance and the variations in cropping pattern found around the country
- Within-season hispa population dynamics were examined in 10 districts with a view to within-season forecasting
- Relationships between hispa abundance and environmental variables were examined, chiefly relative humidity and temperature. Models based on both humidity and temperature were developed and district differences in humidity were compared with those of hispa
- Protocols for current and future data collection were established and implemented

5. Studies on the Endemic Range of the Rice Hispa

5.1. Introduction

In the literature (e.g. Karim, 1986), the rice hispa is reported as endemic to Bangladesh, particularly the southwestern tidal wetland areas. Johnsen *et al*., (1997) disproved the notion widely held at that time that the rice hispa over winters on wild rice and other plants in the Sunderbans. Through surveys they found the rice hispa to be widely distributed in the southern districts in the winter months (November – January); here they survive on rice ratoons after the harvest of tidal wetland rice. Nonetheless, it is an insect with a strong dispersal capacity (Islam, 1997), and in December and January it concentrates on newly planted boro rice in the endemic area, where it multiplies (Johnsen *et al*. 1997). Later, adult hispa migrate to attack late - planted modern variety boro.

Despite the dispersal behavior of the insect, a question remains about the true extent of the endemic distribution (i.e. the winter distribution). Surveys by BRRI in the early 2000s revealed that the rice hispa can appear at any time in any part of Bangladesh; currently the north eastern part is more prone to rice hispa incidence while southern districts have been relatively unaffected.

The purpose of the studies here was to determine more precisely the geographical range of the rice hispa during the main rice growing seasons. Of particular interest was the question of what areas is the rice present the year round and reproducing? The data collected for one division, Sylhet, was also used to develop a GIS model to predict the range of hispa on a more local scale.

Here, the rice seasons are defined as: “Boro” (November-June), “Aus” (March-August), “Deepwater Rice” (March-December) and “Transplant Aman” (July-January)..

5.2. Methods and materials

Quantitative surveys were made for the rice hispa in the southeast, central and northern regions of Bangladesh in the Boro, Aus and T. aman seasons during 2002 – 2003. However, as it is already known that the rice hispa does over winter in the south, the main concentration of the survey effort was made in the central and northern regions.

5.2.1 Sampling units and their selection

Sampling units (= sites) were parts of rice fields and other habitats, approximately 0.5 ha in size. The vast majority of units were, however, located in rice fields. The units were located the main rice growing Districts of the south, and central/northeast regions (the northeast region equates to Sylhet Division). To select the sampling units, each of districts in these regions was divided into strata, based on the length of Kharif growing period. Units were then chosen at random along the main roads and tracks of each strata; in general, and where possible, proportional sampling was used, i.e., the larger the size of the strata within a district, the greater the number of units chosen. To choose sites at random, maps were used and distances along access roads chosen at random. The geographical coordinates of each site were taken with a GPS unit. Each survey in each season took approximately two weeks to complete. It should be noted that during the practical running of the survey, some sites could not be reached as they were inaccessible (deep water - especially during the monsoon period, no tracks etc.), so other sites were chosen close by. The number of units sampled during the rice seasons of 2002-03 is shown in table 5.1; the data is displayed as the number of sites per administrative District.

5.2.2. Sampling procedure within a unit

The different developmental stages of rice hispa (egg, larva, pupa and adult) were recorded from a unit as follows:

Sweep net collection: From each site 20 complete sweeps were taken at random from the vegetation, e.g. rice, wheat, weeds etc. Then,

Scouting (visual) counts: A 30-minute scouting was done in each unit to record the number of rice hispa adult, egg, larva, and pupa and damaged leaves. The surveyor walked a ‘zig-zag’ path from one side of the unit to the other and covering the entire length of the site. The total numbers of each stage for each unit were recorded for both methods.

5.2.3. Prediction of rice hispa spatial incidence using GIS interpolation

The data from the northeastern districts of Sylhet Division (Sylhet, Moulvibazar, Habiganj and Brahmanbaria) was used to produce maps showing the spatial incidence of the rice hispa for the whole survey period. To do this, the data for different rice hispa stages (the numbers for all sites were added together for each district and rice season) were categorized in the following scales**:**

Scale	Hispa number
0 (None)	0
1 (Very low)	<100
2 (Low)	101-500
3 (Medium)	501-1000
4 (High)	1001-1500
5 (Very high)	>1500

The transformed data were then interpolated in a GIS system (ArcInfo) at BRRI, Gazipur (by the Division of Agricultural Statistics) to produce maps of rice hispa incidence.

Table 5.1. Number of sites (units) surveyed in different seasons at different parts of Bangladesh during 2002-2003.

Districts	**Boro**		**Aus**		**T. Aman**
	2002	2003	2002	2003	2003
Northeast region					
Sylhet	18	12	15	18	12
Moulvibazar	21	15	14	15	7
Habiganj	17	19	13	18	8
Sunamganj	5	7	2	1	2
Central region					
Brahmanbaria	5	2	5	-	-
Narshingdi	1	1	1	4	-
Gazipur	1	1	15	1	-
South region					
Barisal	25	19	17	-	11
Bhola	18	9	18	-	18
Pirojpur	15	12	14	-	11
Jhalokathi	6	3	9	-	12
Borguna	5	-	5	-	-
Bagerhat	12	-	12	-	-
Khulna	7	-	8	-	-
Satkhira	12	-	13	-	-
Patuakhali	13	-	8	-	-
Madaripur	3	-	3	-	-
Faridpur	-	-	1	-	-
Total	184	100	173	56	81
Total sites surveyed	594				

6. Influence of Host Plants on Adult Rice Hispa Settlement, Feeding, Oviposition and Survival

6.1. Introduction

The quality of the host plant influences the feeding behaviour of phytophagus insects (see Heinrichs, 1988 and papers therein). As a result the survival and movement of these insects (particularly adults) are affected to a large extent. Equally importantly, the quality of the food also influences egg production and oviposition in this group of insects. For example, the fecundity of some insects is usually reduced with the ageing of the host plant. Most of the rice currently grown in Bangladesh is susceptible to attack from the rice hispa, whether or not there is a yield loss component resulting from the attack. The extent to which the standing crop of rice at any one time might act as a limiting factor to the colonisation and growth of rice hispa populations is largely unknown. Previous work by Islam (1997) shows that the rice hispa 'infestations' can be found on rice from 25- 85 days old but it is not clear what stages of hispa were recorded, whether they feeding, or whether the hispa was reproducing on all ages of the plant?

The application of fertilizers to cultivated plants will lead to a change in the chemical composition of the plants and this may influence feeding and reproductive behaviour in phytophagus insects. For example, the application of general fertilizers has reported to increase pre-imaginal mortality in some insect pests and to a reduction in size and fecundity of the survivors (Johansson, 1964). But in the case of the rice hispa, infestation levels in rice fields was found to increase with increasing nitrogen doses up to 120 kg/ha (Dhaliwal et al., 1980). Nitrogen, being the main component of amino acids, is reported to facilitate the reproductive success of many plant feeding insects.

Finally, t is reported in the literature that the rice hispa can feed on feed and lay eggs on a number of wild grasses that grow in rice fields; it also shows the same behaviour on cultivated wheat. But previous work by BRRI (in a study of seven common grass species) has shown that the hispa cannot complete its life cycle on any of the species (Islam, 1997 provides a review of the previous work). Nonetheless, this earlier work does show that some species of wild grasses and wheat may provide nutrients to a developing hispa adult population. Islam (1997) did report, however, that a worker in India (Acharya in 1967) had reported that the hispa could complete its life cycle (with similar development times to rice) on the grass, Paspalum sanguinale. In addition, recent surveys by BRRI, particularly in the northeastern region, have revealed that the immature stages of hispa can be found on a number of (then) unidentified grasses; raising the question again of what the host range of the hispa might be?

Thus, the studies reported here were designed to examine adult rice hispa settlement, feeding and oviposition (and in some cases, survival of the immature stages) in relation to:

- different ages of rice plants;
- different levels of fertilizer applications to rice plants; and
- different weed species that commonly grow throughout large areas of the lowland rice growing region of Bangladesh.

6.2 Materials and methods

6.2.1. Rice plant age

Experiments were conducted to provide a choice and in a no - choice situation for the rice hispa adults. In the choice method, potted rice plants (variety BR3 which is commonly grown in Bangladesh) 40, 55, 70, 85, 100, 115, 130 and 145d old (all transplanted at 25 days) were arranged in a circular fashion, approximately 0.5 m apart, and covered by a mosquito net (figure 6.1). Adult hispa beetles of uniform age were released in the center of the cage at a rate of three pairs per pot (all at the same time) and left for four days; this cage design was replicated 10 times. Adult settlement was scored after two days and adult feeding (area of rice leaves grazed) and the number of eggs laid per age of plant was scored after four days.

In the no - choice study, the same rice variety and ages of seedlings were used for the main experiment. Five pairs of hispa were confined to each seedling for two days using transparent mylar cages (figure 6.2); each age of seedling was replicated six times using a completely randomized design. The same data as above was scored at the end of the experiment but in addition, the survival of the different stages was also recorded. The experiments were conducted at the BRRI Research Station, Gazipur, in an open area next to a nethouse insectary.

6.2.2. Fertilizer

In this experiment, six doses of urea fertilizer (0, 0.25, 0.5, 1.0, 2.0 and 4.0 g N/Kg soil) were applied separately to individual potted rice plants (variety BR3) aged 40 days old. These doses represented 0, 45, 90, 180, 360 and 720 kg urea/ha. The doses of urea were incorporated with the pot soil (known to be low in nitrogen) in the form of a water solution.

Each of the potted plants were then infested with three pairs of adult hispa beetles when the plants were about 70 days old and the insects were confined by transparent mylar cages for 48 hours. Feeding, oviposition and the development and survival of the immature stages were observed for each treatment and percent egg hatch, grub, pupa and adult formation was recorded. Each pot was considered as a replication and the experiment was conducted in a completely randomoized design in the field with three replications; the study was done at BRRI, Gazipur.

6.2.3. Different weed species

Two types of alternative hosts were studied:

Rice field weeds that are common throughout most of the lowland rice growing area: *Echinochloa crusgalli*, *Eleusine indica*, *Digitaria sangguinalis, Hymenachne acutigluma* and *Hymenachne* sp.*;* the last two tend to be found in semi-aquatic environments.

Weeds that were recorded in the northeastern region during the BRRI surveys (see Output 5) and that were mostly growing in semi-aquatic situations. BRRI was not able to identify these during the main part of the project but a report on partial identifications has recently been sent by Dr T A Cope, the Herbarium, Royal Botanic Gardens, Kew, London which gives some information. Further collections will need to be made to obtain specimens in flower. The species are: Tamabil weed (no ID yet), *Hygroryza aristata*, *Hymenachne acutigluma*, Dhirasram narrow (no ID yet), Sylhet weed (no ID yet), *Echinochloa* sp., *Oryza* sp. It will be seen that the third species is the same as that in the first list.

The two groups of weeds were subjects of separate studies but both studies included cultivated rice, variety BR3; the rice used was about 70 days old (from planting). Some observations were made on the rice field weeds in a 'choice' situation and these are reported below. But the main studies for this group focussed on a no – choice experiment to record rice hispa feeding, oviposition and immature stage development/survival. For each group of weeds, individual plants (at about the same growth stage) were planted in earthen pot of 10 cm diameter. Each pot was then covered by iron cage covered with nylon net and was considered as a replication. Three pairs of adult hispa beetles (of uniform age) were released on each plant and the parameters list above were recorded 48 hours after the release of the beetles. The trials were conducted in a completely randomized design with 10 replications.

For the weeds from the northeastern region, both choice and no-choice experiments were conducted. The experimental set up was the same as that described above for the rice age (and the rice field weed work); ten replications were used for both situations.

All the experiments were conducted at BRRI Gazipur, in an open area.

6.2.4. Analysis of the data

The choice experiments were analysed qualitatively but non-parametric statistical methods will be explored for publication of the work. Where appropriate, the no-choice experiments were analysed using one-way ANOVA and Chi – squared tests.

Figure 6.1. Choice experiment, BRRI, Gazipur (photo, BRRI)

Figure 6.2. No-Choice experiment, BRRI, Gazipur (photo, BRRI)

7. Field Studies on Rice Hispa Survival and Mortality

7.1. Introduction

In this section we report on some ecological studies that were conducted to characterise the survival of immature stages of rice hispa in the field and to identify significant mortality factors that influence the survival of the stages. The influence of the host plant species on adult rice hispa settlement and oviposition and survival of immature stages were covered in the previous output.

The studies were designed to complement the historical data analyses reported earlier (output 4). The main purposes were to identify any geographical or seasonal differences in mortality factors that might operate within the endemic range of the insect and/or in rice hispa population 'non-outbreak' versus 'outbreak' situations. Of special interest in these studies was the influence of relative humidity (RH) (because of the findings described earlier), flooding and natural enemies, especially insect parasitoids. Although there are several reports in the literature on the parasitoids of rice hispa (see literature review), it is still not clear what the primary parasitoids are and whether there are any major geographical differences in the species community. There are also conflicting opinions in the literature about the importance of natural enemies, particularly parasitoids. The implications of the studies for the management of rice hispa are discussed at the end.

Thus, more precisely, the objectives of the studies were as follows:

- to characterise schedules of survival and mortality (i.e. the components of overall generational mortality) of rice hispa geographically and seasonally: in endemic versus non-endemic ranges of rice hispa; and in non-outbreak versus outbreak situations.
- to identify significant mortality factors (biotic and abiotic) acting on the immature stages of rice hispa and how the impact of these might vary throughout the endemic range of the rice hispa.

However, the concept of endemic and non-endemic areas was abandoned mid-way through the project because of the survey results (see output 5) indicated that the rice hispa is endemic throughout much of the lowland rice growing area of Bangladesh.

The original study design was to construct life tables (Southwood, 1978) by sampling natural field populations. This was not possible in most hispa - prone areas because of the low incidence of the insect during the course of the project (see output 5). Instead cohorts of rice hispa eggs were used – i.e., the placement of synchronised populations in the field during the different rice seasons to monitor their development. This technique allowed the construction of single generation life tables. Values of survival from these tables were then used to determine geographical and seasonal patterns, and to determine relationships with major abiotic and biotic factors. Two basic designs were used to determine these relationships: 'with and without' a particular factor and/or correlation analysis.

7.2. Study design and methods

The following studies and field trial designs were conducted:

- Geographical and rice season patterns of rice hispa survival: life table survival and other parameters were measured in all main rice seasons (boro, aus and t. aman.) in the south (Barisal District, 2002, 03, 04), centre (Gazipur District, 2002, 03) and northeast (Habiganj District, 2004), i.e. throughout the endemic range of the hispa. This study also allowed a comparison to be made of population 'non-outbreak' versus 'outbreak' conditions as a series of small outbreaks had been recorded throughout the northeast region during the period of the project.
- Relation of survival rates to ambient RH and flooding from rivers: the objectives were to determine if overall survival rates were limited by ambient minimum RH values, and if the natural flooding of rice can affect the survival of hispa.
- The natural enemy community attacking immature hispa and the relation of rice hispa survival to parasitism: the objectives were to characterise geographically the natural enemy community of rice hispa immature stages and to determine the impact of the main species. The emphasis was on parasitoids as previous work by BRRI has highlighted the possible importance of this group of natural enemies
- Crop diversity study: the objective was to determine if rice hispa survival rates are different in rice mono – cultures versus rice grown in mixed crop situations. Factors that might influence are differences in natural enemy activity or micro - climate.

7.2.1. Establishment of rice hispa cohorts

Cultures of rice hispa were established in small net house insectaries (with ambient temperature and relative humidity conditions) at BRRI field stations at Barisal and Gazipur; the insectary at Barisal had to be constructed especially for the project. A pair of young adults were confined, using a cylindrical net cage, for 3 days on a rice plant, generally 40-45 DAT (i.e. 65 – 70 day old rice); this was mostly done on rice growing in field plots but in in Barisal in 2002 insectary potted rice plants were used and then transferred to the field. The procedure was replicated to include 10 –50 plants. At the end of the 3 days the adults and the cage were removed and these were then used to generate another cohort; in general, two to three successive cohorts were set up for each trial to create a total cohort of reasonable size (i.e. the eggs from each cohort and study were added together for the analyses). A daily census was made of each cohort and the numbers of each stage recorded. Efforts were made to standardise methods between sites and in this context technical staff were moved between BRRI Regional Research Stations to develop experience. Also, a qualitative assessment was made of the census technique to ensure that the census itself did not cause any significant mortality – which it did not.

The field plot sites in all three regions were approximately 1000 m^2 and set up at the BRRI Regional Research Stations. The field plot in Barisal was exposed to the regular seasonal flooding from the river systems that exist in the south. The rice varieties used for the studies depended on the rice season but all were known to be susceptible to rice hispa attack. The varieties included: BBRI dhan 28/29, BRRI 3 (boro); BRRI dhan 27 (aus); and BRRI dhan 32 (t. aman). The eggs, larvae and pupae were then counted and assessed each day to measure the survival/mortality of the stages of the rice hispa.

7.2.2.Measures of relative humidity (RH)

Daily measures of RH (maximum and minimum) were taken from the BRRI Regional Research Station meteorological departments.

7.2.3.Natural enemy community and parasitoid attack rates

Parasitoid species and parasitism rates were measured by using the 'trap plant' method of Van Driesche and Bellows (1996). For the rice hispa study this was done by placing four to five rice plants (40-45 DAT), with either rice hispa eggs or 1st-4th instar larvae (in equal numbers and set up in the insectaries as described above), randomly through the field plots containing the cohorts. These were left out for two days. Several groups of pot plants were generally set during the periods the rice hispa cohorts were running in the different rice seasons but this was not always possible because sometimes the stock cultures of rice hispa in the insectaries ran low. After the two days, the pots were taken to the insectaries and all parasitoids were reared out. The total numbers of eggs or larvae were also counted. Parasitism was calculated as a single figure for each group of pots.

Insect predators were sampled in the area of the field plots by using sweep nets in nearby rice fields; this sampling was an on-going activity by BRRI and not a project activity. However, casual observations on insect predator activity were made on the cohorts during the census counts.

An assessment was made of the overall impact of natural enemies on the survival of the immature stages of rice hispa; this was done at Barisal in 2003. Rice hispa cohorts kept under a nethouse were compared with cohorts in the open. The expectation was that survival rates should be higher in the net house than in field and that this would be due to an absence of natural enemies.

7.2.4. Crop diversity study at Habiganj

Cohort and parasitoid trials were set in a rice monoculture versus a more diverse crop system in Habiganj District during the boro and aus seasons of 2004. Rice mono-cultures sites were chosen at the BRRI Regional Research Station (which were in an area of rice mono-cultures in general) and mixed crop systems were at farms approximately 12 km away. Crops grown at the farms included rice, taro, bean, gourd and banana. Cohort and pararsitoid trials were conducted as above, the trials being set in a rice crop in the farm situations.

7.2.5. Data/Statistical analyses

Statistical analyses where appropriate, were based on Sokal and Rohlf (1995) and utilized standard parametric tests (ANOVA, t – tests, and correlation and regression). Most data was transformed to arc sin values. As variability was expected to be high most acceptance/rejection of null hypotheses were set at the 10% level of significance.

The analysis of the survivorship data presented here was kept simple to illustrate the major points of studies. A more detailed survivorship analysis (based on survivorship curves) is being conducted for the formal publication of the results.

8. Recommendations for Integrated Pest Management (IPM) Technologies and their Dissemination

A national workshop was held in April 2004 (24-25th) to develop recommendations for the IPM of rice hispa and identify dissemination pathways. It was entitled:

'Ecology and Management of Rice Hispa in Bangladesh'

The workshop was organized by the staff of the Entomology Division of the BRRI Central Research Station at Gazipur. The invitations included all the organisations involved in the project (BRRI, DAE, CABI, NRI and Imperial College) and also IRRI Bangladesh and some NGOs (e.g. PETRA, CARE) but in the end representatives from the last two groups were unable to attend because of other engagements. But a number of meetings between project staff (from all the participating organisations at one time or another) and IRRI Bangladesh, PETRA and CARE have taken place throughout the project so the views of these organisations were well known to the project. For DAE, the Project Director, Strengthening Plant Protection Services Project (SPPS) within DAE was also invited.

The principal aims of the workshop was to provide a forum for the discussion of the research results covered under outputs 1 – 7 in this report and then to develop recommendations for IPM. But the workshop recognized that DAE already has some IPM actions for rice hispa in place (as it has for other pests – see outputs 1 and 2) and thus the current DAE IPM programme was taken as a starting point in the discussions on new recommendations. It was also recognized that some of the research being discussed at the workshop was not complete at the time of the workshop and thus some conclusions were only preliminary.

As part of the discussions, the workshop participants considered:

- Additional follow –up research on agreed critical topics.
- The implications of the research (in the context of what is already 'on the ground' in terms management tools) for the farmer, State level organisations and NGOs and further actions needed for dissemination.
- The actions needed for practical uptake, validation and adoption (at farmer and other levels).

9. Preparation of Publications

The following categories of publications have been planned for the dissemination of the project outputs and recommendations:

- A technical report (this one) and a workshop proceedings; the former as a summary of the research for all the project participants and other interested parties.
- A guide to the main parasitoids of rice hispa in Bangladesh for researchers.
- A popular style 'booklet' summarizing key findings for policy makers, extension workers and researchers.
- Research papers for referred scientific journals. The journals chosen (and whether national or international) will depend on the subject matter and target audience.

OUTPUTS

1. Farmers Perceptions of Hispa and Controls

1.1. Informal survey

Full interview notes are given in Appendix 1.3. By good fortune, interviews achieved a combination of one-to-one and group sessions. Initially, at each sampling point a conversation was struck up with the first farmer met, usually one or two men working nearby, walking along the road or waiting for a bus. Over a period of 10 to 15 minutes a small crowd would gather, and the discussion expand to include up to 20 people. This obtained the advantages of both one-to-one and group interviews. Most sessions lasted between 10 and 30 minutes. Farmers may have given answers to the local researcher than to the international researcher - even though the latter's interviews were conducted entirely through the former as an interpreter. Three farmers described Allah to the local researcher as the source of their farming expertise, whereas in 70 interviews this answer was never given to the international researcher.

Farmers were prepared to answer questions about the size of their farms, duration of harvests and estimates of pest losses. The statistics describing these are given in Appendix 1.4. Statistical analysis found a significant correlation between MCP and WPA (r^2=0.2583; F=10.1015[1,29]*). Differences between the two measures were assessed for changes over the country, by the regression of the ratio MCP/WPA (i.e. person-month provisioning per weighted acre of crop) against geographic coordinates and found no significant differences (for East, t(slope)=1.3394[29]ns; for North t(slope)=1.2359[29]ns).

1.1.1. Hispa as a pest

Farmers distinguished hispa, stemborer and brown planthopper, and could explain clearly how observed differences in their ecology and behaviour led to differences in control. They recognised patterns in attack and colonisation, and readily articulated and discussed concepts such as the preference of pests for certain crop characteristics.

Most farmers reported that hispa had always been a problem, and was not very different from as far back as they could remember. Those who considered the situation to have improved attributed this to the use of chemical controls; those who considered it to have deteriorated considered this due to climate change or the weakening of chemicals - apparently due to restrictions on the more powerful and dangerous active ingredients rather than to evolution of resistance. Hispa losses in unprotected crops were estimated as approximately 1/3 to 1/2 of production, though one case of total loss was reported.

Hispa and stemborer were the most-commonly-discussed pests; brown planthopper was generally the third-most-serious pest; also mentioned were rice hopper, rats, cutworms and caterpillars. Hispa was largely seen as with distinct ecological characteristics in contrast to stemborer or "masra" (a generic local term for rice stem borers such as *Scirpophaga incertulas* and *Sesamia inferens*), summarised in Table 1.1.

Table 1.1. Contrasted characteristics used by farmers to describe and distinguish rice hispa and rice stemborer.

Hispa	Stemborer
Variable	Constant
Climate-sensitive	Constant
Plant-phenology-sensitive	Constant
Unpredictable	Predictable
Extrinsic	Intrinsic
Sudden	Gradual
Epidemic	Endemic
All-or-nothing	Ever-present in degree
Variable in presence	Variable in level
Treated on a threshold	Treated preventatively/prophylactically
Treated with variable timing	Treated to a regular schedule
Requiring "fire-brigade" control	Amenable to suppressive management
Requiring insecticidal control	Amenable to traditional control

Many, though not all, farmers described hispa in a characteristic way. It was seen as either absent, or present in abundance - “thousands and millions”, “too many to count”, “turning the fields black” - with no low but non-zero levels which were observable but not worth treating. This all-or-nothing quality made the decision to control self-evident and easy, allowing application at a threshold of insect density which was recognised with confidence, and with little risk that a spray could be wasted if the infestation turned out to be less serious than it first appeared.

Farmers were widely ignorant of the life cycle of hispa, and often unable to associate larval and adult damage with the same culprit. A persistent feature was a tendency to ascribe hispa build-up to “elsewhere” - an alien and irresponsible place where hordes of pests assembled – generally the Sunderbans in the South and India in the North.

Most farmers specified that hispa arrived in their fields as adults, descending from the air in large numbers, often at night. The direction from which they came was often specified.

Farmers applied preventative measures against stemborer but not hispa. They were generally confident in their ability to recognise imminent hispa damage and to act in time to forestall it, having a few days grace between the arrival of adults and the infliction of serious damage. The trigger was typically observations of adults in fields, at densities estimated to look dangerous, made with subjective impressions rather than formal counts or quantifications. Many also recognised the weather conditions likely to lead to an outbreak - overcast and damp, with steady wet conditions rather than periodic downpours - hispa favouring wet and humid conditions, more so than stemborer, so that in wetter areas and periods hispa was relatively more abundant than stemborer. Weather conditions put farmers on general alert, but were not a certain indicator as the insects’ aerial arrival was unpredictable – some in these conditions specifically scouted their fields once or twice a week. Several ascribed to hispa a distinct preference for plants when “succulent” or “soft” – often bushy but before booting - and reported that stands at less attractive stages would be left by adults flying off to seek better ones. Some farmers said that insects could identify “succulent” rice plots, and moved about an area to remain on the best stands, leaving an area if one nearby became more attractive. Late-planted plots, and those that had been fertilised, were seen as particularly inviting. Stemborer was seen as less choosy about its diet quality. While stemborer controls (such as granular insecticides) were plainly directed against larvae, hispa seemed to be known more for its damage as adults than as larvae, and it was against adults that controls (such as sprays) were largely directed.

1.1.2. Chemical controls

Most respondents relied on insecticides for control of insects. This was largely out of a lack of anything else - some reported dissatisfaction with the results and some the difficulties in affording treatment, but nonpesticidal alternatives were generally disparaged, as helpful in lowering populations when not serious, but inadequate in the face of an outbreak. Generally, insecticide control was seen as satisfactory, with losses virtually eliminated by applications. Most farmers sprayed (or wished they could) one, two or three times on each rice crop.

Farmers considered more effective insecticides a more valuable improvement than better information support. Information about pest management came largely from extensionists or dealers – when receiving advice from dealers farmers recognised potential conflicts of interest. The DAE was generally approved of. Farmers rarely accepted advice without some experience or evidence of its value. There were feelings that the Government should provide material assistance - “Who will get the pesticides for the farmers if not the DAE?”

There was a tendency for farmers to apply soil granules against stemborer (generally preventatively) and cover sprays against hispa (generally remedially). This distinction was based on how the perceived differences in the pests’ ecology led to differences in the probability and timing of attack. Many applied the same products against both hispa and stemborer when these happened to arrive together, but also often specifically against one or the other. Controls were often too expensive to be afforded. To protect fish, shrimp and rice plants, and to avoid wasting chemicals, many farmers emphasised the care with which insecticide must be applied: systemic granules were often applied to standing water, but with careful rules and provisos - such as with a certain safe maximum water depth or a specification that the water not be in motion; sprayer nozzles were often held low above the canopy to minimise drift of spray into fish channels. These rules were described as arising from experience and observations in the field. Farmers who reared fish or shrimp were particularly aware of the damage that insecticides can do, and careful to minimise the risk of poisonings. Shrimp farmers were opposed to any idea of aerial sprays. Human safety was never raised as an issue, and no protective clothing was seen.

1.1.3. Sprayers

Most farmers who needed to apply pesticide and could afford it found access to a sprayer of some sort. Those without their own often rented or borrowed one from a dealer, neighbour or the extension service. When cheaper sprayers were available they were often favoured, such as small piston-operated sprayers with a 10L shoulder-slung tank and a piston dispenser, or locally- or home-made tin or bamboo piston-sprayers, acknowledgedly inefficient, and treated as “deciduous” in that they worked for a year then fell to pieces and had to be replaced. Farmers did not report tank-mixing of pesticides with fertilisers. Sprayed pesticides may have been more valued against hispa because they were seen as deeper in the canopy than stemborer adults, and so requiring better spray penetration.

1.1.4. Nonpesticidal controls

Sweepnets were widely known, although more farmers had heard of sweepnetting than practised it, and it was not seen as much use (perhaps because few did it more than once or twice a season), and as more effective against stemborer than hispa. Those who claimed to practise it against hispa did not kill their captures in kerosene (as often recommended) but squashed or drowned them, some, they claimed, after releasing beneficial insects such as dragonflies and ladybirds. Sweepnetting was felt able to dampen down a pest population that was not serious, but to be inadequate when there was a major attack. It was sometimes said that vigorous sweepnetting could delay the onset of an attack, and so reduce by one the total number of sprays needed on a crop. It was not always effective enough to justify the effort - those who were most enthusiastic had hired hands to sweep rather than doing it themselves.

Leafclipping was not recorded as practised – it was often characteristically rejected without being tried, as its whole idea was prejudged, without trial, as damaging and dangerous to the crop. Lights to attract and kill moths were little used, and quite expensive. A variety of other, largely strange and folkloric, controls was reported, including beating the crop with sticks or, specifically, spiny branches to facilitate access of pesticide to larvae, and the application of kerosene by brushes or ropes. The only nonpesticidal control which was not seen as markedly less effective against hispa than against stemborer was the beating of plants, mostly done to knock adults into the water, and not widely practised.

A few farmers had experience of the payment of hispa bounty – they pointed out that for the recipient the trade was only worthwhile when hispa was very abundant and so the requisite volume could be caught without too much effort.

1.1.5. Natural enemies

Farmers were aware of vertebrate natural enemies, particularly ducks, fish, frogs and wild insectivorous birds, particularly the black drongo or long-tailed blackbird, *Dicrurus macrocerus* (Grimmet *et al.*, 1999) - in the South (though not in the North) the installation of perches for these birds was quite popular, due to their low effort and opportunity costs - easy to find and install, so worth putting in even if their return were small. Most farmers believed these vertebrate predators ate hispa more reluctantly than stemborer – reportedly from observation, but possibly because farmers thought hispa looked unpalatable if they imagined themselves in the role of an insectivore. The predation effect was generally thought to be useful, but not able to control the population. Few arthropod predators and no parasitoids were mentioned.

1.2. Formal survey

Due to the flexibility in addressing the numbers of control options with which respondents were familiar, the length of individual interviews varied considerably. Although the questionnaire allowed for discussion of up to five controls each against hispa and masra, no more than three were reported, and so discussion of controls used only 60% of the space allotted in the questionnaire.

Answers were coded into questionnaire booklets, and entered into an Excel spreadsheet file.
Overall, it was concluded that the villages selected were relatively well-favoured by access to DAE support and communications links. Differences between the four villages were rarely apparent, and results tabulated by village, when these provided little illumination, are presented in Appendix 1.5.

Categories of information were addressed separately as follows.

1.2.1. Wealth

Wealth information was gathered by two different sets of questions. First, production was estimated from information about land and its productivity. Each farmer was asked the total area farmed. To accommodate differences in the quality of land, the area of plots in full-time private crop production was distinguished from that of other plots - either partially unproductive such as flooding (beel), grazing (haor) or fallow, or partially owned such as sharecropped, rented, mortgaged or managed for a landlord - and the area of the latter divided by two to reflect its reduced productivity, before all areas were added up to obtain a "Weighted Productive Area" (WPA). This area, asked in decimals, was multiplied by an estimated rice yield of 10kg/decimal/harvest (2.5MT/Ha), and by two for the typical two annual rice harvests, to obtain an annual estimated own-farm-production "Rice-Equivalent Income" (REI):

REI (KG/year) = WPA x 10 x 2

Second, consumption and provisioning were assessed by asking farmers how many months they subsisted on their own rice harvests, to obtain a "Rice Provisioning Ability" (RPA). The RPA is a familiar statistic in Bangladesh and has been converted into monetary values (Mennonite Central Committee, 1996) as the cash value of 15KG of rice per adult per month (half this value for children under 12), multiplied by two to include other foods. The RPA was multiplied by the number of family members to obtain the "Monthly per Capita Provision" (MCP) of output by the whole farm, and two to include other foods. (Data from 31 respondents in the informal survey found a correlation coefficient of 0.2583* of RPA and MCP). On an assumption that children were one third of the typical family this was multiplied by 5/6. This obtained an annual figure for own-farm-production "Rice Equivalent Consumption" (REC):

REC (KG/year) = MCP x 15 x 2 x 5/6

The cash value of rice was estimated as Tk12/KG in 1995 (Mennonite Central Committee, 1996), 10 in the key informant survey and 6.825 as the mean of the respondents in this survey). In theory, REI and REC should be the same, as both represent family own-farmed throughput in rice-kg-equivalents per year per household. Their similarity was examined by finding for each respondent the ratio REI/REC: the mean value of this ratio was 3.47 (with standard deviation 4.38, maximum 39.20, minimum 0.89) - considered closely similar for data of this sort, as less than one order of magnitude. REI and REC were significantly associated (r^2=0.0640; F=8.0631[1,118]**. Subsequently, the single value used to denote "wealth" was for each farmer the mean of the REI and REC, as a value in annual income in rice-kg-equivalents. Table 1.2 gives these for different wealth categories.

Farmers were divided into categories as "poor", "middling" and "wealthy". It was decided not to obtain these categories by dividing the sample into terciles, but instead to try to apportion farmers to "natural" categories. These were obtained by using descriptors of wealth categories of farmers from a comprehensive wealth ranking exercise by PETRRA (2000), dividing farmers according to local peoples' perceptions in ten areas of Bangladesh, and summarised in Appendix 1.1. This used up to five categories of "wealthy", "medium-wealthy", "medium-poor", "poor" and "very poor". The borders dividing the "medium-poor" from the "poor" (and below) was, on average, RPA=7 and farmed area=0.65acres; that between "medium-poor" and "medium-wealthy" (and above) was RPA=12 and farmed area=2.5 acres. For the lower bound, RPA was considered more appropriate than area as better reflecting nutritional ability than a land area whose productivity depends on quality; for the upper bound land area was considered more appropriate as an RPA of 12 is the maximum, and is commonly reported by many farmers who are not evidently "wealthy" (and in this case by 69 of the 120 respondents). Thus farmers were considered "poor" if with an RPA of less than seven months (N=11), "wealthy" if with a weighted production area of over 2.5 acres (N=57), and "middling" if in between (N=52). The numbers in these categories compare with those by PETRRA respondents (omitting the poorest category who do none of their own cultivation) of 28% "poor", 33% "middling" and 39% "wealthy". Table 1.2 gives the mean "wealth" values, as calculated above, for households in these categories in the four upazillas.

Table 1.2. Wealth per household as annual income in rice-kg-equivalents as given in the text, for the four upazillas assessed and in the wealth categories of A for "wealthy", B for "middling" and C for "poor".

	Sylhet						Moulvibazar					
	Golapganj			Balaganj			Sardar			Rajnagar		
	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
A	6037	[2476]	(18)	6308	[2955]	(16)	8609	[10814]	(14)	6400	[2926]	(9)
B	2786	[334]	(10)	2510	[637]	(11)	2400	[425]	(13)	2603	[761]	(18)
C	2925	[530]	(2)	2367	[501]	(3)	2025	[641]	(3)	1325	[43]	(3)

Farmers were asked their ages and numbers of years of farming experience, and gave replies of respectively between 16 and 70, and between 3 and 60.

1.2.2. Information access

Access to information is important in agricultural technology and its development. Farmers were asked how many years they had been in school, how many meetings annually they had with extensionists, and a number of questions about information sources, which were coded to obtain an overall score for IPM Information Quality (IIQ) as indicated in Table 1.3. It is expected that the sample of farmers interviewed represented a sector of the total which overall was well-informed and well connected to extension services.

Table 1.3. Percentages of respondents (N=120) with different sources and levels of pest management information and training. Overall, 95% of respondents received support from extensionists, and this answer obtained a score of "1". Other scores were awarded for the source of pest management information (from the DAE or IPM courses, themselves or neighbours, or pesticide dealers and salesmen) and IPM training as in the Table. These three scores were added to obtain an overall score for IPM Information Quality (IIQ) with a maximum of 5 and minimum of 0. All IPM training was provided by DAE.

Pest management information source	DAE or IPM course	Self or neighbour	Dealer
Percentage of respondents	83	16	1
Score	2	1	0
Type of IPM training	Class or FFS	Demonstration	None
Percentage of respondents	32	10	58
Score	2	1	0

The IIQ was expected to be associated with the number of meetings each farmer had annually with an extensionist (as a separate indicator of information access), and the two were significantly associated (r^2=0.2815, F=46.2310***[1,118]). The distribution among wealth categories and zones of the IIQ, annual number of extension meetings and the number of years spent in schooling are given in Table 1.4. Subsequently, a single value denoting access to quality information was devised as the mean of the IIQ and the annual number of extensionist meetings (divided by three to place it on the scale of the IIQ).

Table 1.4. Distribution among respondents in different zones and wealth categories of numbers of years schooling, annual numbers of meetings with extensionists, and IPM Information Quality (IIQ) score.

District	Wlh	Sylhet		Moulvibazar		
Upazilla	Cat	Golapganj	Balaganj	Sadar	Rajnagar	Overall
Number of years of schooling	A	4.9	4.6	7.0	2.4	4.9
	B	5.0	5.3	5.3	4.0	4.8
	C	8.0	1.7	1.7	3.3	3.3
Extension meetings annually	A	9.2	10.3	12.1	6.7	9.8
	B	6.8	10.4	12.2	8.7	9.6
	C	4.5	6.3	10.0	5.3	6.7
IPM Information Quality	A	3.5	2.8	4.0	3.4	3.4
	B	3.6	3.3	4.5	3.4	3.7
	C	2.0	3.0	5.0	3.3	3.5

1.2.3. Seriousness of insect pests

In order to put into context the seriousness of hispa and other insect pests, farmers were asked to rank and score the seriousness of all rice production problems. In the hope of obtaining a true list, this was asked before the interest of the researchers in insect pests was disclosed (not a guarantee of success, however, as word about the interests of such interesting objects as researchers may travel fast in village communities). The numbers of respondents citing each problem, and the mean score of seriousness awarded, are given in Table 1.5. It may be seen that overall insects were seen as the worst problem, rating "very serious", followed by floods and droughts rating "middlingly serious". Although the question was open-ended, no other problems (e.g. weeds or vertebrates) were mentioned.

Table 1.5. Serious rice production problems as numbers of farmers listing each problem, and the average score awarded (as 3 = "very", 2 = "middling" and 1 "a bit" serious).

Problem	Insects	Flood	Drought
(N)	(120)	(44)	(5)
Ave	2.99	2.16	1.80

1.2.4. Hispa losses

As the informal survey had shown a characteristic perception of hispa attacks as episodic or "lumpy" in distribution, these were asked not as overall losses but as frequencies among years characterised as "serious", "middling" and "good". Respondents were asked for each type of year its frequency (over the nine years since 1996 - relatively memorable as the year of the first Sheik Hashina government) and the production in maunds per decimal, converted to financial losses. The results are given in Table 1.6.

Table 1.6. Losses to hispa reported in "serious", "middling" and "good" years, as the frequency, yield and losses to hispa in each, converted by the rice sale price reported by each farmer in Tika per maund (mean 282.2 [SD=22.5], N=119 – equivalent to c.Tk7/KG, 1 maund=40KG). Yield of 0.4 maunds/decimal (at 40KG/maund and 250 decimals/Ha) equals 4MT/Ha – in line with other yield estimates for unattacked rice under these conditions. This obtained a frequency-weighted mean loss per annum of 39.9 Tika/decimal [SD=16.7], or Tk9975/Ha.

	"Serious"		"Middling"		"Good"	
	Mean	[SD]	Mean	[SD]	Mean	[SD]
Frequency	0.340	[0.125]	0.215	[0.127]	0.444	[0.246]
Yield (maunds/decimal)	0.067	[0.071]	0.271	[0.066]	0.398	[0.057]
Loss (maunds/decimal)	0.331		0.127		0	
Loss (Tk/decimal@282.2)	93.4		35.7		0	

1.2.5. Categorisation of pest ecology

Farmers were asked the ecological conditions favouring hispa attack, as weather, crop stage, land type and season, with the results as summarised in Table 1.7. These are broadly in agreement with observations by BRRI scientists and published reports. Thakur *et al* (1979) found hispa incidence associated with high temperature and humidity; Rao (1977) reported an incursion into Andhra Pradesh following heavy rain, high humidity and "intermittent bright sunshine". Islam (1989) reported attack at tillering led to 52% loss, but at stem elongation only 37% loss.

Table 1.7. Ecological conditions favouring hispa attack, as the numbers of farmers answering (N), and percentages reporting the weather conditions, rice growth stages, soil type and rice season which most favoured hispa attack.

Weather:-	Sunny	Cloudy	Light Rain	Heavy Rain
(N=116)	0	47	47	6
Crop stage:-	Early Tillering	Mid-Tillering	Late Tillering	Booting
(N=119)	53	17	29	2
Land type:-	Damp	Wet	Dry	All
(N=113)	52	47	0	1
Season:-	Aman	Aus	Boro	Other
(N=119)	100	0	0	0

Respondents were also asked which was more serious, the adult or larval damage, using the photographs shown in Figure 1.1 to identify larval damage as the informal survey had shown that some farmers at least do not associate this damage with hispa adults. Of 118 respondents 44% considered the adults more serious, and 56% the larvae. This was contrary to the indication by the informal survey, which although not formally quantified covered a wider area and range, and may indicate an unusual level of awareness among the sample.

Ecology and pest status of hispa was often asked in contrast with that of the stemborer or masra. Differences in perceptions of these two pests were first contrasted in the informal survey report, and these findings were confirmed in this study. Respondents were asked the source and proximity of infestations of the two pests, and their answers are summarised in Table 1.8. They were also asked, in open ended questions, to describe anything they had seen of the pests reproducing, and the responses are listed in Table 1.9. Although the source of hispa was more often described as from the field than the land, its location was given as “abroad” more often than for masra, which was reported as entirely of local origin.

Table 1.8. Numbers of respondents (N) describing the source and proximity of attacks by hispa and masra, and the percentages of these giving each answer.

	Source			Proximity		
Pest	(N)	Air	Field	(N)	Nearby	Abroad
Hispa	(59)	22	78	(18)	78	22
Masra	(36)	94	6	(13)	100	0

Table 1.9. Observations on reproductive biology of hispa and masra.

Hispa	Masra
Black eggs (x2)	Black eggs on leaves
Eggs on the leaves	White larvae (x2)
Small eggs on leaves	
Black eggs on leaves (x2)	
Black eggs covered by net	
Soft, white larvae (x2)	
Small larvae on leaves	

Respondents were also asked which if any rice varieties had elements of resistance or susceptibility to hispa and to masra. The numbers of people citing each variety are listed in Table 1.10RS, and the numbers growing each variety listed for comparison in Table 1.11. Resistance to both pests was reported as virtually non-existent (though higher for hispa than for masra). BRRI dhan 11 was identified as particularly susceptible to hispa (and to some extent masra), and was also the most widely-cultivated; this indicates that the susceptibility of this variety to hispa has not undermined its popularity, although the (distantly) second most popular variety, Pajam, was the only one with any indication of hispa resistance.

Table 1.10. Rice varieties reported as susceptible and resistant to pests, as numbers of respondents (of 120) mentioning each variety as in each category.

	Hispa		Masra	
	Susceptible	Resistant	Susceptible	Resistant
BRRI dhan 11	15	0	5	1
BRRI dhan 32	2	0	0	0
Najirshail	1	0	0	0
Kalijira	1	0	0	0
Murali	0	0	1	0
Thakurbhog	0	1	0	0
Mainashail	0	2	0	0
Pajam	0	5	4	0

Table 1.11. Rice varieties grown, as numbers of farmers (of a total of 120) reporting growing each variety in the Aman and Aus seasons (no respondents reported cultivation of boro).

Variety	Aman	Aus
BRRI dhan 11	117	0
Pajam	37	0
Chandina	19	1
BRRI dhan 28	17	19
BRRI dhan 3	10	0
BRRI dhan 30	9	1
BRRI dhan 32	6	7
Najirshail	5	0
Mainashail	4	0
Kalijira	3	0
Thakurbhog	3	0
BRRI dhan 29	2	4
Balam	2	0
Biroi	2	0
BRRI dhan 22	2	0
BRRI dhan 10	1	1
Chinirgura	1	0
BRRI dhan 38	1	0
Mainabhog	1	0
Tulsimala	1	0
Goarchara	1	0
Birpak	1	0
BRRI dhan 31	1	0
BRRI dhan 40	1	0
China	0	68
Murali	0	53
Changri	0	24
IRRI 8	0	14
BRRI dhan 1	0	13
BRRI dhan 26	0	4
BRRI dhan 2	0	3
BRRI dhan 21	0	1
BRRI dhan 27	0	1
Malashail	0	1

Hispa and masra were compared as to the frequencies of their attacks. Farmers were asked the numbers of years since 1996 in which pests caused losses which were "serious", or "middling" (or "lesser"); from these percentage frequencies were calculated in which pests were "serious", "middling/lesser" and absent (as the two other categories subtracted from 100). From these figures were calculated a single-figure index of “lumpiness” for each pest, calculated as the product of the percentage frequencies of “Serious” and “Absent” years, divided by the percentage frequency of “Middling/lesser” years (plus one to forestall division by zero). These values are given in Table 1.12, which shows the much lumpier distribution for hispa than for masra; this corresponds with the finding of the informal survey, and of the reputation of hispa as arriving infrequently but inflicting serious damage when it does so.

Table 1.12. Comparison of frequencies of hispa and masra outbreaks of different levels of intensity.

	Pest (N)	Hispa (119)	Masra (92)
Percentage incidence	“Serious”	32	4
	“Middling/lesser”	19	53
	Absent	49	43
Lumpiness index		20	4

1.2.6. Incidence of pest management practices

Farmers were asked of which pest management practices they had knowledge or experience, against hispa and masra. Three methods were reported for each: sprays, sweepnetting and leafclipping against hispa; and chemical soil granules, sprays and sweepnetting against masra (farmers were asked for knowledge of other methods but none was reported). Table 1.13 gives the incidence of different pest management practices among farmers by wealth categories. It seems that poorer farmers used the relatively costly chemical-based technologies slightly less than richer, and the low-input-cost sweepnetting relatively more; but also that the richer made more use of leafclipping, seen by many as high-risk and labour-intensive.

Table 1.13. Incidence of pest management practices among farmers in different wealth categories, as numbers of respondents (N) and percentages of these reporting use of each practice.

Wealth category (N)		A (57)	B (52)	C (11)
Hispa	Sprays	98	96	91
	Sweepnetting	42	56	64
	Leafclipping	25	25	9
Masra	Granules	60	65	64
	Sprays	7	2	0
	Sweepnetting	2	0	0

Table 1.14 gives the same values separately for each zone. There was an indication of differences among zones, with hispa spraying (and masra granuling) universal in three areas, but less frequent in Golapganj, and leafclipping relatively frequent in Moulvibazar Sadar Upazilla but less common in Balaganj.

Table 1.14. Incidence of pest management practices, as in Table 1.13, broken down among zones.

Region		Sylhet						Moulvibazar					
Upazilla		Golapganj			Balaganj			Sadar			Rajnagar		
Wealth category (N)		A (18)	B (10)	C (2)	A (16)	B (11)	C (3)	A (14)	B (13)	C (3)	A (9)	B (18)	C (3)
Hispa	Spray	94	80	50	100	100	100	100	100	100	100	100	100
	Sweepnetting	50	20	50	31	27	33	36	69	100	56	83	67
	Leafclipping	39	20	0	6	9	0	36	31	33	11	33	0
Masra	Granules	11	0	0	75	73	67	79	69	100	100	94	67
	Spray	6	0	0	6	0	0	14	8	0	0	0	0
	Sweepnetting	0	0	0	6	0	0	0	0	0	0	0	0

The perceptions of performance of controls, and background to decisions concerning their use, were assessed in three separate analyses, designed out of the results of informal surveys.

1.2.7A. Farmer pest management decisions A: Cost/benefit comparisons

Farmers were asked the quantities, costs and benefits of hispa management options, to allow the economic evaluation of controls.

Costs were itemised for each hispa (though not masra) control practice by asking the unit price (P), the quantity (Q) (volume of inputs, hours of labour) to treat the specified plot (area A) once, and the number of times per rice season the operation was performed (N). Inputs per season were calculated as P.Q.N/A.

Returns were considered difficult to conceptualise as quantities and so the farmer was allowed to specify return estimates in any of three ways:

- as a return in yield in units per unit area
- as a percentage reduction in the loss
- as a percentage reduction in the population of hispa

Most farmers in fact answered this question in at least two of the three possible ways, and so for all farmers estimates of yield per unit area could be made. In eight cases (seven for sprays, one for sweepnetting) the answer was given in pest mortality only - these were adjusted to yield-per-unit-area values using the equation for linear regression of the two values for the other farmers who gave both answers. All labour costs were converted into cash equivalents; where family labour was used and so no price given the median value for all farmers (Tk100/day) was used. Similarly, when sprayers were borrowed or owned the cost was taken as the median hire price reported by those who hired. The costs and benefits reported, calculated as discussed, are given as means in Table 1.15. It appeared that although the costs of non-pesticidal controls were lower, the percentage returns to insecticide use were larger.

Table 1.15. Reported costs and benefits of hispa control options, in units of Tk/decimal/season, as means among numbers of farmers given as (N). Overall values are also given in Tika/Ha/season, at a rate of 250decimals/Ha.

Control	Spray	Sweep	Clip
(N)	(116)	(60)	(28)
Chemical cost	3.6		
Labour cost	0.8	2.4	
Sprayer/net cost	0.1		
Total cost	4.5	2.4	2.7
Benefit	60.0	15.3	28.0
Total cost (Tk/Ha)	1125	600	675
Benefit (Tk/Ha)	15000	3825	7000
Percent return	1229	544	951

The same values are given broken down among wealth categories in Table 1.16. There was some indication that wealthier farmers invested more in crop protection by all three techniques, though also their perceptions of returns were less - implying that use of controls was more based on the ability to perform them than on perceptions of return to investment.

Table 1.16. Costs and benefits of hispa control options, as in Table 1.15, with separate values for different wealth categories.

Wealth category	A		B		C	
	(N)	Mean	(N)	Mean	(N)	Mean
Spray - chemical cost	(56)	3.8	(50)	3.6	(10)	2.8
Spray - labour cost	(56)	1.1	(50)	0.6	(10)	0.5
Spray – sprayer cost	(56)	0.1	(50)	0.1	(10)	0.1
Spray - total cost	(56)	5.0	(50)	4.2	(10)	3.4
Spray – benefit	(56)	59.3	(50)	59.7	(10)	64.9
Sweepnet – cost	(24)	2.9	(29)	2.1	(7)	1.7
Sweepnet - benefit	(23)	16.8	(29)	13.6	(7)	17.7
Leafclip – cost	(14)	2.9	(13)	2.5	(1)	1.7
Leafclip – benefit	(14)	27.6	(13)	28.3	(1)	30.0

The same values are given broken down among zones in Appendix 1.5 Table A1.5.1. No differences between zones were apparent.

Among investments in hispa management, respondents were also asked whether the labour used was family, hired or a mixture of both. The relative composition of these are given in Table 1.17. This indicates that wealthier farmers made more use of hired labour for spraying, sweepnetting and leafclipping. Farmers who sprayed against hispa were also asked where the sprayer came from, with the replies summarised in Table 1.18 – few differences in sourcing among different wealth classes were apparent, though the importance of Government agencies as a source of loaned sprayers was clear.

Table 1.17. Sources of labour used for hispa management practices, as percentages of labour hired. Respondents' answers were coded as hired = 1, mixed = 0.5, family = 0.

Wealth category		A	B	C
Sprays	%	51	30	30
	N	(56)	(50)	(10)
Sweepnetting	%	35	19	14
	N	(24)	(29)	(7)
Leafclipping	%	54	27	-
	N	(13)	(13)	(0)

Table 1.18. Sources of sprayers used for hispa management, as numbers of respondents in each wealth class, and percentages among these who reported sprayers as owned, hired or borrowed and, if borrowed, from whom.

				% Borrowed from			
Wealth category	(N)	% Owned	% Hired	All borrowed	Union Parishad	Agricultural Office	Neighbour
A	(55)	9	24	67	15	16	36
B	(50)	4	38	58	10	18	30
C	(11)	9	18	73	9	27	36

1.2.7B. Farmer pest management decisions B: Evaluation of options by criteria

Matrix scoring of options by attributes is a well-known analysis tool for elucidating how people distinguish technology choices and the criteria they use for them (e.g. McCracken *et al.* 1988). Farmers were asked, for each practice of which they had knowledge, to award scores for characteristics, on a scale from "none" (Score 0), "a bit" (1), "middlingly" (2), and "very" (3). The characteristics graded in this way for each practice were effectiveness (as "good at control") and a series of problems - money expense, use of labour, tiresomeness as work, risk to health and damage to crop plants; additionally for spray controls was included access to a sprayer, and additionally for sweepnetting access to a sweepnet. The answers to these were sorted into a series of scoring matrices.

Table 1.19 gives the resulting matrix of mean scores across all farmers. It suggests that use frequency was more closely determined by the perception of effectiveness at control than of other questions such as cash costs or health or crop risk (though the negative perceptions of the labour demands, and their tiresomeness, may have weighed against sweepnetting and leafclipping - this may vary between those using hired as opposed to family labour). This was in contrast to the findings of a similar study of grasshopper control in Sahelian West Africa (Stonehouse et al., 1997) where in a highly cash-strapped community concern over the cash costs of controls was more influential than any other criterion, including effectiveness. The preferred status of chemical controls to non-pesticidal alternatives was apparently associated with their perception as more effective. Table 1.20 gives the values broken down among wealth categories, and the same values further broken down among zones are given in Appendix 1.5, Table A1.5.2.

Table 1.19. Score matrix of farmer opinions of six insect control technologies, by frequency of use (as "Number since 1996" - a nine-year period) and criteria of effectiveness and a number of problem scores, with "All problems" as the sums of the problem score values above.

Pest	Hispa			Masra		
Control	Spray	Sweep	Leafclip	Granules	Spray	Sweep
(N)	(116)	(60)	(28)	(75)	(5)	(1)
Number since 1996	2.46	1.18	1.18	3.71	1.60	1.00
Good at control	2.69	1.17	1.64	2.49	2.40	1.00
Problem of money	1.44	1.13	1.71	1.61	0.00	0.00
Getting sprayer/net	1.91	0.03			3.00	
Labour	0.18	1.32	2.32	0.04	0.00	0.00
Tiresomeness	0.25	2.07	1.00	0.13	0.00	3.00
Health	1.83	0.00	0.00	1.31	1.80	0.00
Crop damage	0.04	0.02	1.11	0.05	0.00	3.00
All problems	5.65	4.57	6.14	3.14	4.80	6.00

Table 1.20. Scoring matrix of attributes of control practices, of numbers answering (N) and mean scores, as in Table 1.19, given separately for different wealth categories.

Pest	Hispa								
Control	Spray			Sweepnetting			Leafclipping		
Wealth category	A	B	C	A	B	C	A	B	C
N	56	50	10	24	29	7	14	13	1
Number since 1996	2.71	2.26	2.00	1.29	1.14	1.00	1.29	1.08	1.00
Good at control	2.71	2.70	2.50	1.13	1.21	1.14	1.50	1.85	1.00
Problem of money	1.29	1.50	2.00	1.17	0.90	2.00	1.57	1.77	3.00
Getting sprayer/net	1.89	1.84	2.40	0.08	0.00	0.00	-	-	-
Labour	0.23	0.16	0.00	1.79	1.07	0.71	2.50	2.31	0.00
Tiresomeness	0.21	0.34	0.00	1.79	2.17	2.57	1.07	0.85	2.00
Health	2.02	1.60	1.90	0.00	0.00	0.00	0.00	0.00	0.00
Crop damage	0.02	0.08	0.00	0.04	0.00	0.00	1.07	1.23	0.00
Pest	Masra								
Control	Granules			Sprays			Sweepnetting		
Wealth category	A	B	C	A	B	C	A	B	C
N	34	34	7	4	1	0	1	0	0
Number since 1996	4.15	3.38	3.14	1.50	2.00	0.00	1.00	-	-
Good at control	2.58	2.40	2.50	2.50	2.00	0.00	1.00	-	-
Problem of money	1.50	1.62	2.14	0.00	0.00	0.00	0.00	-	-
Getting sprayer/net	-	-	-	3.00	3.00	0.00	-	-	-
Labour	0.09	0.00	0.00	0.00	0.00	0.00	0.00	-	-
Tiresomeness	0.15	0.06	0.43	0.00	0.00	0.00	3.00	-	-
Health	1.35	1.24	1.43	1.75	2.00	0.00	0.00	-	-
Crop damage	0.06	0.06	0.00	0.00	0.00	0.00	3.00	-	-

1.2.7C. Farmer pest management decisions C: Threshold control decisions

Discussion with farmers in the informal survey led to the formulation of a set of conditions for threshold control, in the perception by the farmer of the likely future development of the pest infestation if threshold controls were and were not taken, hingeing on the reliability of the warning of an outbreak which is given by the signals. There was first a state of heightened awareness of risk, prompted by "cloudy weather" (taken as an indication of high atmospheric humidity) and second the specific trigger provided by the appearance of the first hispa adults. At this point two features contributed to the threshold spray decision (1) the costs of both (a) a false positive and (b) a false negative, and also (2) the perception of the time which is allowed to act in, and critically whether enough time was given to allow effective action to be taken. The conditions necessary for threshold, as opposed to preventative, control were therefore surmised to be as follows:

1 - Pest arrival is episodic, not constant
This requires that the pest may or may not cause economic damage in any year - threshold control has no relevance in cases where pest attack never happens nor where it can be assured to happen in every year. This was asked for both hispa and masra as frequencies in which each pest was very serious, “middlingly” (or “lesser”) serious, and thus (by implication and subtraction) not serious, to allow frequency distributions of attack, as discussed above.

2 - Upon receiving a warning, control can be deployed in time
This requires that either there is a non-damaging symptom appearing with enough time for controls to be used, or controls may work remedially to recover damage done; in either case, the time interval for controls to be used must be shorter than the time interval between warning and irremediable damage (forecast interval longer than infestation interval). This was asked for both pests as whether attack development was “smooth or sudden”, and whether, if it was “sudden” some symptoms were visible beforehand as a warning and, if so, how long before. The constraint of “suddenness” on control was assessed by scoring for all controls as “the difficulty of conducting operations in time”. For sprays against hispa, additionally, the actual number of days taken to conduct a spray, on receiving a warning, were asked.

3 - The warning given of impending damage must be satisfactorily accurate
This has two components: (a) the accuracy of avoiding a false negative (omitting an application which was necessary), which has priority over (b) avoiding a false positive (carrying out an unnecessary application). Avoiding a false negative (3a) is another way or expressing the requirement for timely warning (2), as accuracy of perception of an outbreak increases as the critical damage caused by the outbreak draws nearer in time. Additionally, the risk of a false positive (3b) was assessed by asking whether sometimes a small population was observed which, in the event, did not turn out to be economically threatening.

Respondents were asked their hispa spray thresholds, with the distribution of answers as in Table 1.21 - a mixture of thresholds observed as “damage” and as counts of between one and thirty insects per hill. Other thresholds were given as a simple scale of “0” for “No threshold” (regular application), “1” for “Any at all, no matter how few”, “2” for “A few” and “3” for “A large amount”. It was anticipated that these thresholds would be significantly (and negatively) associated with frequencies of use of controls, and this was confirmed (negative association r^2=0.0975; F=12.5356***[1,116]).

Table 1.21. Spray action thresholds for hispa reported by 116 respondents. Given are percentage giving each answer (a single respondent giving the threshold as "some" was given a score of 2 as a central value).

		Threshold						
			By count of insects per hill					
Criterion	Always (no threshold)	By damage	1-5	6-10	11-15	16-20	21-30	"A large amount"
%age	11	21	9	9	7	4	2	36
Score	0	2	1	2	2	2	2	3

The ecological influences on threshold use of controls was also assessed. These are tabulated first in Table 1.22, showing ecological characteristics of hispa and masra in contrast, second in Table 1.23, showing ecological characteristics of individual control practices in contrast, and third in Table 1.24 as some additional questions asked only of the single practice of spraying against hispa. Table 1.22 shows how on every characteristic hispa lent itself ecologically to threshold control in a way masra did not - a more episodic distribution, a more sudden appearance (though with no longer warning time when appearance was sudden) and a lower risk of a false positive as an observed population turning out, in the event, to be harmless.

Table 1.22C. Ecological characteristics of hispa and masra in contrast. "Lumpiness" is as in Table 1.12, above. Also given is the suddenness of appearance (the percentage of respondents describing it as "Sudden" as opposed to "Smooth"); the mean number of days of warning provided by a few being visible if arrival is "Sudden"; the number of days by which outbreak may be predicted (including"0" if it cannot); and the possibility of a small, harmless population (as the percentage of respondents reporting the existence of harmless populations as opposed to those denying them).

	Hispa		Masra	
Characteristic	(N)	Mean	(N)	Mean
"Lumpiness"	(119)	20.3	(92)	4.4
"Suddenness"	(119)	63.9	(92)	7.6
If appearance "Sudden": with how many days warning?	(75)	1.5	(7)	0.7
Predictability (days)	(119)	0.8	(92)	0.8
Possibility of "harmless" population (% "yes" as opposed to "no")	(119)	6.7	(92)	18.5

The implied effects of these influences on the use of controls are summarised in Table 1.23. Regarding hispa, sprays had a lower threshold than the non-pesticidal controls, and was done more often, but was a more difficult decision and more difficult to carry out in time. Regarding masra, granules had a lower threshold, and were used more often, but were an easier decision and easier to carry out in time. There was some indication that wealthier farmers encountered fewer difficulties with carrying out sprays on time, but this was not significant (association of timing difficulty score with farm wealth r^2=0.0148; F=1.7087[1,114]ns).

***Table 1.23. Characteristics of perception of control practice options. Given for each option is the number of uses in nine years, the score for threshold at which it was used (as in Table 1.21 and the accompanying text) and scores for difficulty in taking the use decision, and in carrying out the control in adequate time (both scored as 0 for "no difficulty", and 1 for "a bit", 2 for "middlingly"* and 3 for "very" difficult).**

Pest	Hispa			Masra		
Practice (N)	Sprays (116)	Sweepnetting (59-60)	Leafclipping (28)	Granules (65-75)	Sprays (5)	Sweepnetting (1)
Number in 9 years	2.46	1.18	1.18	3.71	1.60	1.00
Threshold Score	2.04	2.42	2.32	1.29	2.40	2.00
Decision Difficulty	1.64	1.08	1.50	0.97	1.80	2.50
Timing Difficulty	1.63	0.03	0.39	0.35	0.40	2.00

For hispa sprays, additional clarifying questions were asked. These included fear of a false positive (that a spray may turn out to have been unnecessary) and false negative (that a spray not done may turn out to have been necessary after all). Responses to these questions are summarised in Table 1.24.

***Table 1.24. Characteristics of decisions about the use of insecticide sprays against hispa, as the seriousness of problems (both as the means of scores of 0 for "not serious", and 1 for "a bit", 2 for "middlingly" and 3 for "very" serious) and the mean number of days needed, first, to spray in time after the decision is taken and, second, to prepare and carry out the spray*.**

Characteristic	Unit	(N)	Mean
Seriousness of false positive	(score)	(116)	0.09
Seriousness of false negative	(score)	(115)	1.03
Time needed for spray, after decision	(days)	(116)	2.56
Time needed to prepare for spray	(days)	(116)	1.67

It may be seen that the conditions for threshold sprays again appeared to be met - the risk of false negatives was low (though not as low as that of false positives) and the time needed to prepare for a spray was within that allowed by the warning provided by observation.

It was hoped that the more detailed questions relating to this one control - sprays against hispa - would provide confirmatory information which would be associated with the simpler, "shorthand" information gathered in fewer questions for the other practices. First, it was reasoned that the grace allowance of time - the difference between the time in which the spray was needed and the time it actually took to prepare - would be negatively associated with the score for "difficulty in carrying out the spray on time"; this was not confirmed (positive association r^2=0.0303; F=0.2984ns[1,116]). Second, it was reasoned that the seriousnesses of false positives and negatives (taken as the sum of the two scores) would be associated with the score (given for all controls) for the difficulty of the spray decision; this was confirmed (positive association r^2=0.0418; F=5.0622*[1,116]). Third, it was anticipated that the seriousness of a false negative would be associated with the problem of a timely intervention (as longer warning time is partly interchangeable with greater accuracy); this was not confirmed (negative association r^2=0.0043; F=0.5014ns[1,116]. Fourth, it was anticipated that the serious of a false positive would be associated with the existence of a visible-but-harmless population (since they are in effect the same thing); this was not confirmed (with possibility of a harmless population scored as a Boolean as "possible=1" r^2=0.0004 F=0.0413ns[1,116]).

Finally, in addition to the differences in decision backgrounds between practices outlined above, differences within practices - i.e. between different individuals using the same practice - were examined to see whether the reasons for decisions about the intensity of use varied between practices. This was done by multiple regression of two decision outcomes - the threshold at which controls were used and the level of difficulty of the decision - against a suite of candidate explanatory variables. Three of these were characteristics of the farmer, as each individual's number of years of farming experience, wealth (measured as the farm income calculated above as the mean of REI and REC above and as in Table 1.2), and access to information (measured as the mean of the two information scores - IPM Information Quality Score and number of annual meetings with extensionists - discussed in Table 1.3 and the accompanying text. Alongside these were three characteristics of pests, derived from farmers' descriptions of pest ecology, as the lumpiness of attack (measured as above in Table 1.12), the amount of warning in numbers of days of advance predictability and the possibility of a "false positive" decision as a result of the observation or non-observation of populations of pests too small to do damage (measured as a Boolean variable with value "1" for observation, "0" for non-observation). Threshold levels and decision difficulties were regressed against these six variables separately for four controls - spray, sweepnetting and leafclipping against hispa, and granules against masra - as for the other practices (sweepnetting and spraying against masra) too few respondents had given answers. The results are presented, as the level of significance and the direction (sign) of each association, in Table 1.25.

Table 1.25. Regressions of aspects of pest management decisions against farmer and pest characteristics. Each value is the significance level of the association (P), subtracted from 1 and expressed as a percentage (i.e. the conventional significance limit of 0.05 would be expressed as "95%") multiplied by the sign of the slope of the association so that positive associations are positive values and vice-versa. For four practices two outcomes - the decision threshold and the score of difficulty in taking a decision - were regressed against three characteristics of the farm and farmer - years of experience, farm income and access to information - and three characteristics of the pest - the lumpiness index as in Table 1.12, the number of days warning of outbreak, and the possibility of a harmless pest population (as 1 for such populations seen, 0 for not seen).

Practice and Decision	(N)	Farm characteristics			Pest characteristics		
		Farming experience	Farm income	Information score	Lumpiness index	Days warning	Possibly harmless
Thresholds							
Hispa spraying	(114)	91	-85	-7	-62	-	-90
Hispa sweepnetting	(60)	24	-17	11	-89	-27	9
Hispa leafclipping	(27)	86	-45	57	92	-96	-45
Masra granuling	(60)	-44	-80	99	-54	-88	-87
Decision difficulty							
Hispa spraying	(114)	-51	-67	-91	-55	-	-8
Hispa sweepnetting	(60)	-58	71	7	43	-35	7
Hispa leafclipping	(27)	-9	-35	-11	30	-99	43
Masra granuling	(60)	41	-43	-88	77	47	-51

The indications were that farmers with more years of experience tended to carry out all hispa controls, and sprays in particular, at higher thresholds (i.e. less often) and to find the decisions less difficult. Wealthier farmers were likelier to use controls at lower thresholds (i.e. more often) and to encounter fewer difficulties in deciding to perform them. Access to information apparently had little influence on hispa controls, but appeared to make granule applications against masra less likely, and decisions in general less difficult. Perceptions of pest characteristics appear to have had few effects.

1.2.8. Farmer evaluations of government support to pest management

Farmers found hispa control decisions taxing, and only a minority took the decision alone, but with neighbours or extensionists as in Table 1.26. Information support was evidently important in farmer decision-making with regard to hispa control. Table 1.27 gives the mean scores for usefulness awarded to different Government supports to hispa control, by those farmers with experience of them.

Table 1.26. Reports of hispa spray decisions taken alone or in consultation, as percentages of 115 respondents.

Taken alone	Taken with neighbour(s)	Taken with extensionist(s)
17	19	64

Table 1.27. Mean scores (with numbers of respondents, N) of approval for activities in support of hispa control by Government (as 0 for "not useful", and 1 for "a bit", 2 for "middlingly" and 3 for "very" useful). The mean warning time reported by respondents as useful for a hispa forecast was 10.15 days (N=27).

Hispa management support	(N)	Mean
Aerial spray	(18)	3.00
Bounty payment	(0)	-
Loan of sprayer	(97)	2.80
Donation of sweepnet	(73)	1.48
Donation of pesticide	(39)	2.51
Advice about Hispa	(118)	2.50
Advice about Masra	(92)	2.28
Hypothetical Hispa warning	(28)	1.64

Table 1.27 indicates that farmers were most enthusiastic for material support requiring no activity from themselves (aerial sprays), moderately enthusiastic for material support to pesticide use (sprayer loan and pesticide donation) and less enthusiastic for sweepnet support. Encouragingly, advice received was rated relatively highly (although not truly scaleable with the others as not asked as part of the same question set).

1.3. Conclusions

1.3.1. Informal survey

The advantages and limitations of the perceived control options are summarised in Table 1.28.

Table 1.28. Summary of advantages and limitations of hispa controls perceived by respondents in the informal survey.

Practice	Advantages	Limitations
Pesticide sprays	- Effective, efficient	- Expensive and demanding of resources, in getting a sprayer as well as buying chemicals - Some risk to water food sources
Sweepnetting	- Can provide hispa protection quickly and without purchased inputs	- Not as good at control as sprays - Time-consuming
Leafclipping	- Some protection	- Not believed to be effective - Time-consuming - Seen as damaging to plants
Beating	- Some protection	- Cumbersome and strange - Never really developed or implemented in a systematic or clear way
Natural enemies	- Some protection - Very low cost (putting up bird perches)	- Not effective enough to exert control - Not effective enough to justify pesticide restraint

1.3.2. Formal survey

Wealthier farmers had better access to schooling and to extensionists, but not necessarily to superior information for pest management. Commercial dealers and salesmen were only rarely a source of pest management information, with DAE providing most advice.

Overall, insect pests were reported as the worst production problem, and “very” serious, with flood and drought lesser, and “middlingly” serious.

Hispa losses were seen as characteristically episodic and “lumpy” between years, with approximately one third of years “serious” (with rice losses of 13.24KG/Ha) and one fifth of years “middlingly serious” (with losses of 5.08KG/Ha) for hispa problems, which were minor in the remainder. Averaged over a number of years with a rice prices of 7Tk/KG this obtained weighted losses of Tk49975/Ha/year.

Hispa attacks were said to be favoured by cloudy weather or light rain and damp or wet ground, and to be most serious in Aman rice in early tillering. In contrast with “masra” (a generic local term for all rice stem borers), hispa attacks arrived with a much “lumpier” distribution. The variety BRRI dhan 11, reported to be the most susceptible to hispa, was also the most popular.

Among hispa control practices, sprays were most popular, carried out by more than 90% of farmers, even more so among the relatively wealthy. Sweepnetting was carried out by 60% of poorer farmers and 40% of richer. Leafclipping was carried out by approximately 25% of farmers, and apparently less common among the poor.
Rationales behind choice of practices were assessed in three ways:
A - Economic assessment estimated percentage returns to hispa controls to be 1229% for sprays, 544% for sweepnetting and 951% for leafclipping. Farmers appeared confident of the positive economic returns to their actions.

B - Matrix scoring of options by criteria found that choices were made by the selection of controls for their perceived effectiveness, rather than their avoidance for their perceived problems and disadvantages.
C - Assessment of control thresholds as functions of the perceptions of their ecology found that hispa management by thresholds was stimulated by the perception of hispa attacks as “lumpy”, warnings as reliable, and the ability to exercise controls within the warning period provided by observations. Wealthier farmers tended to spray at lower thresholds (i.e. more often) and more experienced farmers at higher thresholds (i.e. less often).

Opinions among farmers as to the usefulness of Government support tended to favour direct intervention, particularly when requiring no effort on the farmers’ part. A hypothetical hispa advance warning system was estimated to be midway between “a bit” and “middlingly” useful.

Hispa management practices were influenced by perceptions of attacks, and the needs for remedies, more than by other factors such as wealth. In the North-East of Bangladesh land is more commonly rented or sharecropped than in other parts of the country, but respondents did not report influences of the tenancy relationship such as discussing control operations with landlords, or going to landlords to borrow sprayers. This tallied with the findings of the preceding qualitative semi-structured interview survey, carried out in the North-East and also in the South, which found little evidence of influences on pest management decisions by the tenancy relationship.

Farmers typically had little knowledge of hispa biology; at the same time, there was little evidence, in these areas, of farmer lack of knowledge about non-pesticidal controls. These farmers may be taken to have been well schooled in IPM and other progressive issues, as is indicated by the high score awarded to pesticide sprays for “health risks” in Table 1.19.

Access to controls was not reported by respondents as a particular problem. In Table 1.19 spraying against hispa scored more than sweepnetting and leafclipping for problems of money, but this was only a “middling to small” problem and was outweighed by the difficulties of labour and tiresomeness awarded to the more labour-intensive nonpesticidal controls. In Table 1.23 the problems of carrying out sprays on time (and making the decision to do so) were rated more highly than for nonpesticidal alternatives, but still only “middling to small”.

This sample provided little evidence of serious 'gaps' where cultural controls and/or insecticide use could be improved through availability, training etc. Samples of this sort are, however, highly prone to neglect the most vulnerable communities (as is any sampling system restricted to road transport when many farms and villages are not easily accessible by this means).

1.3.3. Overall summary and conclusions

Perceptions tended to make farmers view hispa, in comparison with other pests, as more requiring of insecticide sprays, and of state and other institutional support.

As a consequence of the perceived "episodic" distribution of hispa attacks, loss estimates depended on whether the specific season under discussion was one suffering an attack. Farmers were asked to estimate the frequency of hispa attack years which were "bad", "middling" and "good" and the yields in each of these categories, with the results given in Table 1.29.

Table 1.29. (summarising 1.6). Losses to hispa reported in "serious", "middling" and "good" years, as the frequency, yield and losses to hispa in each, converted by the rice sale price reported by each farmer of Tk7/KG. This obtained a frequency-weighted mean loss per annum of Tk9975/Ha

	"Serious" Mean	"Middling" Mean	"Good" Mean
Frequency	0.34	0.22	0.44
Yield (MT/Ha)	0.67	2.71	3.98
Loss (MT/Ha)	3.31	1.27	
Loss (Tk/Ha)	23 350	8 925	

Farmers tended to rely on insecticide sprays for hispa control. The promotion of non-pesticidal controls by the DAE and others has clearly assisted in the use of these, and of sweepnets in particular, though these are useful suppressants rather than "solutions" to an outbreak. Farmers in this tended to follow the prescriptions of DAE advice, using sprays as a last resort, though perhaps more readily than the extension would promote. Table 1.30 shows the percentage of respondents reported as having used hispa controls in the last nine years, and Table 1.31 the frequency of use of those who used them. It can be seen that more made use of sprays than of non-pesticidal options, but that farmers used them (and all hispa controls) only in a minority of years. Table 1.32 shows the percentage returns to investments by each control, as reported by farmers, and indicates the higher perceived return to spraying. The scoring matrix of farmers' answers indicates that while sprays were seen as more expensive than sweepnetting, and a health hazard (implying this was a sample of relatively well-informed farmers) these disadvantages were outweighed by their greater effectiveness, and also the much higher awards for labour demands and "tiresomeness" awarded to non-pesticidal controls, and that these translated into more frequent use of sprays than other controls - at odds with their promoted role as a last resort. It also reflects the difficulties farmers had with leafclipping, considering it long and tiresome work, costly (in hired labour) and damaging to plants. Access to controls was not reported as a particular problem.

Table 1.30. (summarising 1.13). Percentage incidence of pest management practices among farmers in different wealth categories.

Category	A	B	C
Sprays	98	96	91
Sweepnetting	42	56	64
Leafclipping	25	25	9

Table 1.31. (summarising 1.20). Percentage frequency of performance (over nine years) of pest management practices, among farmers practising them, in different wealth categories.

Category	A	B	C
Sprays	30	25	22
Sweepnetting	14	13	11
Leafclipping	14	12	11

Table 1.32. (summarising 1.15). Reported costs and benefits of hispa control options, as percentage returns on expenditure.

Control	Spray	Sweep	Clip
Percent return	1229	544	951

Insecticides are currently the 'key' control option but this is not necessarily a situation of “pesticide abuse”. Most farmers use sprays against hispa, but only in a minority of years – granted the limited effectiveness of alternatives this may well be (from the farmers’ point of view if not that of the environment) the current optimum strategy, with high flexibility of use in response to the perceived lumpy distribution of pest seriousness between years. This use of sprays as a last resort, behind an initial defence of nonpesticidal controls, reflects DAE opinion. The difference is that not all farmers use nonpesticidal controls first.

2. Economic Costs and Benefits of Hispa Management Options

2.1. Farm-level returns

Due to the severe weather and flooding of 2004, the experiment encountered obstacles, and in the event data were gathered from only four plots – one in aus and three in aman – and no data of pest infestation were gathered which could allow this to be compared between treatments. Pest infestation data were gathered, however, early in the attack on each plot, before control operations started, to allow the overall level of attack to be compared between farms. The data sheets for each farm, listing yields, inputs and outputs, are given in Appendix 2.2.

The initial assessment was of yield and the increases in it attributable to the treatments. Table 2.7 shows the results obtained from the harvested plots. There was an overall significant difference between the three treatments (F=6.4966[2,6]*) though less than that between the four sites (F=10.7514[3,6]**); the difference between the level of improvement obtained by the two controls was not significant (related t=1.4172[3]ns {P=0.2514}). The percentage increases obtained – 55% for sprays and 34% for sweepnetting – were in broad alignment with those from the literature assembled in Section 2.1.1.

Table 2.7. Results from comparison of three hispa control regimes on four farms in 2004. Given for each is the yield, and for the two protected plots the percentage yield increase, over the unprotected plot, attributable to them.

	Yield (MT/Ha) in plots under protection by			Percentage increase attributable to	
Farm	Spray	Sweep	None	Spray	Sweep
A (aus)	4.3	4.6	4.4	-3	3
B (aman)	4.3	3.7	2.9	48	26
C (aman)	3.2	2.6	1.4	129	84
D (aman)	4.1	4.0	2.9	44	40
Mean	4.0	3.7	2.9	54	38
SD	0.5	0.8	1.2	55	34

The different levels of yield between the various farms (blocks) was in large part due to variations in the level of hispa attack encountered, as is shown by the infestation records, taken before the first control operation over the whole plot, summarised in Table 2.8. The plot in which controls in general and insecticide in particular fared worst (A) was that in which attack was lightest, and that where they performed best (C) was where it was heaviest, and this may explain some of the variation in control performance.

Table 2.8. Background conditions of pest infestation and plant production, on farm trial plots assessed before controls were carried out.

Farm	Mean Growth stage	Tillers per hill	Leaves per tiller	Leaves per hill	BPH Adults per hill	% Dead hearts /white heads	Hispa Adults per hill	Hispa % leaf damage
A	4.0	11.3	4.0	44.9	0	0	1	12
B	2.0	14.6	4.7	68.6	0	1	290	23
C	2.0	11.5	4.6	52.7	0	3	415	46
D	2.3	7.4	5.0	37.1	0	0	4	11

A subsequent assessment examined cost/benefit return ratios by the two controls, with the results summarised in Table 2.9. These may be compared with the cost and return estimates obtained in the formal farmer survey and given in Table 1.15: overall spray costs in Tika/Ha are here 2578 and there 1500; spray returns are here 9869 and there 15000; sweepnet costs are here 1223 and there 600; sweepnet returns are here 7357 and there 3825. These figures indicate that the two studies each reinforce the validity of the other.

Table 2.9. Itemised costs and returns of insecticide cover spray and sweepnet controls of hispa in four farm plots, 2004. All values are given per hectare, and all costs in Tika. Underlined values are supposed (farms A,B and C used family labour; farm D owned its own sprayer).

	Insecticide					Sweepnet				
Farm plot	A	B	C	D	**Mean**	A	B	C	D	**Mean**
Cost per operation										
Insecticide	Cy-per-meth-rin	Ra-loth-rin	Cy-per-meth-rin	So-bic-ron						
Insecticide cost	1200	580	750	1243	**943**					
Man-hours of labour	9	17	21	18	**16**	17	13	16	18	**16**
Labour cost	<u>156</u>	<u>278</u>	<u>347</u>	298	**270**	<u>278</u>	<u>208</u>	<u>260</u>	298	**261**
Sprayer hire daily	30	50	50	<u>50</u>	**45**					
Sprayer cost	47	139	174	<u>149</u>	**127**					
Number of operations	1	3	2	2	**2**	4	6	4	5	**5**
Cost per harvest										
Insecticide	1200	1740	1500	2486	**1731**					
Man-hours of labour	9	50	42	36	**34**	67	75	63	89	**73**
Labour cost	<u>156</u>	<u>833</u>	<u>694</u>	595	**570**	<u>1111</u>	<u>1250</u>	<u>1042</u>	1488	**1223**
Sprayer cost	47	417	347	<u>298</u>	**277**					
Return										
Rice price (1KG)	8	9	9	10	**9**	8	9	9	10	**9**
KG over unprotected	-150	1400	1800	1250	**1075**	150	750	1180	1143	**806**
Return to control	-1200	12600	16200	11875	**9869**	1200	6750	10620	10857	**7357**
Total cost	1403	2990	2542	3379	**2578**	1111	1250	1042	1488	**1223**
Total benefit	-1200	12600	16200	11875	**9869**	1200	6750	10620	10857	**7357**
Net return to cost (%)	-186	321	537	251	**231**	8	440	920	630	**499**

Table 2.9 indicates that the cost/benefit return ratios of both methods were valuably positive, 500% for sweepnetting and 230% for spraying. Again, the returns to control were least in the lightly-attacked plot A and highest in the heavily-attacked plot C – but the heavy attack did not seem particularly to favour sprays over sweepnetting, as may have been expected of the “Fire brigade” role sometimes attributed to sprays.

2.2. Government-Level Returns

2.2.1. Sweepnet donation

Each donated sweepnet was estimated to cost the Government 80-100Taka, and to last for 6 seasons. Sweepnetting was estimated from the experimental data to increase yields when under hispa attack by 35%.

2.2.2. Provision of sprayers and pesticide

Each hand sprayer was estimated to cost the Government Tk3500, and to last for 15 seasons if properly maintained (it may require some small repairs during its life).

Each motorised power sprayer was estimated to cost Tk5000-15000 depending on the type. A better-quality one may last for three seasons if properly maintained (requiring some small and running repairs).

Donated pesticides were estimated to cost the Government Tk800-1000/litre. To spray one hectare requires approximately 800 to 1700ml per spray.

Insecticide spraying was estimated from the experimental data to increase yields when under hispa attack by 55%.

2.2.3. Farmer training

The costs and returns to farmer training by the SPPS programme were calculated from SPPS literature. The analysis is given in full in Appendix 2.3. This concluded an implied cost of training farmers in rice hispa IPM as Tk50/farmer, and of the increase in yield due to improved hispa control as 12%.

2.2.4. Comparison of returns to state investments

The estimated figures above obtained the estimates of cost benefit returns in Table 2.10.

Table 2.10. Estimates of costs, benefits and net returns to hispa control operations funded by the state. Estimates have been made from a variety of sources. Those for yield increase returns to controls are assigned to the years categorised by farmers in the formal survey as "Bad" and "Middling" for hispa attack damage, with their reported frequencies and rice yields, as set out in Table 1.6: In a "bad" year yield is estimated as 0.067 maunds/decimal (equivalent to 0.067x40x250=670KG/Ha), and these years arrive with a frequency of 0.340; in a "middling" year yield is estimated as 0.271 maunds/decimal (equivalent to 2710KG/Ha), and these years arrive with a frequency of 0.215. These estimates were made with a price of rice of 7.5Tk/KG, and the size of an individual farm as 0.01Ha.

Action	Unit	Cost /unit	Service life	Cost/ season	Cost /unit	Cost /Ha	Yield increase	Yield increase	Benefit /Ha	Net return
Unit	Unit	Tk /unit	Season /unit	Ha /unit/ season	Tk /unit/ season	Tk /Ha/ season	%	KG /Ha/ season	Tk /Ha/ Season	%
Training	Farmer	50	20	0.01	2.5	250	12	175.2	1314	426
Sweepnet	Net	90	6	0.01	15	1500	35	511	3833	156
Spray	Sprayer (M)	10000	3	50	3333	67				
	Sprayer (H)	3500	15	10	233	23				
	Pesticide	900	1	1	900	900				
	Spray (H)					923	55	803	6023	552
	Spray (M)					967	55	803	6023	523

The values in Table 2.10 are estimates, and should be hedged with a variety of caveats. Many of the values were estimated, and these may materially affect the outcomes quite significantly, as was shown by a simple sensitivity analysis. In particular, the estimates of the areas treatable per season by different types of sprayer may be too low, and the returns to sprays are considerably improved if these are adjusted upwards; also the analysis is sensitive to the value used for the size of an individual farm, for which 0.01Ha may be too high - if farm size is 0.002Ha, returns on sweepnets become negative (-48.9%) and those on training are greatly reduced (5.1%) whereas those to sprays remain the same.

2.3. Conclusions

2.3.1. Farm-level returns

This study implies confirmation of what was already more or less known – that pesticide sprays provided the best protection against hispa at farm level, and positive economic returns, but that sweepnetting also provided protection and, as involving less financial outlay on pesticides and accessible to those using only unpaid family labour, did so while incurring considerably less investment and therefore risk. The compatibility of these findings with the leafclipping finding in the literature is unclear, and perhaps not entirely relevant as farmers are generally deeply reluctant to clip leaves.

2.3.2. Government-level returns

Overall, it may be provisionally concluded that the returns to investments by different hispa management support options available to the Government are broadly similar.

2.3.3. Summary and conclusions

A survey of the literature found little evidence of useful levels of hispa control to be obtained by predators, parasitoids or host resistance.

Farm-level yield increases obtained by sweepnetting and insecticide sprays under hispa attack were assessed by a field trial on four farms in 2004. While obtaining results less clear than hoped due to adverse weather, this obtained estimates of yield increases and net returns to cost as summarised in Table 2.11. While gross returns to sprays may be larger, sweepnetting may offer better net returns due to its lower investment costs. There was an indication that the returns to both controls, and pesticides in particular, were greatest at higher levels of pest infestation.

Table 2.11. (summarising 2.9). Percentage inferred yield increase, and costs and returns (in Tika/Ha) of insecticide cover spray and sweepnet controls of hispa in four farm plots, 2004.

Control	Spray	Sweep
Yield increase (%)	55	35
Total cost	2 578	1 223
Total benefit	9 869	7 357
Net return to cost (%)	231	499

Estimating the costs and benefits of Government options is prone to a wide source of errors, and of dependencies on the scale they are calculated. In spite of this, estimates were made of the unit costs, benefits and returns to control activities by the State, and these are summarised in Table 2.12. Overall, there was a surprising level of similarity among the levels of return to the different options.

Table 2.12. (summarising 2.10). Summary of estimates of costs, benefits and net returns to hispa control operations funded by the state, frequency-weighted for possible benefits in years when hispa attack may be "serious" or "middling" to obtain a mean value per year. These estimates were made with a price of rice of 7.5Tk/KG, and the size of an individual farm as 0.01Ha. Costs and benefits are in Tika/Ha, yield increases and net returns as percentages.

Action	Cost	Yield increase	Benefit	Net return
Farmer training	250	12	1314	425.6
Sweepnet donation	1500	35	3832.5	155.5
Field spray (hand-operated)	923	55	6022.5	552.3
Field spray (motorised)	967	55	6022.5	523

3. Options for Institutional Frameworks for Implementing Rice Hispa Control

3.1. Newspaper study

Seven Bangla-language and nine English-language reports were found, in national and regional newspapers, between 1997 and 2003. The reports are appended in Appendix 3.1. Most reports did not distinguish effects attributed to different pests, and the effects summarised below are largely attributed to all insects.

The reports in both languages often followed a set pattern of reporting, as (1) extent of damage, (2) expressions of alarm by farmers, (3) farmer requests for Government assistance and sometimes (4) a report of activities, usually planned rather than actually performed, by the authorities.

The language used was generally dramatic and cataclysmic, treating outbreaks as sensational events rather than routine. Only emergency reports were treated as "news" - no items recorded the easing of crises or Government intervention taking effect.

Associated with reports was typically a discussion of the desirability and limitations of chemical control. Frequently pests were cited as unable to be controlled, and pesticides as either ineffective or excessively costly. Pesticide availability and cost problems were emphasised, one case linking losses to a "crisis of insecticides" in the headline; another citing an "abnormal price hike of insecticides" – implicitly criticism of the development of a free market in pesticides.

Reporting was as much of social impact and requests for government support as of the outbreak itself: attacks were reported as social phenomena. Expressive words describe the difficulties of farmers – "frustrated", "disheartened", "fed up", "grave concern" and even "in deep despair".

For insect outbreaks, there was a clear, widespread and uncontested presumption of a duty of the Government to help - an implication of acceptance of dependency. DAE help was described as "necessary". Articulated demands were for active intervention rather than training or other support to self-help. Demands were frequently imprecise in this regard ("Farmers urged the authorities concerned to take effective measures"); in the articles examined the requests were not for aerial sprays but for pesticides and sprayers, associated with reports of high prices of the former and shortages of the latter. In one case DAE "traditional" controls were described as inadequate because of high pesticide prices and the DAE as "prescribing natural methods of control."

Government actions were frequently mentioned as absent or inadequate, including in one the headline "Agricultural Department Inactive". Outbreaks were often attributed to this, such as one described as occurring "in the absence of timely spraying of pesticides by the authorities concerned". These criticisms were more vocal in English than Bangla-language publications; papers in Bangla more often reported agency statements about intentions and activities. Government agencies were not openly criticised, but favour was given to complaints by farmers and representatives, while official reassurances were subtly undermined, and set at odds with those by farmers. Reporting of official responses to outbreaks did not appear to represent a generalised distrust of Government and the authorities. The unusual and outbreak nature of pest problems set the presumption of Government assistance to deal with them in contrast with other problems. There were no indications of pest emergencies becoming "political footballs" with the political opponents of the Government making statements that it could do a better job.

3.2. Interview study

The text of the interviews is given in Appendix 3.2.

3.2.1. The rationale for state ivolvement in hispa management

The widespread perception of hispa, by farmers, the public and policy-makers, as in particular need of state intervention, is centred on two key ecological characteristics which define its difference from other pests in the mix of private and state inputs to management. The first of these is that hispa attacks are "all-or-nothing" being either absent or severe, with a "lumpy" distribution over time. At farm level this places a premium on threshold rather than preventative control; at institutional level it indicates a role for forecasting to allow preparation for an epiphytotic. The second characteristic is the wide area covered by infestation and the perceived high mobility of hispa adults, making control more attractive at a large scale rather than field level. At farm level this suggests that control may require synchronisation among all the farmers in an area; it also indicates a need for active intervention at an institutional level, by local or national Government, NGOs, cooperatives or similar, to provide comprehensive area-wide control. These two ecological characteristics also combine to make hispa a particularly frightening pest because of its potential to cause wide-scale destitution, known at least since it was described in 1909 as "the rice hispa that causes famine" (Maxwell-Lefroy, 1909). Their influences on the options of farmers and institutions are summarised in Table 3.1. These two aspects are essentially questions, first, of timing and, second, of scale, and these two come together in the importance of speed in hispa response - that hispa, more than other pests, is perceived as requiring treatment which can reach large areas quickly.

Table 3.1. Influences of two ecological characteristics of rice hispa on the options of decision-makers among farmers and institutions.

Ecological characteristic:	Lumpy time distribution	Wide scale infestation
Farmer options:	Threshold control	Synchronised control
Institutional options:	Forecasting	Active intervention

3.2.2. Options for government intervention

The objective of state intervention in hispa management is to enhance the livelihoods of farmers, and also thereby the national food supply, by reducing losses of yield and income to hispa and, in particular, in "outbreak incidents" bringing the losses within acceptable levels.

The presumption by farmers is that the management of hispa, in particular, is something for which they will receive support from the Government paid for from the public purse by general taxation. This presumption is mirrored by the view of newspapers, and is accepted by the Government itself. There is at present no indication of a move to devolve the burden to costs to specific beneficiaries instead of the public at large. NGOs interviewed focused on social issues and support such as credit, and largely relied for the Government and the DAE for advice and support to insect pest management.

Similarly, the advantages of devolution of operations are little discussed. Generally speaking, DAE operations are managed at national level, rather than local levels. This has manifest advantages in the optimum use of resources, as Bangladesh is not a large country, and to move resources about to areas where they are most needed, under central direction, is a logical way to organise pest control assistance.

The views of the staff of the DAE Operations Directorate about the need for different responses to hispa relative to other pests mirror those of farmers. Just as farmers see hispa as likely to arrive infrequently in isolated but destructive episodes, the DAE tends to respond more robustly to hispa outbreaks. There is at present a universal consensus, among farmers, the media and the Government itself, that the management of farm insect pests in general and hispa in particular will continue to be supported by the state, centrally directed and funded from general Government revenue.

At the present, the options available to institutional agents such as the Government are the following:-

1 - IPM Extension advice and training to farmers
2 - Payment of a bounty for hispa collected, to promote control of populations
3 - Donation of sweep-nets to individual farmers
4 - Funded provision of field insecticide controls, by locally-recruited teams
    - Donation of pesticides
    - Loan of spraying machines
5 - Aerial sprays

To these options may be added, as a potential future component, a second form of direct action in the form of mass releases of bioagents or natural enemies – the primary candidates being parasitoids such as egg parasitoids and entomopathogenic fungi such as *Beauvaria*.

The relative importance of these different options for the management of the four principle rice insect pests - hispa, stemborer, brown planthopper and leaf-folder - is summarised in Table 3.2.

Table 3.2. Scoring matrix of the importance of intervention options against four major rice pests - hispa, stemborer (masra), brown planthopper (BPH) and leaf-folder - as perceived by personnel at DAE Operations. Personnel were asked to score for "Importance" the roles of the different actions available to the Operations Unit in response to the various pests. Scores are 2 for maximum, 0 for no-use and '-' for not applicable.

Operation	Hispa	Masra	BPH	Leaf-folder
IPM Training	2	1	1	0
Bounty Payment	1	0	0	0
Sweep-Net Donation	2	1	0	0
Pesticide Donation	2	0	1	0
Sprayer Loan	2	1	2	1
Aerial Spray	1	-	-	-
Sum	10	3	3	1

Table 3.2 shows that, in almost every category, the options available to Government were seen as more important for hispa than for other pests: there was a recognition that, relative to other pests, hispa had a greater requirement for state and social action rather than leaving farmers to their own devices. This was particularly so for options such as aerial sprays which allow a quick response to treat large areas. Of the options available, in the case of hispa in comparison with other insects the options of IPM training and the loan of sprayers tended to be used against all pests, the provision of nets and pesticides against hispa and one other pest, and two of the most intrusive actions - the bounty payment system and aerial sprays - restricted to use against hispa alone.

3.2.2A. Farmer training and the provision of information

Farmer training has formed a major thrust of DAE operations in recent years, particularly with the assistance of the Danish DANIDA programme. There has recently been, and is currently, a move away from the traditional "visiting-extensionist" model to an approach of farmer field schools in the mode of those developed in Indonesia.

DAE farmer advice for hispa management focuses on (a) clean cultivation and similar practices to discourage pest outbreaks (b) non-pesticidal methods, particularly sweepnetting and leafclipping and (c) the use of insecticide sprays as a last resort in the case of heavy attack. The restraint of insecticide use is specifically for the protection of natural enemies. This advice partly reflects what farmers were disposed to do anyway - because farmers see hispa as episodic, arriving in serious numbers or not at all, farmers were in any case likely to use insecticides when an episode occurred, and not to do anything when one was absent, as with no hispa in evidence any controls would be to no effect, and to consider the decision as to whether or not to act to be not very difficult. DAE advice therefore to some extent rationalises and confirms this approach, with the addition of non-pesticidal controls used against populations intermediate between "absent" and "serious".

Training provides a multitude of useful services, not least in that hispa management training can and does work alongside the provision of other useful information in the management of other pests and other aspects of the farm. It also has no "downside". By itself, though, it will and does not satisfy the demands of farmers, supported by the press and public, for more active interventions.

3.2.2B. Hispa bounty payment

When hispa is at outbreak levels, one tool is to offer a bounty payment, most recently of Tk20/KG for adult hispa collected in the fields and brought in. The benefits of this practice are difficult to quantify, but as an additional benefit offer employment to vulnerable country people in times of economic difficulty. As the deal is best for the recipient when hispa is very abundant and therefore collection of a unit volume less strenuous, uptake at the height of outbreaks may be greater than in critical "building-up" periods, when intervention may be more important.

3.2.2C. Sweepnet donations

Sweepnet donations have no "downside" and provide a useful resource to farmers. Farmers will not view sweepnetting alone as sufficient when hispa presence is heavy, and will then seek to spray, but this does not diminish the real usefulness of nets.

3.2.2D. Field sprays

When hispa outbreaks are serious, DAE intervenes directly by supplying sprayers and pesticide for use by locally-assembled teams directly to farm fields. Sprayers and pesticides are generally, but not always, supplied together. There is an aim to have a network of depots at Upazilla, District and National levels, to allow a fluid deployment, combining on-the-spot storage with mid- and central-level strategic reserves which may be moved to outbreaks.

Field-level sprays were widely seen as useful and appreciated. They most obviously satisfy the demand for "action" by the Government that is articulated in newspaper reports of pest outbreaks.

3.2.2E. Aerial sprays

An aerial spray capacity to deal with serious hispa outbreaks on a very large scale has long been a visible line of defence. Sprays over large areas were last conducted in 1992, and some to control populations developing in isolated, uncultivated areas in 1997. In other words, the capacity has been largely inactive for over a decade. Money was invested in a new fleet of three aircraft, including two adaptable for temporary conversion to an alternative "peacetime" role for VIP transport, which has not yet been used. Funds to maintain the aeroplane fleet in a resting mode is limited, and pilots and other personnel are paid work-rate payments which make their income while operating very considerably more than while inactive, so the fleet of aircraft is temporarily inoperable and staff out of practice. Aerial sprays when carried out were very popular with farmers, who often campaigned vocally for operations to be conducted or extended; environmental voices and others, such as those with shrimp or prawn farming interests, have increased their criticism of the approach since operations ceased.

3.2.2F. Parasitoids

Parasitoids reared for inundative releases require a relatively long period for the build-up of populations large enough, and as a result may only be able to be effective if they can be used preventatively and routinely. The long lead times of production for any "nip in the bud" strategy would need to be informed by unrealistically long warning periods. It remains to be seen whether ecological research may identify ways in which a regular, annual prophylactic release of parasitoids may obtain satisfactory control under all conditions.

3.2.2G. Entomopathogenic fungi

A future possibility may be the use of entomopathogenic fungi for field sprays. Fungi are often slightly frowned on by farmers and the public as producing no dramatic instant knock-down, and delaying effects until more damage is done. On the other hand their lower health and environmental risks make them attractive as a responsible response by the state. The distribution and warehousing system to provide pesticides to the field may pose a strain on the durability of live fungi, but there are technical solutions to these problems (such as batch marker tags which change colour if they are exposed to conditions likely to be damaging to the fungi).

Aerial sprays of chemical insecticides against hispa in the past, while broadly successful, may not be possible again, as public and international awareness of the dangers of aerial pesticide application has increased; scientific and production evidence have emphasised the costs of losses of natural enemies; and the maintenance, and indeed cultivation, of stocks of fish and prawns has increased in significance. On the other hand, aerial spraying may benefit in particular from the use of entomopathogenic fungi rather than synthetic insecticides, if fungi can be shown able to control hispa populations under Bangladeshi conditions. Successful evaluations of fungi in India have not been repeated in Bangladesh, and it is unclear whether these are due to differences in control effectiveness or to assessment conditions.

Experience tends to have found that fungal cultivation, drying and packaging etc. must be carried out with strict attention to quality control, and that production in a single central facility is more likely to be effective than decentralised, localised production. Such centralised production may lend itself well to combination with the central direction of aerial control.

3.2.3. Past changes in the emphasis on control options

Over recent years the relative fortunes of different options have fluctuated, as perceptions of some priorities have changed and DAE has developed and improved its understanding of what produces results. To illustrate this, DAE personnel drew up a series of plots charting the fortunes of the six principal state control options in terms of their expenditure and overall importance, from 1984 to 2003. This indicated the following trends:-

- Training has always and steadily increased in importance, throughout the 1980s and 1990s to the present.

- The donation of nets increased consistently through the 1980s and early 1990s and has been steady, and high, since the early-mid 1990s.
- Bounty payment has had two surges with the big infestations, rising to peaks at the height of infestations, in 1989 and 1995, with much lower levels of importance at other times.
- Sprayer loans rose throughout the 1980s, were high between the late-1980s and mid 1990s, and have since declined.
- Pesticide subsidies rose with similar timing to the loan of sprayers, but at an even faster rate of increase, and have declined with similar timing, but an even faster rate of decline.
- Aerial applications, after intense importance during the last emergency in the late-1980s until the early 1990s, have declined most sharply of all, to minimal importance since about 1992.

3.2.4. Summary of the implications of options available to the state

The advantages and disadvantages of the various options are listed in Table 3.3, along with assessments of how they may develop in future.

Table 3.3. Summary of the Implications of Options.

Option	Advantages	Restrictions
Aerial application – chemicals	- Effective, visible, popular with farmers	- Environmental side-effects are severe, and the perceived importance of these increasing - Role of shrimp/prawn/fish culture is increasing - Lumpiness of demand makes provision of a standing response costly
Aerial application – fungi	- If effective, may offer all the benefits of chemical aerial applications with none of the disadvantages	- Effectiveness of fungi still uncertain - Delay in death of targets may reduce effectiveness in public perception - Lumpiness of demand makes provision of a standing response costly
Sprayer loans and chemical donation for field applications	- Seen as a valuable response - Able to target specific problem areas - Less environmentally and socially risky than aerial applications	- Reaches smaller areas in a longer time than aerial applications - Complications in supply chains, warehousing, transportation etc will inevitably lead to “hiccoughs” in provision
Fungal donation for field applications	- Offers the benefits of chemical applications with minimal environmental risk	- Delays in target kill - Vulnerability of fungi to deterioration in warehousing, transport etc runs the risk of reduced effectiveness, in public perception if not in fact
Net donation	- Offers real support to control of hispa and other pests - No “downside” in terms of environmental/health risks - A “one-off” provision needing no follow-up	- Not seen by farmers as a complete solution to all hispa problems
Bounty payment	- Simple and direct to implement - Provides income assistance to those in need	- Not precisely targetable as to area - Not perceived as very effective or important, particularly in “build-up” periods

Training	- No “downsides” - Can be integrated with other information provisions and capacity-building - Provides a permanent improvement	- Not currently seen by farmers or the media as the only necessary response

3.2.5. The current and potential role of forecasting

An enhanced role for forecasting and the provision of advance information may have impact on of the options available to the Government. Field personnel estimated the necessary lead/warning times for different operations, and these are given in Table 3.4.

Table 3.4. Lead times and duration times for control operations, estimated by DAE personnel.

Operation	Lead time	Duration time
Training	No time	7 days
Net donation	7 days	10 days
Bounty payment	7 days	7 days
Squad organisation	7 days	7-10 days
Sprayer for field sprays	7 days	7 days
Pesticide for field sprays	7 days	10 days
Aerial sprays	21 days*	21-28 days

*** - 21 days would be the ideal “resting level”; from the current state of readiness to operations would take 2 or 3 months; if at a state of high alert and readiness operations could begin in 24 hours.**

The importance of speed raises the question of the role of forecasts and early-warning systems, by which science in the form of insect ecology may provide advance information. The options for action, listed above, may be either supplanted or supplemented by forecasts and early-warning systems - this may provide information either to farmers, to allow them to carry out better pest management, or to institutions, to allow the options listed above to be used more effectively. A key question is how much time would be needed, which depends on what the warning is actually for - which control options it will trigger.

3.2.5A. Forecasting and provision of information and advice to farmers

Outside the field of direct intervention, early warning may allow farmers to make preparations for farm-level control operations, and allow material supports to be gathered together at points chosen at an optimal level effectively to address any particular hispa outbreak. It is not yet clear what might be the value to farmers of a hispa early warning system and what might be the necessary time interval. Farmers may benefit from warnings to save money to buy chemicals, make purchases, negotiate to borrow a sprayer or plan activities to free up labour.

Table 3.5 shows estimates of the time it may take for individual farmers to prepare and carry out private spray operations. These are longer than the mean estimate of 1.67 days obtained by the formal farmer survey (Table 1.24). When asked in the farmer interview survey, this question did not obtain from farmers particularly high estimates of the value of a warning system, or of the difficulty of responding in time to a hispa outbreak, and there is no obvious current benefit from a warning system directed at farmers.

Table 3.5. Estimates, provided by DAE field personnel, of the time taken for individual farmers to prepare and conduct private sprays, for typical members of the three main wealth categories.

Category	Time taken
“Small”	1-2 weeks
“Medium”	1 week
“Large”	No time

3.2.5B. Forecasting and government-supported field sprays

The provision of sprayers and pesticides suffers from difficulties of supply and storage to allow an outbreak to be met promptly. It is currently proposed to allow for reserves to be stored at multiple levels - from national to local - which offers the prospect of a flexible system of sources of supply, relatively close and distant to any one location. Forecasts would allow this system to be operated more efficiently.

Advance warning would allow the movement of equipment, material and personnel to local depots so that it can be quickly and efficiently provided. Managers of the supply of materials in support of field sprays have pointed out that the balance of depot reserves at local, regional and national levels is important, and difficult to optimise. Forecasts as to where material may be needed would considerably ease bottlenecks of supply, and allow the control effect exerted per unit of equipment to be increased.

3.2.5C. Forecasting and aerial sprays

The perceived lumpy time-distribution of hispa dynamics - with serious outbreaks randomly punctuating years of quietness - is difficult to fit with the maintenance of a standing, ready aerial control capability.

On the one hand, aerial sprays have in the past been very popular with farmers and the public, and tend to be favoured for political reasons as providing a highly conspicuous, high-technology provision which is widely witnessed and understood. On the other, during periods of inactivity, pilots find themselves spending years on end sitting about, with only very brief training and familiarisation sorties in aircraft. When outbreaks occur the additional pay generated by additional payments for actual flying can quickly treble or quadruple pilots’ salaries. Similarly, aircraft, with maintenance budgets eroded by years or decades of quietude, may become temporarily unserviceable and require a long period of work to be restored to airworthiness. The Government of Bangladesh has long been aware of the difficulties of this, and aimed to provide an alternative use for the aircraft, in order to make some use of them outside outbreak periods, by ordering dual-purpose machines which can be adapted to carry passengers. A genuine, productive alternative role for the aircraft in non-outbreak years would be an advantage for the financial balance of the operations wing, the airworthiness of the machines and the income and morale of personnel. Options may include air ambulance services to remote communities, the delivery of high-value low-volume relief materials such as medicines to isolated communities in emergencies, and the policing of the coast and territorial waters for the control of smuggling, piracy and illegal fishing.

If suitable alternative uses cannot be found, if an aerial control capability is to be maintained, it must be able to be maintained in a resting state (“mothballed”), for years or even decades at a time, and then brought up to readiness in time when needed, and a forecasting system will clearly be vital for such a strategy. With an adequate early warning system, aircraft could be used for other duties, or maintained inactive in storage, and redeployed when a warning was issued. Pilots might be seconded as "Territorials" to other activities such as commercial flying, and then on warning extracted for pest management duties (which are appreciated by pilots as substantially more challenging and enjoyable than routine commercial aviation) which could, with adequate warning, be relatively smoothly handled (forestalling personnel "bottlenecks", for example, by advanced adjustment of duty rosters such as by rescheduling holidays).

3.2.5D. Forecasting and bioagents

The constraints of a lumpy time distribution have different implications for synthetic insecticides, predators/parasitoids, and entomopathogenic fungi. Forecasting is of particular importance for the production and use of the candidate bio-agents of fungi and parasitoids.

The need, for a presumed continuing institutional role in hispa management, for a rapidly-responding "fire brigade" capability would seem to mitigate heavily against parasitoids and in favour of entomopathogenic fungi. Not only are fungi more easy to apply from the air, but they also have the crucial combined qualities of storeability and shorter "run-up times". Even if they require refrigeration, the fungal pathogens needed to treat, say, a thousand square kilometres may be stored and deployed relatively quickly when called for; parasitoid production will not have this crucial advantage for the foreseeable future.

It is conceivable that early warning may allow the running up of the production of live control agents such as parasitoids. It seems at present, however, that prediction of the accuracy and length of advance warning to rear the several successive generations which would be necessary for rearing on a suitable scale would be difficult to achieve.

The discussion above has indicated there may be a future role in institutional hispa management for aerial applications of entomopathogenic fungi - these would provide the speed and high profile of aerial applications, without the disadvantages of synthetic pesticides (environmental and health risks) or of reared-up insect natural enemies (long run-up times); fungi may be stored at a central depot, and aircraft and personnel seconded to other activities, and a forecast warning system may allow time for these to be extracted from these activities with minimal costs. It is not clear whether the entomopathogenic fungi available for hispa control would be adequate for the task, however. If not, on the other hand, it may be impossible for an aerial application capacity to be used at all.

3.2.6. Summary of the interaction of forecasting and government policy options

For forecasting, the critical influence on policy options is the interaction between the episodic nature of pest incidence, the information capabilities of forecasting, the information needs of forecasting and what is intended to be done. In particular, the benefits of high storeability, a fast response capacity and a long warning time are all essentially to some extent interchangeable, as storeability is a substitute for fast manufacture of controls,and warning allows more time. Options may be considered as three strategies, outlined in Table 3.6. (In the circumstances of public expectation the option “Do nothing” is probably not realistic).

Table 3.6. Characteristics of three strategies for publicly-assisted hispa management.

Option	“Routine /preventative”	“Nip in the bud”	“Fire brigade”
Rationale:-	Only safe control is routine, prophylactic control every year	Early warning allows measures to be used in time to prevent outbreak	Early warning of losses is inaccurate; only real-time information is accurate
Practice:-	Preventative measures are applied routinely every year, with no role for forecasting	Warning system linked to preventative measures to forestall predicted outbreak	Deploy remedial measures only when economic damage is already being caused
Control costs:-	High	Medium	Medium (and lumpy)
Information costs:-	Low	High	Low
Storage needs:-	Low	Medium	High
Fast-response needs:-	Low	Medium	High
Example:-	Parasitoids	Fungi	Pesticides
Main advantage:-	Low risk of warning failure	Low control costs	Low control and information costs
Main disadvantage:-	High and routine controls costs	Risk of warning failure	Risk of controls being too late, tolerance of losses, pesticide reliance

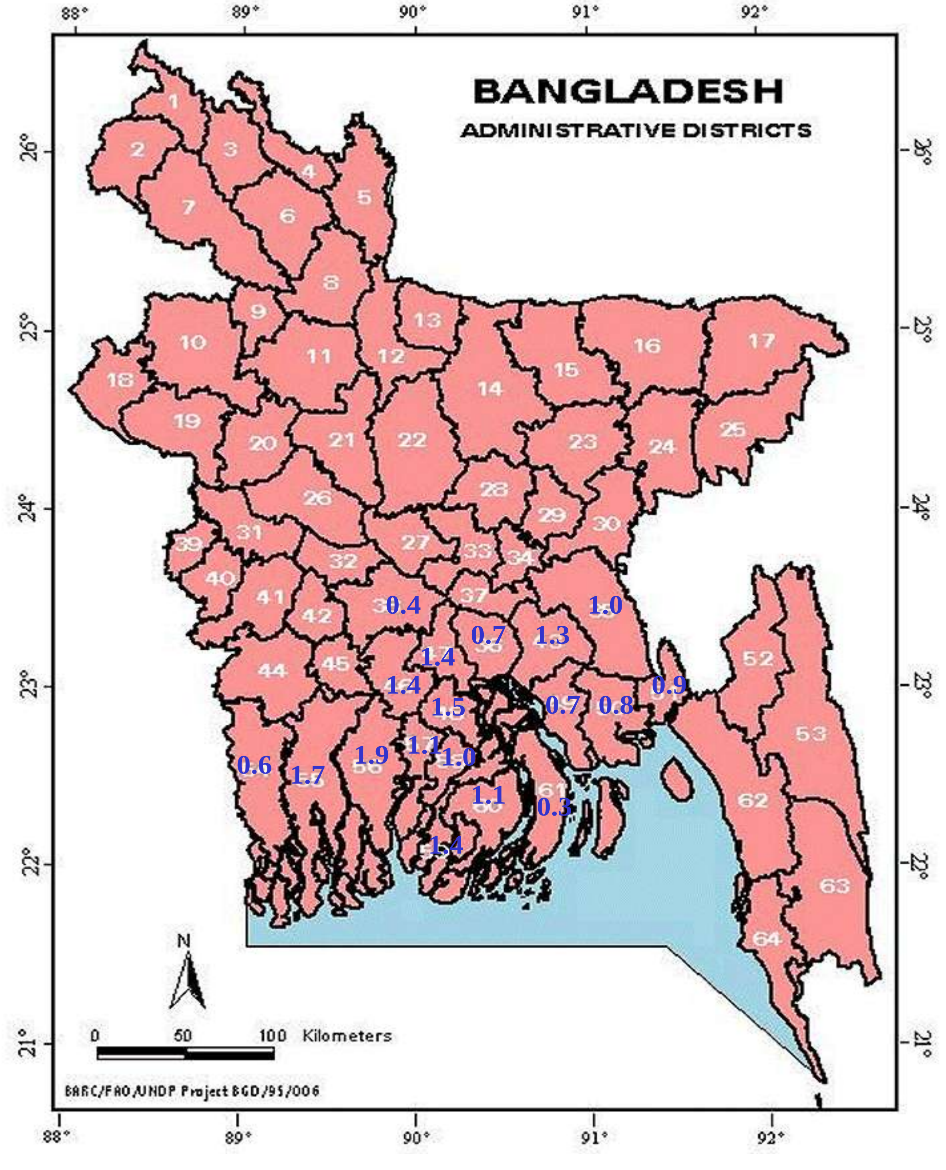
Table 3.6 indicates that for minimising both control costs and crop losses, the “nip in the bud” strategy, using early-warning to deploy preventative measures, is most efficient, if early warning can be made sufficiently accurate and the time allowed by warning is greater than the time needed for response. In its design early and accurate warning may be “traded off” for speed of response once warning is received - this is expected to be obtained from the ability of remedial material to be stored (anticipated as a disadvantage for parasitoids in particular and, to a lesser extent, fungi) and systems for rapid delivery to the field (possibly including arial application).

4. Analysis of Historial Hispa Data and the Development of Forcasting Models

4.1. Patterns of hispa incidence in 18 hispa-prone districts

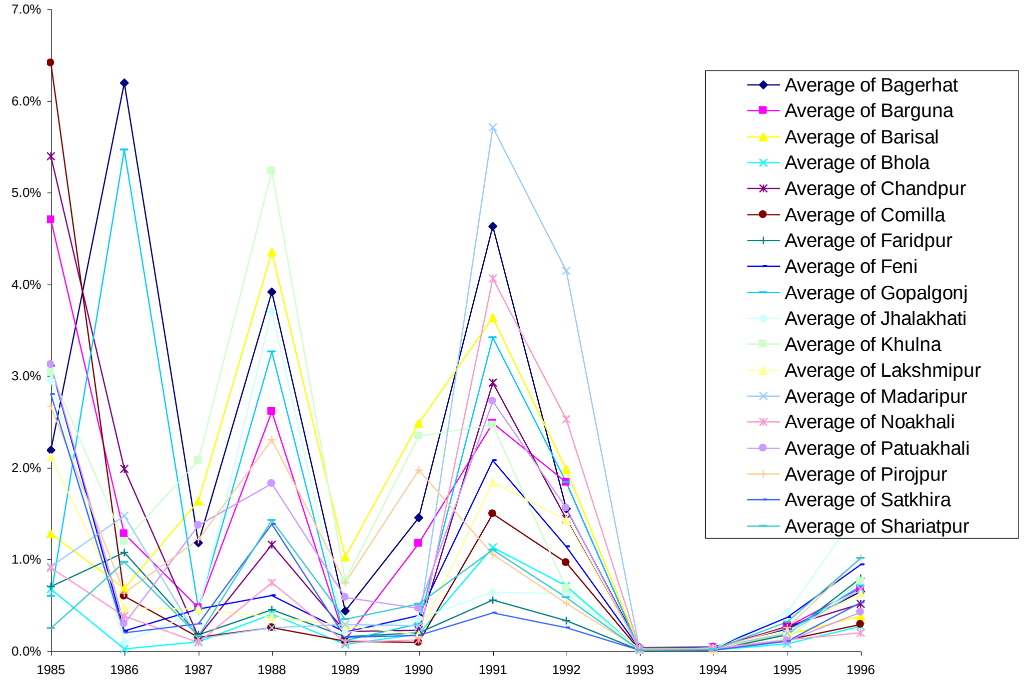
Hispa incidence data for 18 districts have been published (Islam, 1997). The mean area infected each month was calculated from Appendix D of Islam (1977) by averaging over the whole collection period from 1985-1996, and this was standardised by the district cultivable area. Mean % area infected per district ranges from 0.3% to 1.9% (Fig. 1). Incidence may be higher in the S than the N but the trend is not very strong, probably as a result of the districts being selected 18 perceived to be most hispa prone which are all in the southern part of Bangladesh. Thus, N ('North') in this context refers to the more northerly of these eighteen districts.

Fig. 4.1. District map of Bangladesh. Districts are labelled by the mean area affected by rice hispa over the period 1985-1996. Area is given as a % of the total cultivable area.



Mean % area infected by hispa was calculated for each for each year (the area infected each month averaged over the year and divided by the total cultivable area). The majority of districts had peaks in 1986, 1988 and 1991 (Fig. 2). The pattern of hispa incidence across years appears very similar between different districts. This synchronous pattern of hispa incidence was confirmed by plotting the area of the district infected by month again standardised by the total cultivable area (Fig. 3). This suggests that whatever is driving hispa populations is common to some extent to all 18 districts, and/or rapid and widespread migration is an important factor.

Fig. 4.2. Mean % of the cultivable area infected by rice hispa in each district, from 1985-1986



Next, districts in the N were compared in more detail with districts in the S on the basis that as hispa is more prevelant in districts in the S hispa epidemics in the N could arise as a result of migration from the S. Therefore peaks in hispa incidence would be expected a month or so later in the N, than in the S. 4 S districts with high hispa incidence were taken at random: Khulna, Bagerhat, Barguna, Pathuakhali, and similarly 4 N districts with lower hispa incidence: Faridpur, Shariatpur, Madaripur, Chandpur. In fact no such lag was obvious from Fig. 4. But the S districts did appear to peak in the year previous to the main peak for all 8 districts. This was also shown by the annual data in which the peaks for the S districts had a shoulder (Fig. 5). This suggests some factor in the S drives the epidemic which "primes" the N districts for a peak in the next year.

Fig. 4.3. Area infected (as a proportion of the total cultivable area) by month, for 5 districts (the first 5 alphabetically).

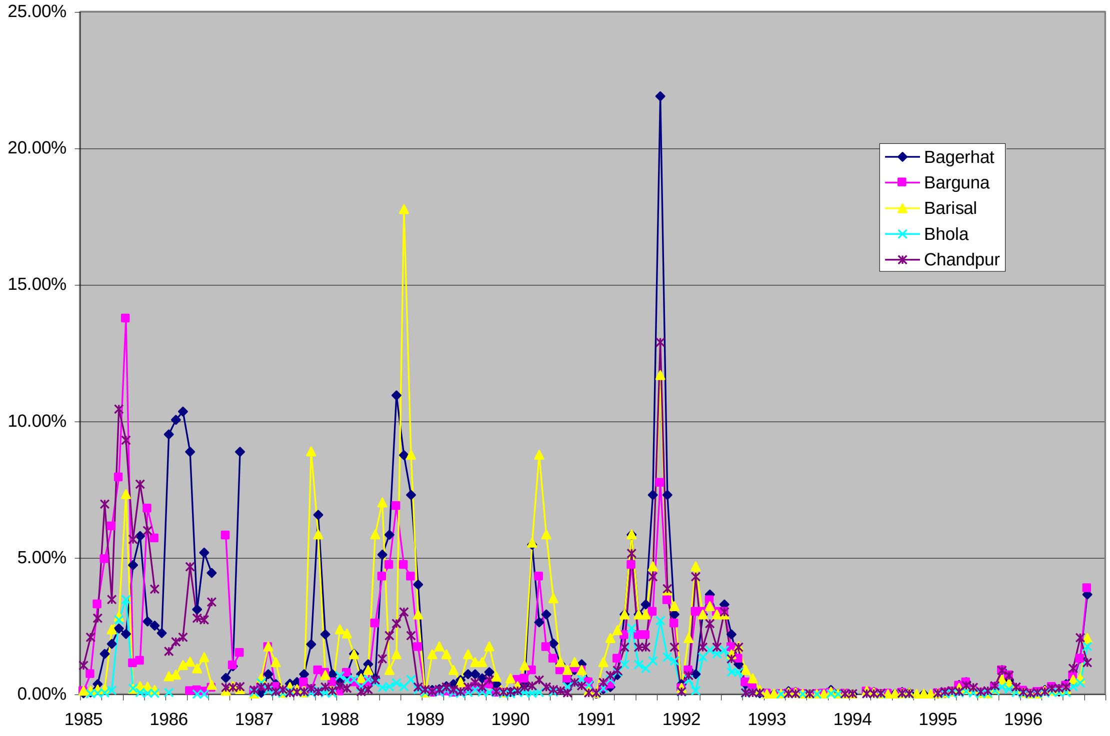


Fig. 4.4. Area infected by hispa (as a proportion of the total cultivable area) by month from 1985-1986 for 8 districts,: red lines the four S districts; black lines the four N districts.

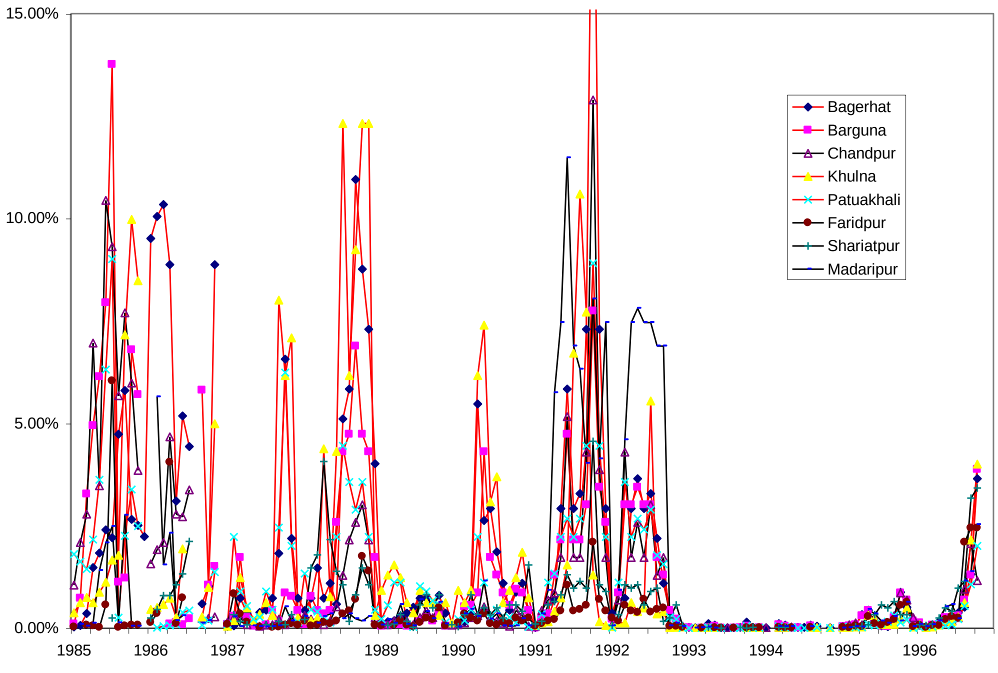
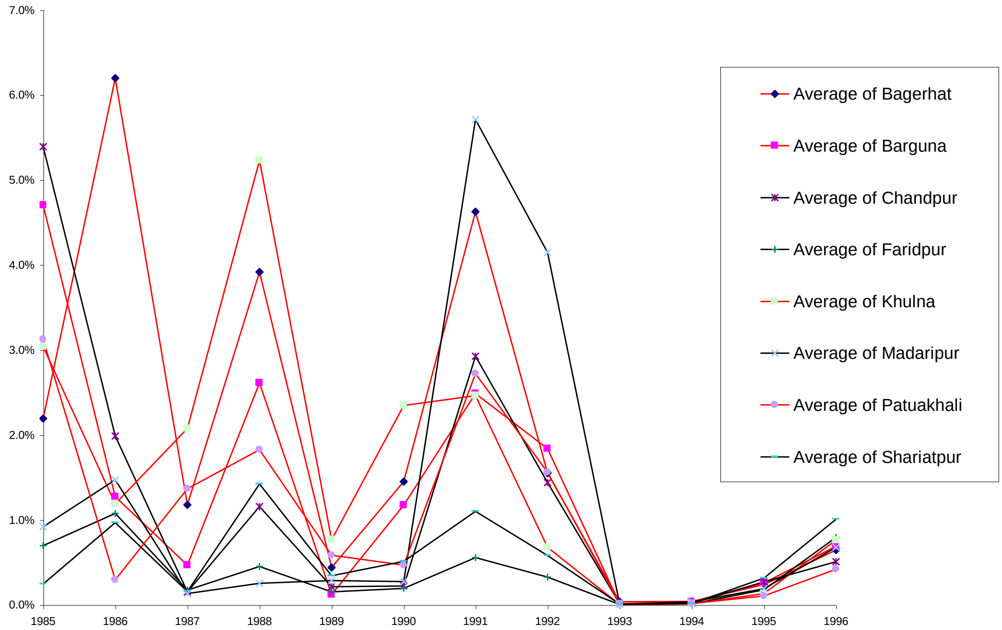


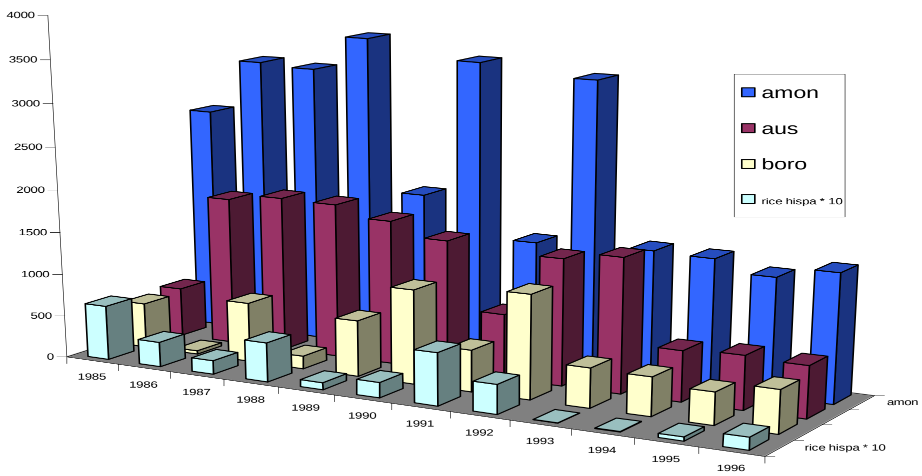
Fig. 4.5. Mean % of the cultivable area infected by rice hispa for 8 districts, from 1985-1986: red lines the four S districts; black lines the four N districts.



Areas of rice crops

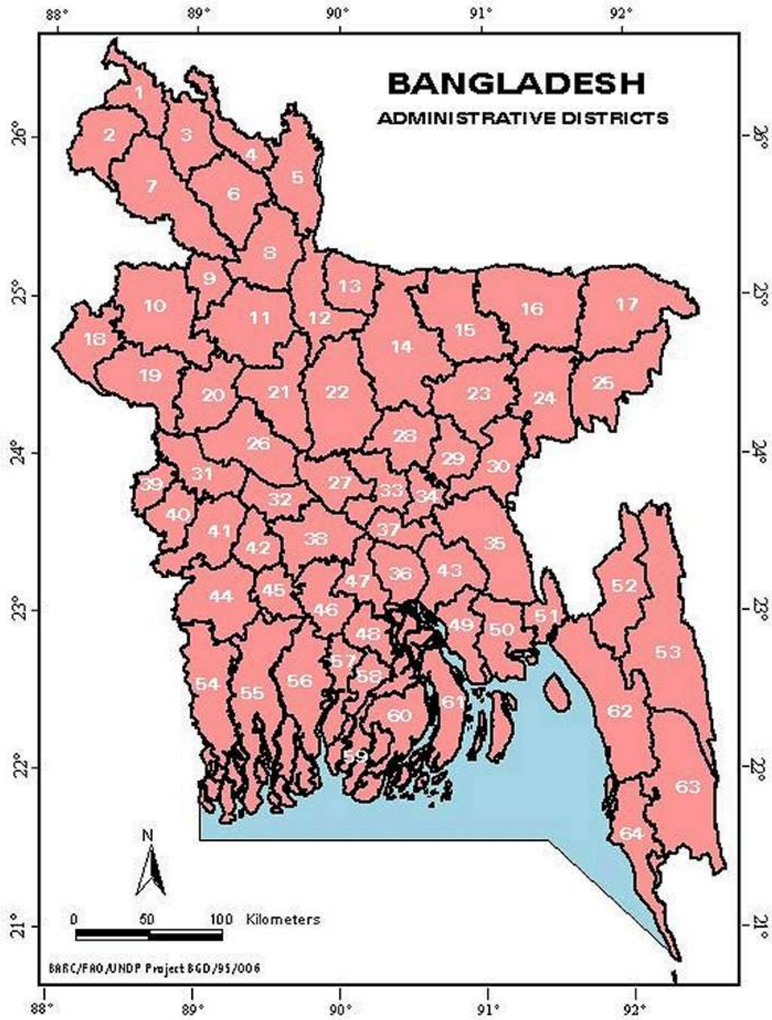
Total area over all districts under boro, aus, amon decreases in later years (Fig .6) (data from Shahidul Islam PhD thesis, Appendix E). The average hispa infested area is also included for each year on this chart and there does not appear to be any obvious relationship of area of any amon, aus or boro with hispa infected area.

Fig. 4.6. Total area (summed over all 18 districts) under amon, aus, boro in each year 1985-1996. Also the average hispa infested area in each year (pale blue) summed over the 18 districts. The hispa infested area is averaged over all three crops. It is also scaled up by a factor of 10x to fit the y-axis scaling.



Web Resources

http://www.mindspring.com/~gwil/ybd.html;
http://www.bangla2000.com/Bangladesh/districts.shtm



From:
http://www.fao.org/waicent/faoinfo/agricult/agl/swlwpnr/banglade/e-map3.htm

1	Panchagarh	14	Mymensingh	27	Manikganj	40	Chuadanga	53	Rangamati
2	Thakurgaon	15	Netrakona	28	Jaydebpur	41	Jhenaidah	54	Satkhira
3	Nilphamari	16	Sunamganj	29	Narsinghdi	42	Magura	55	Khulna
4	Lalmanirhat	17	Sylhet	30	Brahmanbaria	43	Chandpur	56	Bagerhat
5	Kurigram	18	Nawabganj	31	Kushtia	44	Jessore	57	Pirojpur
6	Rangpur	19	Rajshahi	32	Rajbari	45	Narail	58	Jhalakhati
7	Dinajpur	20	Nator	33	Dhaka	46	Gopalganj	59	Barguna
8	Gaibandha	21	Sirajganj	34	Narayanganj	47	Madaripur	60	Patuakhali
9	Jaipurhat	22	Tangail	35	Comilla	48	Barisal	61	Bhola
10	Naogaon	23	Kishoreganj	36	Sariatpur	49	Lakshmipur	62	Chittagong
11	Bogra	24	Habiganj	37	Munshigani	50	Noakhali	63	Bandarban
12	Jamalpur	25	Moulvi Bazar	38	Faridpur	51	Feni	64	Cox's Bazar
13	Sherpur	26	Pabna	39	Meherpur	52	Khagrachhari		

4.2 Analysis of cropping patterns in the districts of Bangladesh and its relationship to hispa-prone districts

In the cropping pattern information for the districts of Bangladesh (Nur E Elahi *et al*, 2001) eight basic types of rice cropping can be identified: boro only, t aman only, aus only, boro-dw aman, aus-aman, boro-t aman, boro-t aus-t aman (t = transplanted; dw = deep water). These annual rice cropping regimes may include fallow and other non-rice crops of different kinds. These eight basic types are a simplifictaion from Nur E Elahi *et al*, 2001 in that the type aus-aman is an amalgamation of t aus-t aman, b aus-b aman and b aus-t aman (b = broadcast).

Nur E Elahi *et al*, 2001 give the proportion of land area in each district devoted to each cropping pattern. Differences in the rice cropping patterns between districts can thus be characterised by these data. The objective was to see if any features of the rice cropping patterns might be related to the general distribution of previous hispa outbreaks in Bangladesh. Eighteen hispa-prone districts have been identified which are found in the south-western part of the country (Islam, 1997). Historically, outbreaks have been most common in these districts. Hispa outbreaks do however, occur in other districts, for example in 2001 in Sylhet in the north-east of the country.

In an attempt to reduce the complexity of the cropping pattern data, principal component analysis was performed on the eight rice cropping pattern variables over the 64 districts of Bangladesh. Principle component analysis is a multivariate statistical technique the aim of which is to explain the important sources of variation in a data set with a smaller number of variables. The new variables (or axes) are uncorrelated and weighted by the proportion of the variance they explain.

The first four PCA axes explained about 80% of the variation in the eight original cropping pattern variables. The axes are weighted combinations of the original variables and the magnitude of the weightings indicate the contribution of the original variables to each axis. Each of the first four axes was strongly influenced by one of the original variables: the proportion of t aman only, boro and t aman, aus and aman, and boro only, in axes 1, 2, 3 and 4, respectively. Thus a district with a high score on axis 1 can be interpreted as having a large proportion of land on which there is a single t aman rice crop. Axis scores for the districts were plotted to see if any patterns existed which were related to the distribution of hispa-prone districts.

A plot of axis 1 *vs* axis 2 revealed such a pattern (Fig 4.7). These two axes alone explained 65% of the variation in the cropping pattern data set. As such, Fig. 4 7 provides a good summary of the distribution of rice-cropping patterns in Bangladesh. Hispa-prone districts were widely distributed except in one quadrant of Fig. 4 7. No hispa-prone districts were present in those districts with a combination of a low proportion of t aman single cropping AND a high proportion of boro-t aman double cropping. In other parts of the axis 1 vs axis 2 plot, both hispa-prone and other districts occur. This implies that a particular cropping pattern may be a necessary but not sufficient condition for hispa outbreaks to occur. In that part of the plot were none of the districts are hispa-prone (upper left quadrant of Fig. 4 7), it may be that the cropping pattern is in some way not suitable for hispa numbers to build up to outbreak proportions. These districts were distributed primarily in three divisions (Fig. 4 8) and occur in three clusters in different parts of the country (Fig. 4 9). The south-west cluster (Fig. 4 9) comprises a series of districts in Khulna division. These districts are very close (in some cases adjacent to) the hispa-prone districts and are therefore likely to have similar climates. Their proximity to the hispa-prone area therefore lends support to the idea that cropping pattern rather than climate may be an important constraint to the geographical expansion of hispa. Plots of the other PCA axes revealed no clear patterns related to the hispa-prone districts

It is of interest that the four districts of Sylhet division, where outbreaks occurred in 2001, all fall within the part of Fig 7 where the hispa-prone districts also occur (Fig.4 8). This recent outbreak in Sylhet is thus consistent with these findings concerning cropping pattern. Sylhet may have a cropping pattern suitable for hispa population build up, but such a build up may be constrained by other factors in most years.

A cropping pattern has been identified with an absence of hispa outbreaks but the reasons are not clear. It is possible that t aman single cropping implies greater amounts of t aman ratoon, or merely abandoned stubbles. Such ratoon has been suggested at a possible reservoir for over-wintering hispa. Low levels of boro-t aman double cropping are associated with some hispa-prone areas (Fig.4 7). This double cropping usually occurs in quite intensive, relatively highly managed cropping systems. The result could be an indication that districts with more highly managed production are less hispa-prone. Indeed, Stonehouse (2002) reports a view of extension officers, that hispa might originate in areas receiving little management.

It is interesting to speculate whether hispa outbreaks could occur in the parts of Fig 4.9 marked in red where they have not so far occurred. Presumably, other constraints must exist, but these districts may be at risk if these constraints were relaxed.

Fig. 4.7. Principle component analysis of rice cropping patterns in Bangladesh. The subset of Hispa-prone districts exhibit a different pattern from the pattern of the districts as a whole

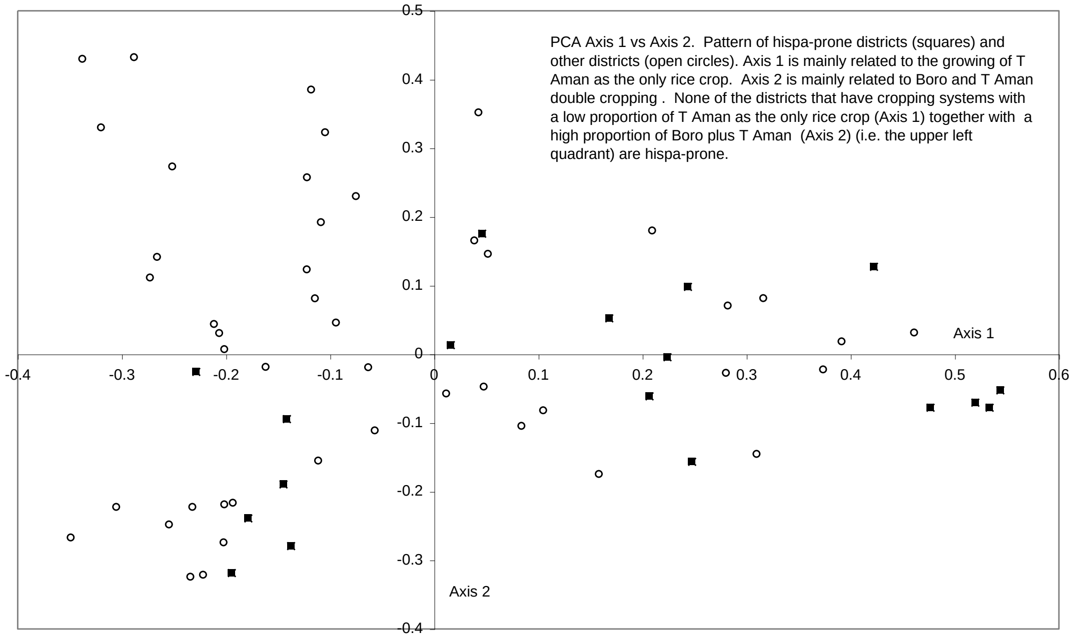
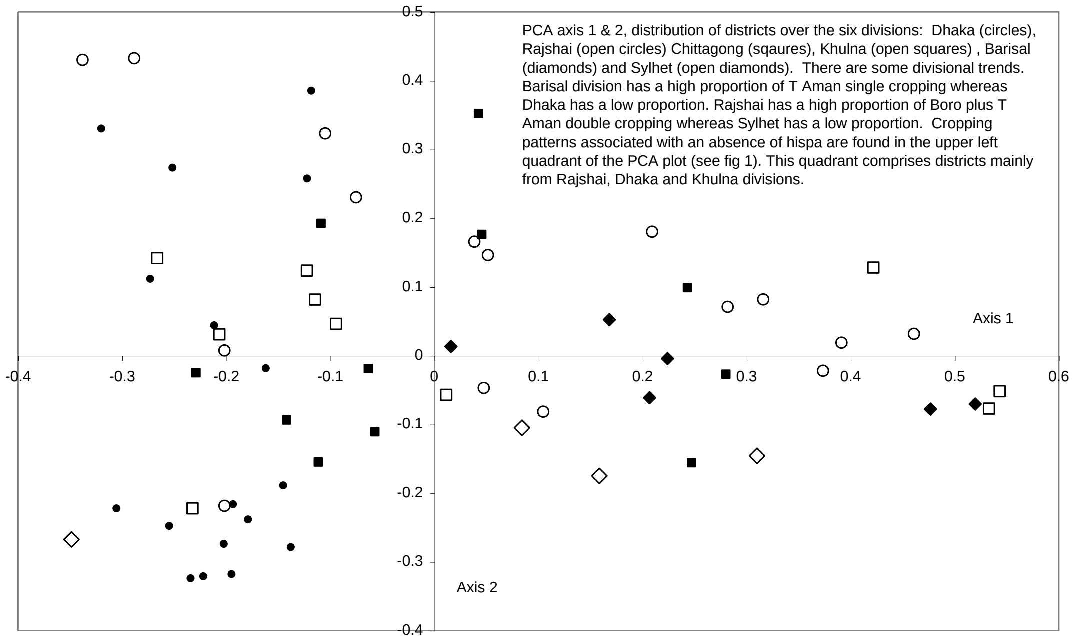


Fig.4.8. Principle component analysis of rice cropping patterns in Bangladesh. Symbols indicate the distribution of districts in each of the six divisions.



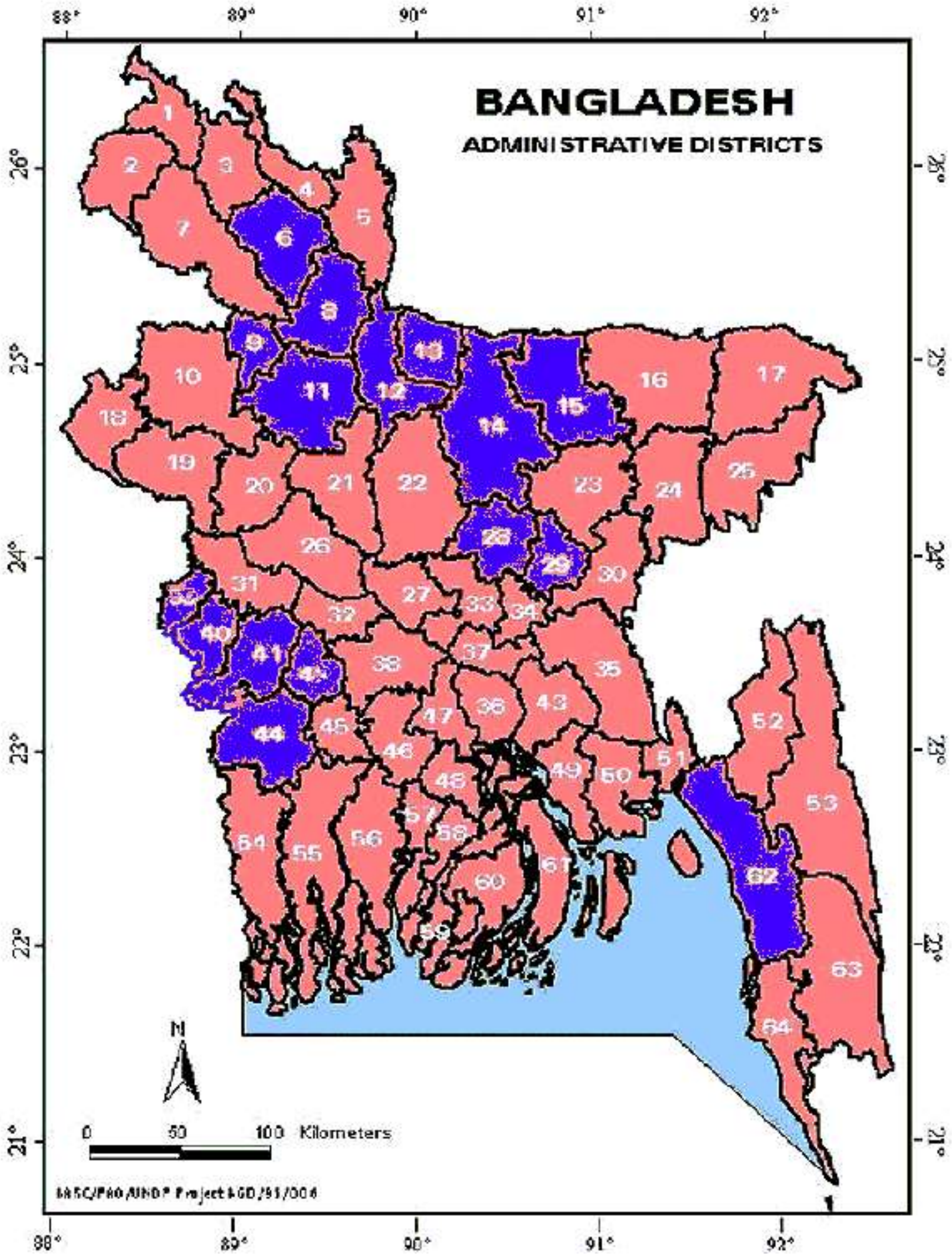
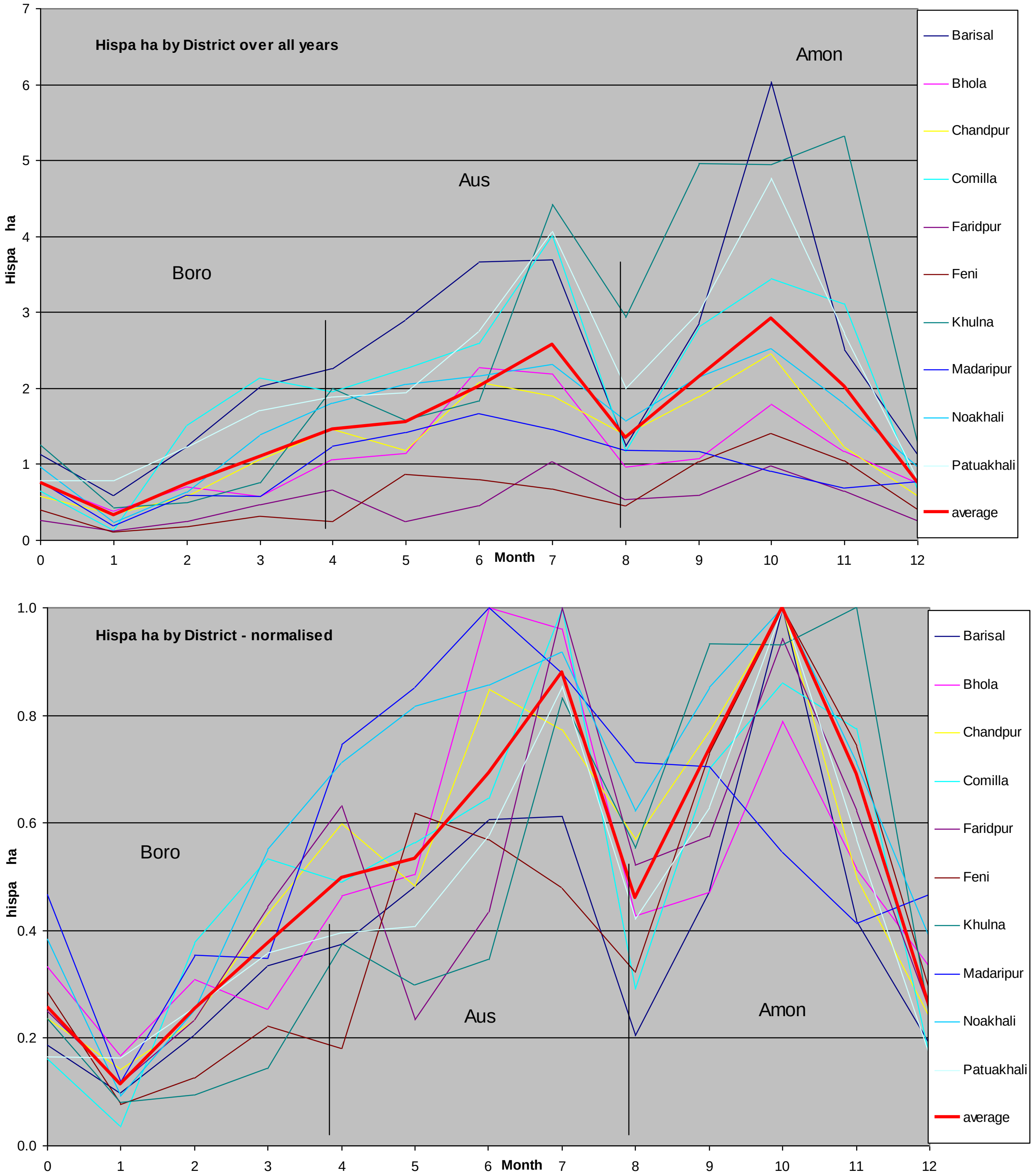


Fig. 4.9. Districts with cropping systems associated with an absence of hispa (upper left quadrant of Fig. 4.7) shown in blue.

4.3 Within-year hispa population dynamics

Ten districts were examined over the period 1985 – 1996. Average monthly values for area infested with hispa were obtained for this period. Fig.4.10 shows the individual data for each district and the average for all districts.

Fig. 4.10 a) Seasonal patterns of hispa abundance in 10 districts (ha x1000) and b) normalised to correct for district differences in abundance



There was large variation between districts in hispa abundance. To make comparison of the seasonal pattern easier, the data for each district were in each case normalised by the maximum value. In the lower graph of Fig. 10, the strong similarity in pattern between districts can be seen. A build up in abundance occurred between January and October with a dip in August, corresponding to the transitions between the Aus and Amon seasons. A different pattern was seen in the Madaripur data where the Amon hispa peak was absent. Amon rice crops are grown in Madaripur and the reason for the different pattern is not known.

There was some evidence that knowledge of hispa abundance in the earlier crops of the season, boro & aus, could be used to predict hispa abundance in the later crops of the same season, aus and boro. Relationships between abundance in boro and aus and between aus and amon were compared.

Taking the12-year district averages, there were good relationships between hispa abundance in the successive rice crops in the same year (Fig. 4.11). March, July and October averages were taken to represent a measure of hispa abundance in the successive rice crops, boro, aus and amon.

For the relationships between abundance in boro and aus and between aus and amon, correlation coefficients were: $r = 0.73$, d.f = 9, $P = 0.02$, and $r = 0.89$, d.f. = 9, $P<0.001$, respectively. Thus, abundance of hispa early in the year may be a good predictor of that later in the year, when populations are larger and damage more important.

Clearly for practical purposes it is important that the relationship holds for individual years as well as for the long-term averages. When individual years were examined separately, the picture became more complicated, with only some years showing significant associations (Table 1). Of most concern, was that in one year, 1995, there was a significant negative relationship between hispa abundance in aus and amon crops.

Whilst the correlation between abundance in successive crops can be very strong in some years, e.g. 1985, 1989, 1990, this is not always the case. More work could usefully be done to explore these relations further.

Fig. 4.11. Relationship between hispa abundance in successive crops in ten districts, based on 10-year district means

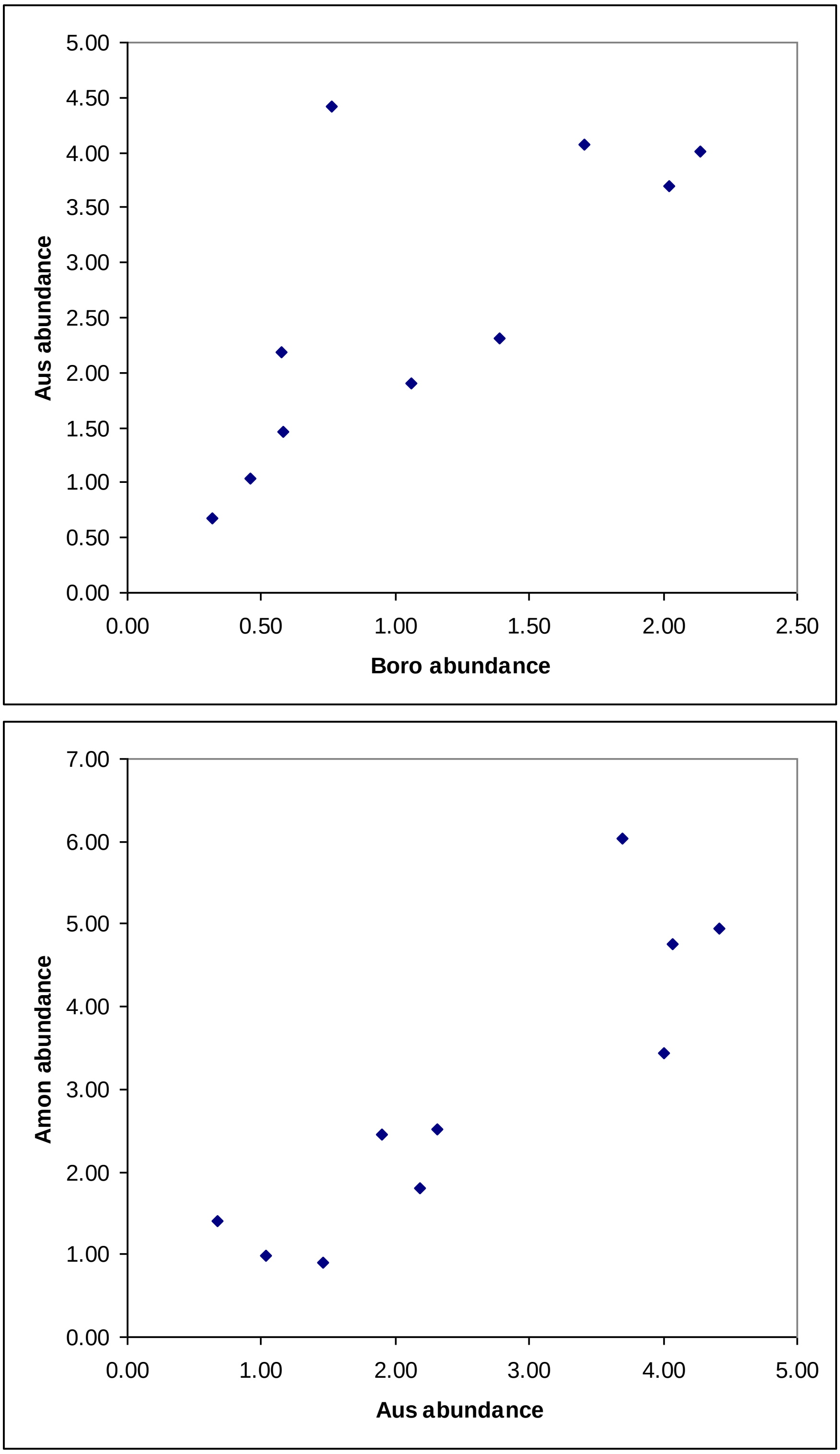


Table 4.1. Correlations coefficients and P values (d.f. = 9) for the relationships between hispa abundance in boro and aus crops and between aus and amon crops, using average values for 10 districts over twelve individual years

year	boro-aus		aus-amon	
	r	P	r	P
1985	0.89	<0.001	0.64	0.05
1986	0.35	NS	-0.19	NS
1987	0.58	NS	0.87	<0.001
1988	0.33	NS	0.83	0.01
1989	0.96	<0.001	0.8	0.01
1990	0.94	<0.001	0.81	0.01
1991	0.28	NS	0.13	NS
1992	0.29	NS	0.25	NS
1993	0	NS	0	NS
1994	0.53	NS	0	NS
1995	-0.21	NS	-0.78	0.01
1996	0.29	NS	0.11	NS

4.4 Prediction of rice hispa outbreaks from winter humidity

Analysis of humidity data summaries for districts of Bangladesh showed that humidity conditions during January to March might be associated with the occurrence of hispa outbreaks later during that year. For Barisal, one of the most hispa-prone districts in Bangladesh, peak hispa abundance was compared with monthy mean minimum humidity for the same year. To simplify the abundance data, years were divided into two groups according to whether abundance was greater or less than the long-term trend. March was usually the month with the lowest average humidity but in some years it was February or January.

Comparison of minimum humidity and hispa abundance revealed that hispa was more abundant in years when the minimum relative humidity was at least 64 %. The one exception was 1985 when hispa was abundant but the minimum humidity was 62. It is also of interest, however, that hispa tended to be abundant in years where humidity was also high in the previous year. Accordingly, a 100% accurate hispa abundance prediction can be formulated based on humidity in the current and the previous years. The form of the algorithm is:

Hispa abundance = high, if minimum humidity $\geq$ 64, or
If minimum humidity $\geq$ 62, and $\geq$ 64 last year;

Hispa abundance = low, otherwise

In Table 4.2 the abundance predictions based on this algorithm are shown along side those observed. In biological terms, the results might imply that hispa numbers are constrained by humidity conditions during the winter. If humidity does not drop too low then this might favour over-winter survival of hispa, and therefore result in higher numbers the following summer.

The effect of humidity in the winter of the previous year is harder to explain, and may actually indicate some dependency of current abundance on prior abundance. It should be noted, however, that it has not been possible to formulate such a simple and accurate algorithm that is a direct function of prior hispa abundance.

Table 2. Results of hispa abundance prediction for Barisal district based on minimum humidity in the current and the previous years

Year	Humidity minimum (month average)	Hispa abundance (greater or less than long term trend)	Predicted hispa abundance
83	57	0	0
84	64	1	1
85	62	1	1
86	63	0	0
87	66	1	1
88	64	1	1
89	58	0	0
90	70	1	1
91	64	1	1
92	59	0	0
93	64	1	1

4.5 Prediction of hispa abundance from a temperature coefficient

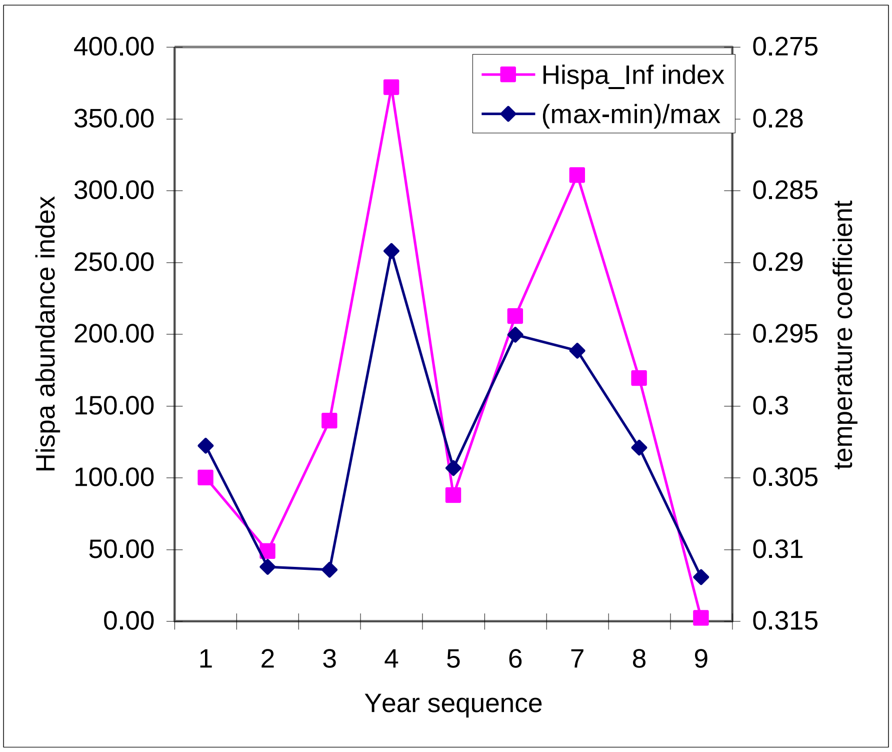
Relative humidity is affected by temperature and there were also some interesting indications that hispa abundance and temperature were related.
There was a good relationship between a coefficient based on maximum and minimum temperature and hispa adundance. The temperature coefficient with used was:

(maximum – minimum) / maxiumum

The coefficient was inversely related to hispa abundance (Fig. 12: note axis was plotted from high to low to assist comparison). A larger value of the coefficient occurs when there is large difference between maximum and minimum temperature and or when maximum temperature is low. Thus, both these factors where associated with LOW hispa abundance.

The results reported for temperature and humidity are rather limited in that they were for a single district, Barisal. Nevertheless, they offer a strong indication that climatic factors are important in hispa population dynamics.

Fig. 4.12. Relationship between a temperature coefficient and hispa abundance over a nine year period in Barisal (see text for details of the temperature coefficient)



4.6 Humidity differences between districts

The relationship between relative humidity and hispa abundance was further explored by examining whether between-district variation in hispa abundance was related to differences between districts in relative humidly. Ten districts were analysed over the years 1985 – 1994.

Cluster analysis was used to group districts according to their similarity in humidity. Three groupings could be distinguished (Fig. 4.13):

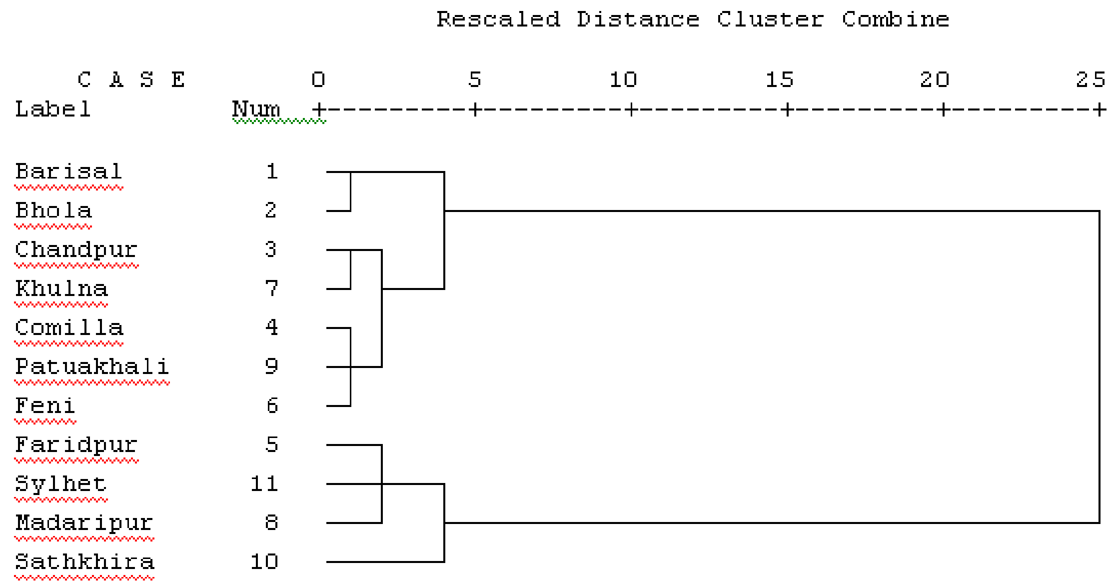
Barisal & Bhola
Chandpur, Khulna, Comilla, Patuakhali & Feni
Faridpur, Sylhet, Madaripur & Sathkhira

Perhaps surprisingly, these groups did not have any clear geographical pattern except perhaps the second group tended to be districts more to the south and/or east whilst the third group tended to be more to the north and/or west.

Fi g. 4. 13. Groupings of ten Bangladesh districts according to similarity in patterns of relative humidity (%).

```
* * * * * * H I E R A R C H I C A L  C L U S T E R   A N A L Y S I S * * * *
* *

 Dendrogram ([Climate] MinRH 1985-1993) using Ward Method
```



Hispa differences between districts

A similar cluster analysis was carried out on the pattern of hispa abundance for most of the same districts and over the same period as for the humidity data. Hispa infestation in hectares was used as a measure of hispa abundance.

The grouping of districts according to the temporal pattern of hispa abundance proved to bear little relationship to the grouping based on humidity pattern. Neither did the hispa groupings show and clear geographical pattern. Four groups could be distinguished (Fig. 14):

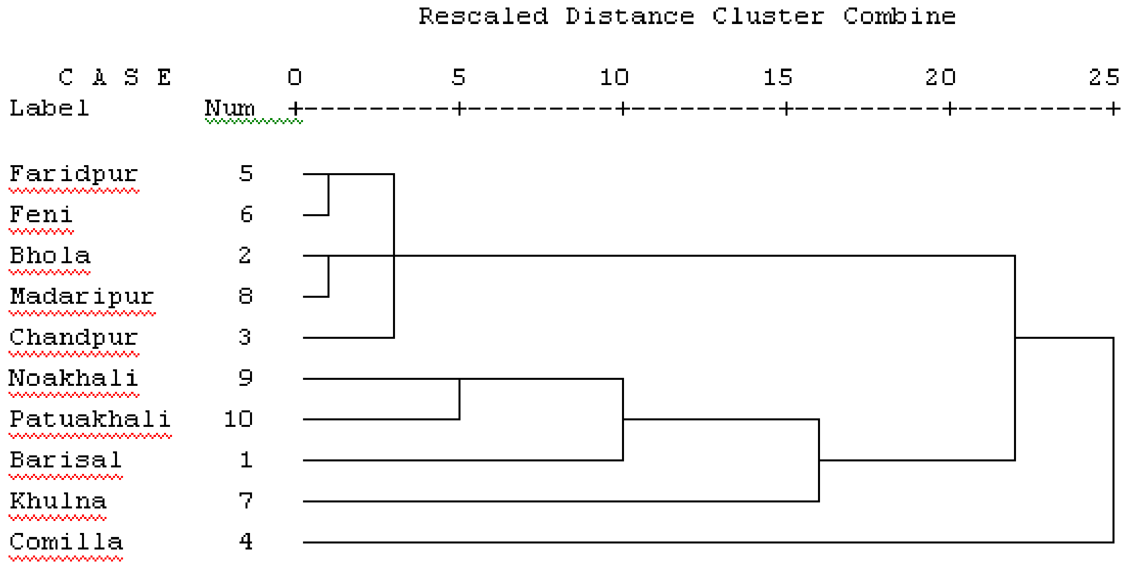
Noakhali, Patuakhali & Barisal
Faridpur, Feni, Bhola, Madaripur & Chandpur
Khulna
Comilla

The first group tended to have high hispa abundance in 1985, 1987-88 and 1990-92 and the second in 1985-86 and 1991-92. The patterns in Khula and Comilla were rather different showing larger distances from other groups in the cluster anlaysis. Khulna had similarities to the first group but with a rather different pattern. Comilla had similarities to the second group but with very high hispa abundance in 1985.

Fig. 4.14. Groupings of ten Bangladesh districts according to similarity in patterns of hispa abundance.

* * * * * * H I E R A R C H I C A L C L U S T E R A N A L Y S I S * * * * * *

Dendrogram ([AppD] Hispa data 1985-1996) using Ward Method

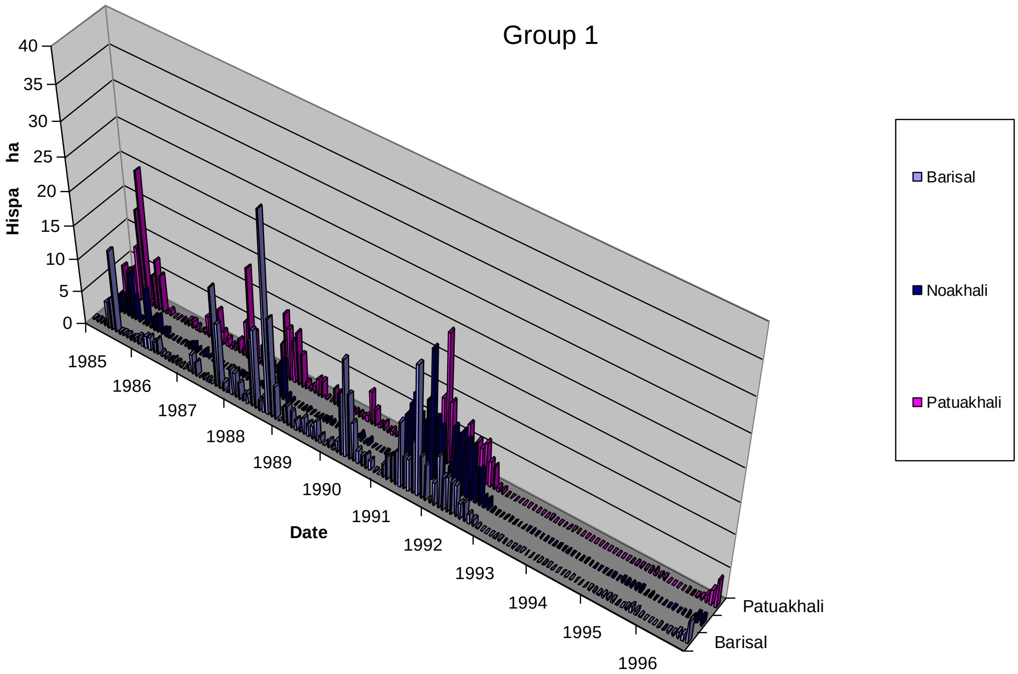


The temporal patterns of hispa abundance associated with the different groups identified in the cluster analysis are shown in Fig. 4.15.

Given the dissimilarity in patterns of hispa and humidity, it seems unlikely that such climatic differences between districts explain why some districts are more hispa-prone than others. It was shown earlier however, that within a district, differences between years could be explained by both humidity (and indeed temperature) variation. Clearly, it is important to explore relationships between hispa abundance and climatic variables further.

Seasonal variation in humidity is parallels seasonal variation in hispa abundance (*cf* Fig. 4.16 and Fig 4.10). However, many other factors vary on a seasonal cycle including rice crop abundance and no cause-effect relationship can be inferred.

Fig. 4.15. Characteristic abundance patterns in the different district groupings identified by the cluster analysis



Group 2

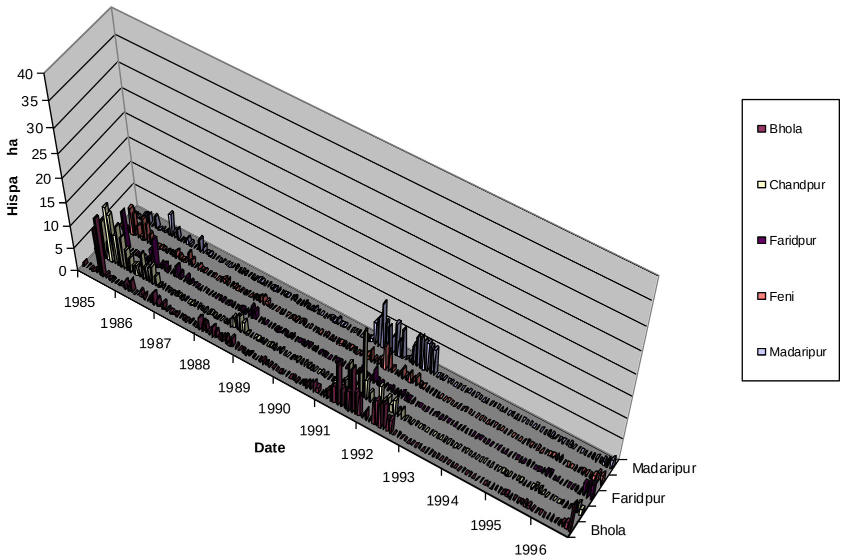


Fig. 4.15 continued

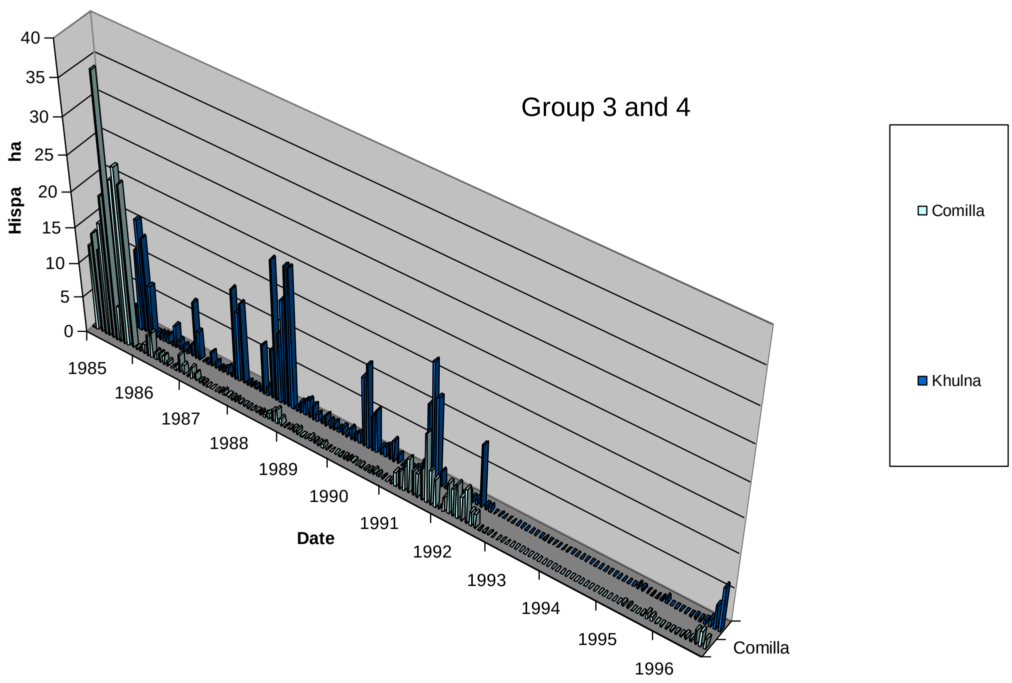
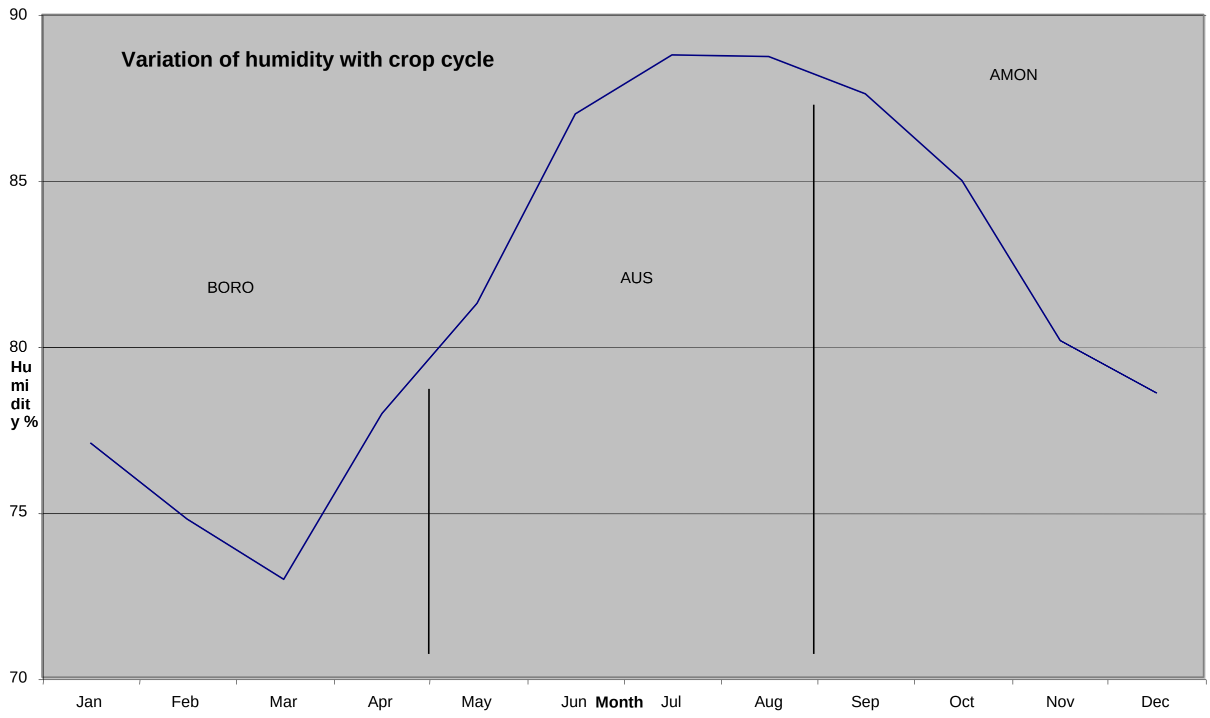


Fig. 4.16. ***Barisal monthly relative humidity 1949-1994 The seasonal cycle shows a lagged relationship to seasonal hispa cycle (Fig. 4.8).***



4.7. Organisation and collation of the hispa data

A protocol has been set up for future computerisation of hispa and associated climatic data. Table 3 illustrates an inventory of part of the data set to help keep track of where gaps exist.

Table 4.3. Example of the data inventory matrix of data types by districts

IslamHispa	NasrinHispa	Clim_Humid	Clim_Temp	Clim_Rain	Hydro data
Bagerhat	Bagerhat				Bagerhat
Barguna					
Barisal	Barisal	Barisal.xls	Barisal.xls	Barisal.xls	Barisal
Bhola		Bhola.xls	Bhola.xls	Bhola.xls	Bhola Kheya ghat
		Bogra.xls	Bogra.xls		
Chandpur		Chandpur.xls	Chandpur.xls		
		Chittagong.xls		Chittagong.xls	
Comilla		Comilla.xls	Comilla.xls	Comilla.xls	
				Cox'sbazar.xls	
		Dhaka.xls	Dhaka.xls	Dhaka.xls	
		Dinajpur.xls	Dinajpur.xls	Dinajpur.xls	
Faridpur		Faridpur.xls	Faridpur.xls	Faridpur.xls	
Feni		feni.xls	Feni.xls	Feni.xls	
Gopalgonj					
		Hatia.xls	Hatia.xls	Hatia.xls	
		Ishurdi.xls	Ishurdi.xls	Ishurdi.xls	
		Jessore.xls	Jessor.xls	Jessore.xls	
Jhalakhati					
		Khepupara.xls		Khepupara.xls	
Khulna	Kulna	Khulna.xls	Khulna.xls	Khulna.xls	Khulna
		Kutubdia.xls		Kutubdia.xls	
Lakshmipur					
Madaripur		Madaripur.xls	Madaripur.xls	Madaripur.xls	Madaripur
		Maijdee Court.xls	Maijdee.xls	Maigdee.xls	
		Mynenshing.xls	Mymensingh.xls	Mymensingh.xls	
Noakhali					
Patuakhali	Patuakhali	Patuakhali.xls	Patuakhali.xls	Patuakhali.xls	
		Rajshahi.xls	Rajshahi.xls	Rajshahi.xls	
		Rangamati.xls	Rangamati.xls	Rangamati.xls	
			Rangpur.xls	Rangpur.xls	
Pirojpur	Pirojpur				Pirojpur
		Sandip.xls	Sandwip.xls		
Satkhira	Satkhira	Sathkhira.xls			
Shariatpur					
		Sitakunda.xls	Sitakhunda.xls		
		Srimangal.xls	Srimangol.xls		
	Sylhet	Sylhet.xls	Sylhet.xls		
	Moulovibazar				
	Hobigonj				
		Teknaf.xls			
					Afraghat

The first column refers to the hispa abundance data previously collated and published in Islam (1997). The second column, hispa abundance data added during the project. The final four columns concern humidity, temperature and rainfall, and hydrological data, respectively. A large body of data relevant to the analysis of hispa abundance is being collated and computerized. This process was begun during the project and analyses where carried out as far as possible. New and potentially useful predictors of hispa abundance have been discovered. A protocol has been set in place to continue to assemble the data sets providing the opportunity for further analyses can be carried out in the future.

4.8. Summary of key conclusions

- Hispa outbreaks appear to build up over two year periods. An increase in hispa infestations in the more southerly districts in one year is sometimes followed by more generally high hispa infestations over all hispa-prone districts in the following year.
- Cropping pattern and hispa distribution are related. It was found that in those districts with a combination of a low proportion of t aman single cropping AND a high proportion of boro-t aman double cropping were never hispa-prone.
- Within a district, hispa abundance in successive crops in the same season was often (but not always) correlated, so hispa abundance in the boro is a potential predictor of abundance in the aus and aman.
- Years with high winter humidity and high winter and summer temperatures tend to have higher hispa abundance. Climatic data did not however explain why some districts were more hispa-prone than others.
- A valuable body of data exists and institutional protocols have been put in place to allow these data to be used for further analyses in the future.

Some of these points are investigated further in output 7.

5. Studies on the Endemic Range of Rice Hispa

5. 1. Southern districts

The rice hispa was scarce and patchy in distribution in all years and seasons of the survey period in the southern districts (table 5.2). But qualitative surveys by BRRI Division of Entomology, in the late 1990s/early 2000s and pre the current project, indicated that the rice hispa was also scarce then.

The current surveys showed that all hispa stages could be found in most of the rice seasons but there was an indication that adult numbers increased during the rice seasons of each year with maximum numbers occurring in the t. aman season. Rice hispa adults were also found on ratoons during the winter months and this in consistent with the results of previous surveys (e.g. see Johnsen *et al.*, 1997).

5.2. Northeastern and central districts

In general terms, the rice hispa was found to be more common in the northeast region (Sylhet Division) than in the central and south regions; but nonetheless, in all regions and districts the insect had a patchy distribution.

In the northeast, the rice hispa was most common in Sylhet District. Here, all stages of the hispa were found in the boro seasons of 2002 and 2003. Immature stages were also found during this season in the neighboring district of Moulvibazar but essentially only adults were found in the rest of this District at this time. As in the southern Districts, the geographical range of the rice hispa moderately increased in the northeast as the rice seasons progressed (table 5.2) particularly through more locations showing a presence of eggs and adults. Of significance was that during the survey conducted during the boro season of 2002, most of the rice growing in the Syhet District, and some of the rice crop in Sunamganj District, was identified as being suitable for rice hispa feeding, egg laying and development, but the incidence of the insect was very low and patchy.

Also of significance was the presence of all rice hispa stages on wild grasses growing in semi-aquatic situations, in uncultivated areas. This was noted throughout much of the northeastern region. The grasses were collected and taken back for growing and identification at BRRI, Gazipur. These are further discussed under Output 6.

Table 5.2. Categories of rice hispa infestation in the northeast/central and south regions in different rice seasons during 2002-2003.*

District	2002											
	Boro				**Aus**				**T.Aman**			
	Egg	Larva	Pupa	Adult	Egg	Larva	Pupa	Adult	Egg	Larva	Pupa	Adult
Central/northeast districts												
Sylhet	5	1	2	4	5	4	5	5	-	-	-	-
Moulvibazar	4	1	1	2	4	5	1	4	-	-	-	-
Habiganj	0	0	0	1	5	2	1	2	-	-	-	-
Sunamganj	0	0	1	1	1	0	0	1	-	-	-	-
Brahmanbaria	0	0	0	0	1	1	0	1	-	-	-	-
Narsinghdi	0	0	0	0	0	0	0	0	-	-	-	-
Gazipur	0	0	0	1	4	4	5	5	-	-	-	-
South districts												
Barisal, Khulna and Bagerhat etc.	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**-**	**-**	**-**	**-**
	2003											
Central/northeast districts												
Sylhet	5	2	1	5	0	1	0	2	5	0	5	5
Moulvibazar	1	1	0	4	5	0	0	3	5	0	0	5
Habiganj	0	0	0	3	0	0	0	2	0	0	0	2
Sunamganj	0	0	0	2	0	0	0	0	4	0	0	3
Brahmanbaria	0	0	0	0	-	-	-	-	-	-	-	-
Narsinghdi	0	0	0	0	0	0	0	0	-	-	-	-
Gazipur	0	0	0	0	0	0	0	0	-	-	-	-
South districts												
Barisal, Khulna and Bagerhat etc.	0	0	0	0	-	-	-	-	1	1	1	1

*** 0 = 0, 1 = <100, 2 = 101-500, 3 = 501-1000, 4 = 1001-1500 and 5>1500**
'-' = no survey was done during this season.

5.3. Prediction of rice hipsa incidence within Sylhet Division

The distribution of the different stages of the rice hispa in the northeast region is shown in figures 5.1 – 5.4; the data for both years of the survey and for all rice seasons have been included on the maps. The data has been plotted on the basis of a 'Thana' (= Uppazilla), this being an administrative unit within a District. Sites where no hispa were found are not shown. As can be seen, adults apparently seem to be found over a wider area (figure 5.4) than the immature stages (figures 5.1 – 5.3) but this may be because adults are easier to sample.

An example of interpolation of the survey data using the egg and adult stages is presented in figures 5.5 – 5.6; this work was done at the BRRI Statistics Division, Gazipur. Different colours have been used on the maps to denote areas that, on the basis of the interpolation, are likely to have a particular category of abundance of the stage in question. As can be seen, the main areas at 'risk' from moderate to high rice hispa incidence are mostly in the northeast part of the Division. Most of these areas show a moderate abundance of hispa (green on the maps). In general there is a close correspondence between incidnce of eggs ans adults. This suggests that eggs are being laid by adults from resident populations.

5.4. Conclusions and implications for management

It is clear from the surveys reported here that all stages of rice hispa can be found throughout a large part of the northeastern region in all rice seasons. Furthermore, it seems that it is reproducing on wild grasses (also see Output 6) as well as cultivated rice. These observations are very significant because they imply that the endemic range of the insect is far greater than originally supposed and may well cover most of the lowland rice growing regions of Bangladesh. This also has implications for the management of rice hispa: population outbreaks in the northeast may stem from the resident hispa populations in that region and not from an over- spilling from outbreaks from southern areas. This is not to say that rice hispa adults may not disperse large distances; they probably do. But the information suggests that hispa is not just a migratory pest.

Another observation is that, in non-outbreak situations, hispa is present but at very low densities and is very patchy in distribtion.

The GIS modelling presented here is a tool that has been explored by BRRI to summarize current survey information and identify rice growing areas that may be at risk from the rice hispa on a local scale. But this approach could be scaled up for all the lowland rice growing areas. A more immediate point though is that work is needed to conduct follow –up surveys to validate the predictions of the GIS model in the northeast in terms of areas at 'risk'.

This approach could be integrated with the modelling of the historical data on rice hispa incidence discussed under output 4. This is being discussed by BRRI and DAE.

Figure 5.1 Map showing the presence of the egg stage of hispa

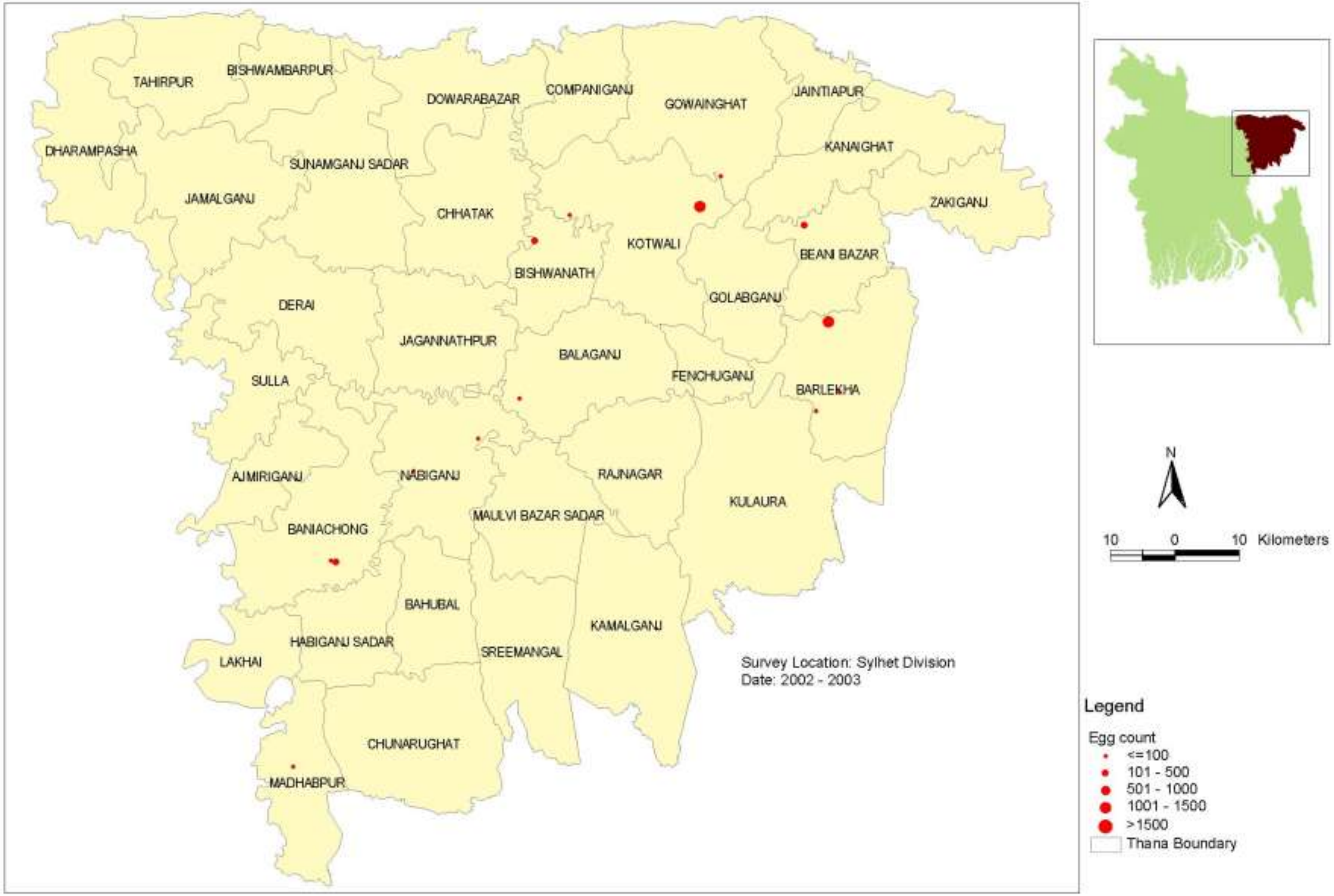


Figure 5.2. Map showing the presence of the larval stage of hispa

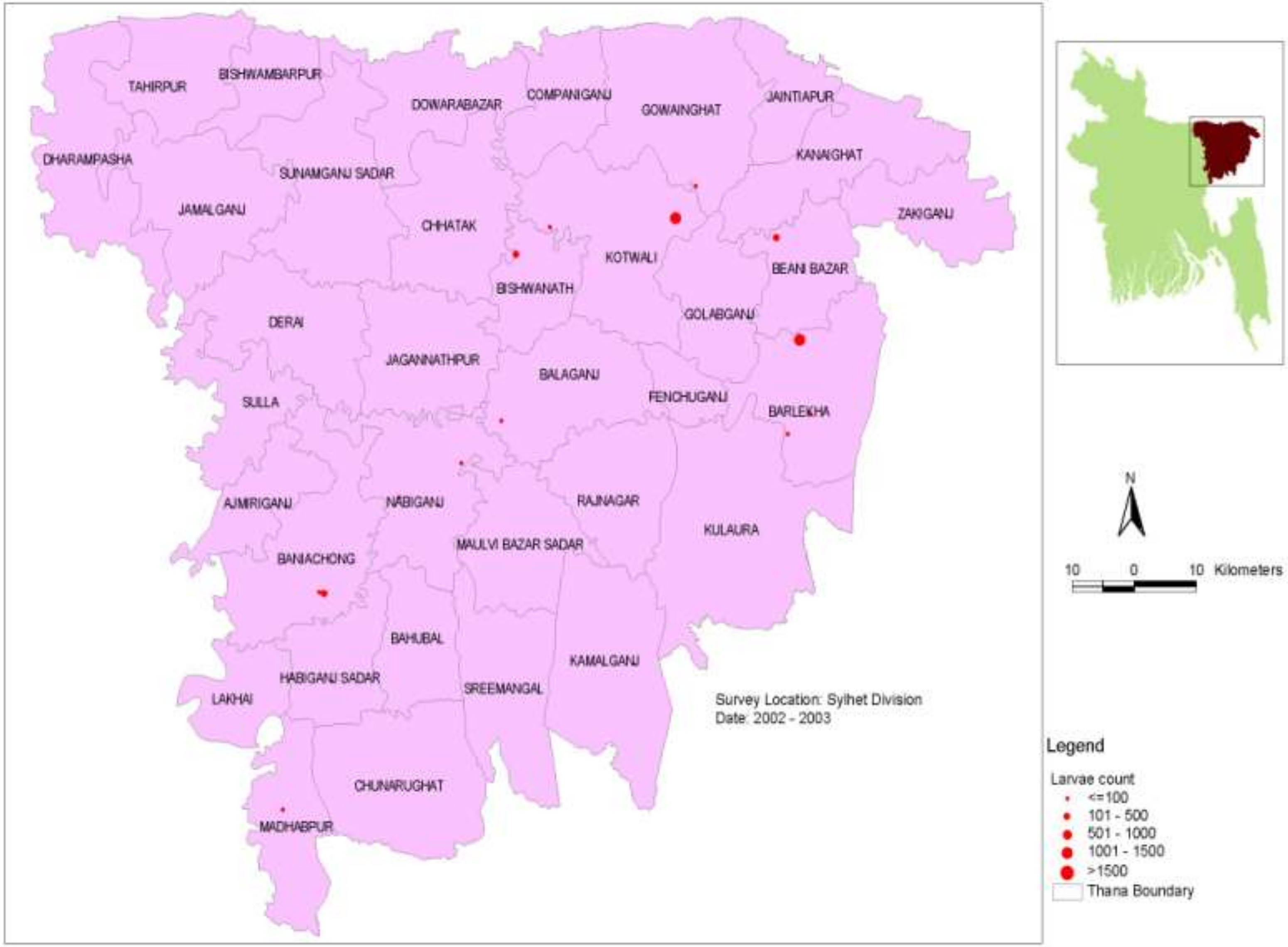


Figure 5.3. Map showing the presence of the pupa stage of hispa

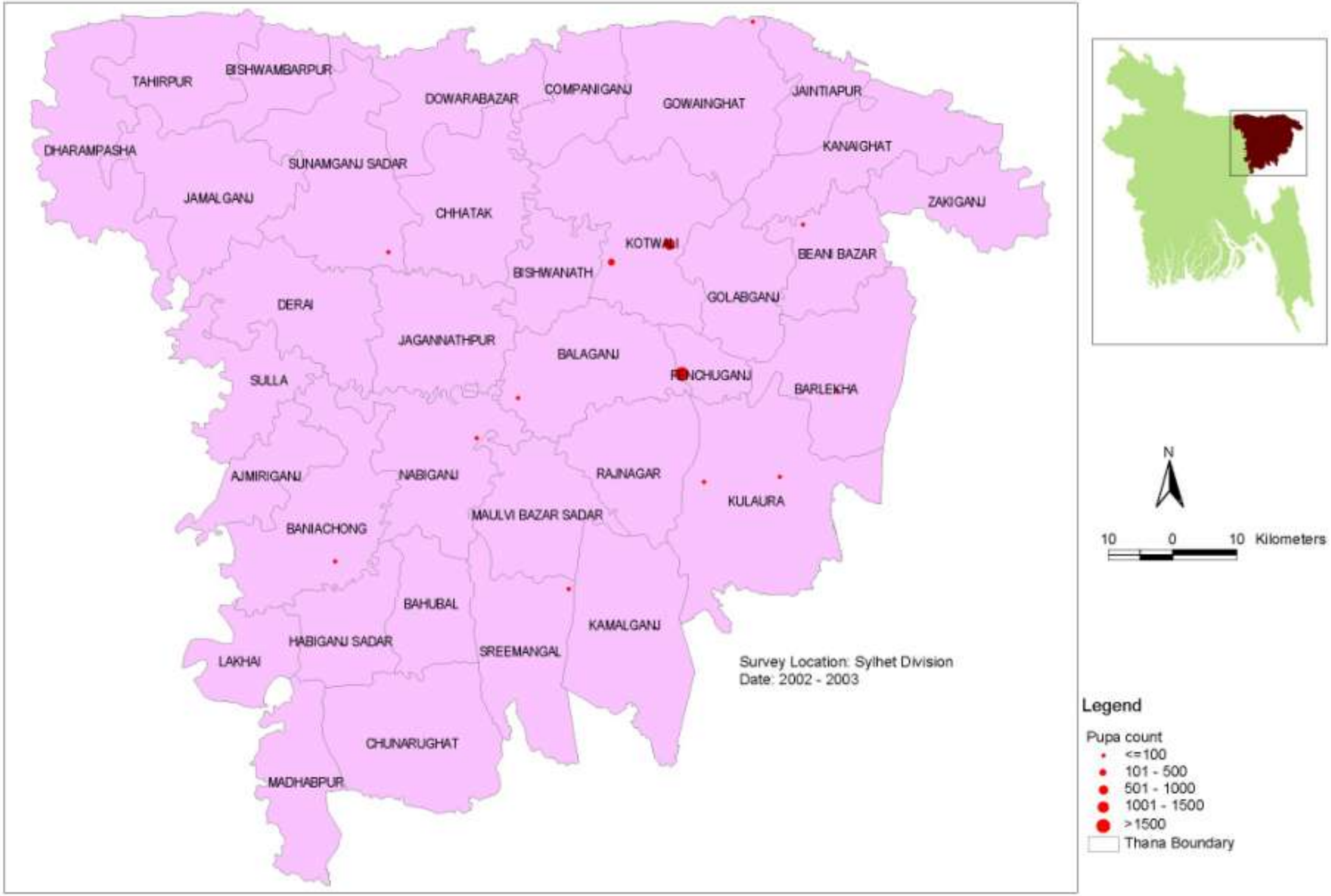


Figure 5.4 Map showing the presence the adult stages of hispa

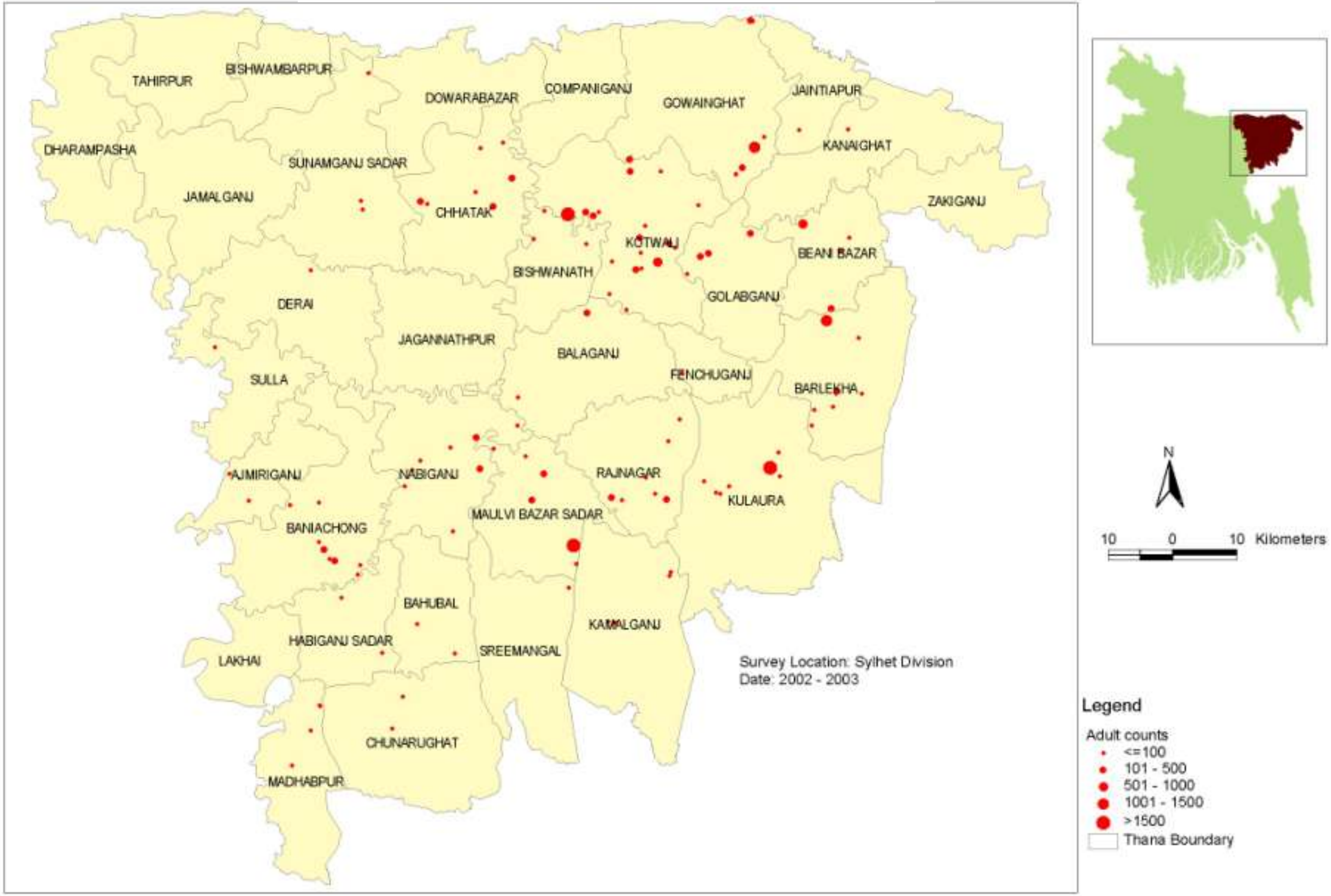


Figure 5.5. Hispa egg 'risk' area

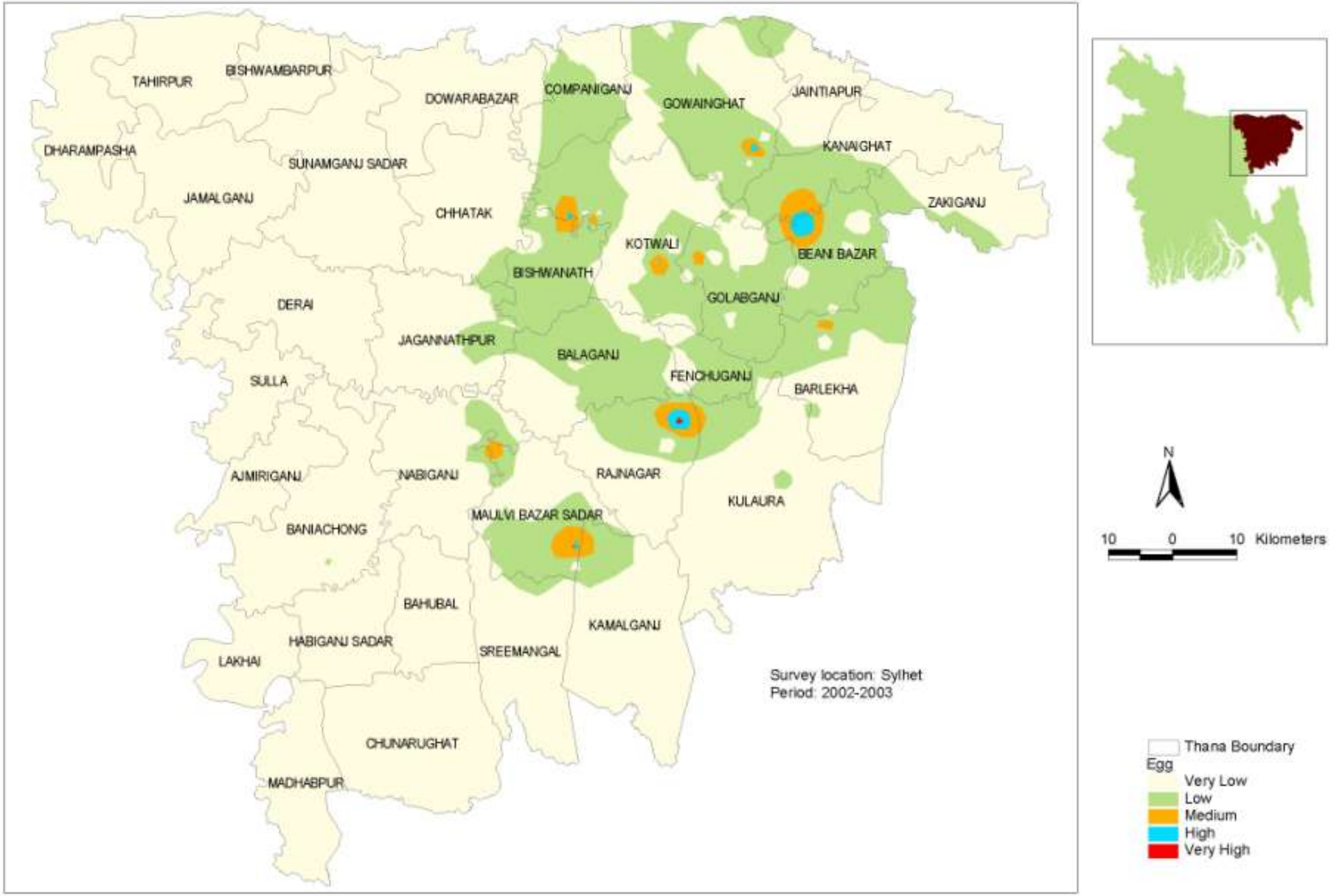
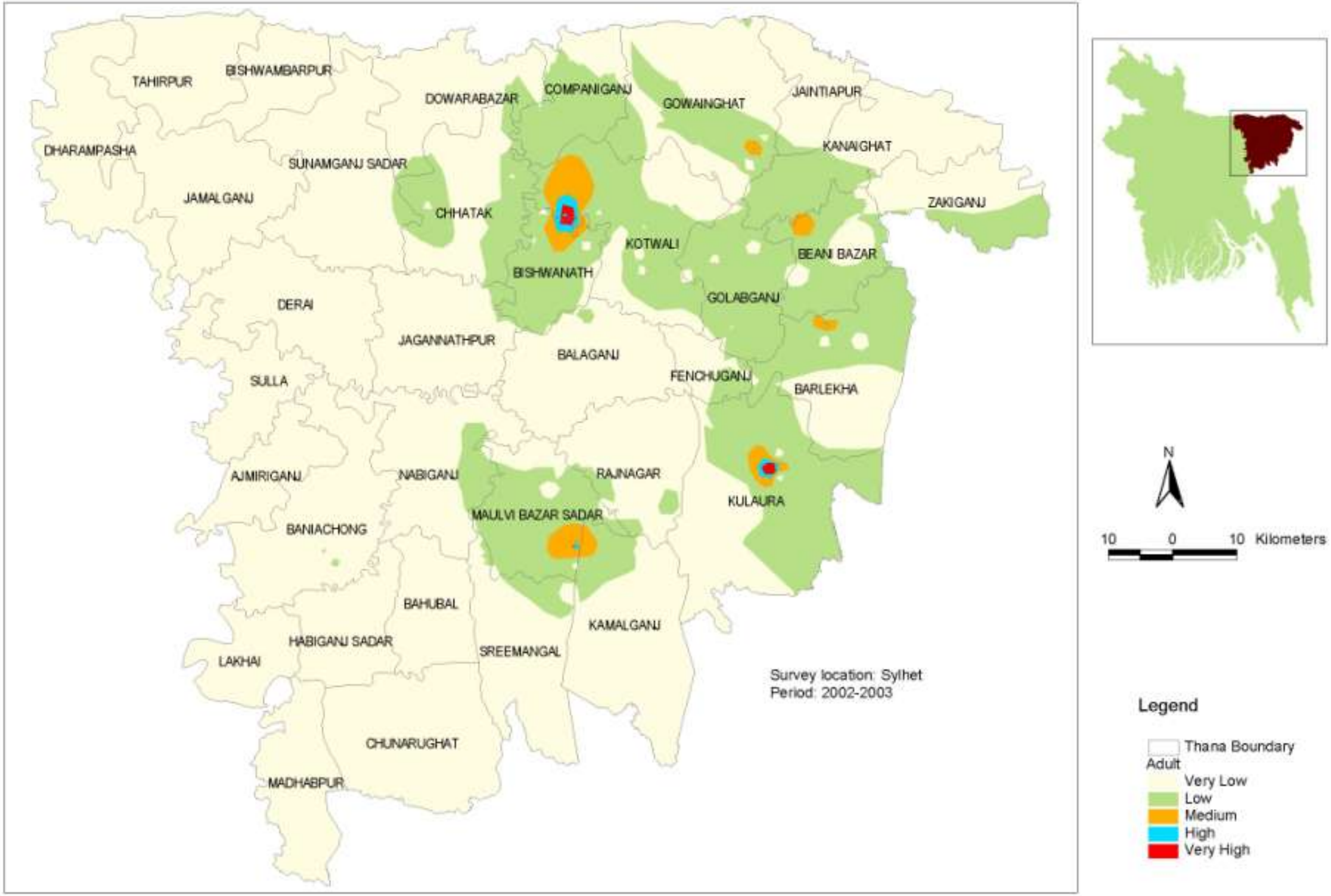


Figure 5.6. Hispa adult 'risk' area



6. Influence of Host Plants on Adult Rice Hispa Settlement, Feeding, Oviposition and Survival

6.1. Rice plant age effects

Choice experiment

Results indicated that highest number of beetles settled on 70-d old plants (approximately 8-10 beetles/plant). Plants of 85 and 100 days old were also moderately preferred (4-6 beetles/plant). Consequently, feeding (mm^2/day) and oviposition (eggs laid/settled female/day) on these plant age groups were higher (approx. 156-304 and 30-48 respectively) (table 6.1). But the insect was able to feed on and oviposit on all ages of the rice presented.

No – choice experiment

In the no - choice situation, the rice hispa adults faired best on the 40-100-d old plants for feeding and oviposition then any other age groups of plant (table 6.2). Thus, under ‘forced’ circumstances, the pest can feed on and lay egg on even younger plants, which it appears not to prefer in a choice situation.

In this particular experiment, the percentage of eggs that hatched were very low and this only occurred on plants in the 40 – 70d old groups (table 6.2). An additional experiment was set up in September 2003 to examine the effects of plant age on the survival of the immature stages; only the younger groups of plants were used given the results described above. Ten replications were run. In this experiment the number of eggs that hatched was approximately the same for all four plant groups (BRRI pers comm. - data not available) but the survival of the larval and pupal stages was greatest in the 50 and 70 day plant age groups (table 6.3). Overall survival was greatest for these groups as well.

Table 6.1. Adult settlement, feeding and oviposition of rice hispa on rice plants of different growth ages, BRRI Gazipur, May 2003. (mean values, choice situation)

Plant age (days)	**Hispa settled (no./plant)**		**Area fed on (mm^2/settled adult/day)**	**Egg laid (no./settled female/day)**
	1st Day	*2nd Day*		
40	1.1	1.5	39.3	4.5
55	4.1	3.5	83.4	17.9
70	10.2	8.1	304.5	48.5
85	4.9	6.3	199.7	30.8
100	4.5	5.5	156.3	33.3
115	3.2	3.3	49.3	6.7
130	2.1	2.1	54.0	7.1
145	1.3	0.6	27.3	2.4

Table 6.2. Feeding and oviposition of rice hispa adult on rice plants of different ages, BRRI Gazipur, May 2003. (mean values, no-choice situation)

Plant age (days)	**Area fed on (mm^2/pair/day)**	**Egg laid (no./female/day)**	**Egg hatched (%)**
40	21.8 a*	8.1 ab	2.04
55	21.0 ab	11.8 a	0.95
70	16.1 b	10.7 a	2.50
85	25.3 a	6.8 ab	0
100	16.3 b	3.1 b	0
115	9.8 c	1.0 c	0
130	2.5 e	0.4 d	0
145	4.5 d	0.2 d	0

* In a column means followed by a common letter are not different significantly ((Duncan's Multiple Range Test – DMRT) at $p < 0.05$.

Table 6.3. Effect of plant age on the survival of rice hispa, BRRI Gazipur, September 2003. (mean values, no-choice situation)

Plant age (days)	**Rice hispa survival (%)**		
	Egg to larva	Larva to pupa	Pupa to adult
50	51.95	76.15	80.62
70	48.51	75.55	81.37
90	55.19	63.68	72.80
115	48.78	0.00	0.00
$\chi2$ test	$\chi2$ = 3.0 df =3 p<0.039	$\chi2$ = 242.1 df =2 p<0.001	$\chi2$ = 481.3 df =2 p<0.001

6.2. Fertilizer effects

The rice hispa beetles fed more and laid a higher number of eggs on the rice plants treated with high levels of nitrogen fertilizer (1-4 g N/kg soil) (table 6.4). This was particularly so for the rates of urea applied at 1 and 2 g/kg of soil. Similarly, the pre-imaginal survival was higher on plants with these treatments. This indicates that the plants that received higher nitrogen were more suitable for both feeding and oviposition and also suitable for hispa development (table 6.4).

Rice hispa reproductive performance and survival was influenced positively at higher rates of urea/ha than reported by Dhaliwal *et al*. (1980).

Table 6.4. Effect of different doses of urea fertilizer on feeding, oviposition and survival of rice hispa, BRRI Gazipur, November 2003. (mean values, no-choice situation)

Doses of Urea (g/kg soil)	**Area fed on (mm^2/pair/day)**	**Eggs laid (no./female/day)**	**Rice hispa survival (%)**			
			Egg to larva	Larva to pupa	Pupa to adult	Egg to adult
0	15.4	0.0 c*	0	0	0	0
0.25	19.4	1.2 bc	24.60	16.67	33.33	9.52
0.5	31.2	2.1 bc	32.86	45.83	100.00	14.47
1	34.7	7.9 a	45.11	50.84	75.97	18.12
2	47.6	7.1 a	58.97	66.67	66.67	27.54
4	38.9	4.6 ab	59.75	45.46	62.07	32.81
$\chi 2$ test			$\chi 2$ = 70.76 df = 4 p<0.001	$\chi 2$ = 89.53 df = 4 p<0.001	$\chi 2$ =177.65 df = 4 p<0.001	$\chi 2$ = 226.57 df = 4 p<0.001

* *In a column, means followed by a common letter are not different significantly (DMRT) at p < 0.05.*

6.3. Different weed species

6.3.1. Weeds in rice fields

Under an initial choice trial (individual plants of each species in one cage together with cultivated rice – this was replicated), rice hispa adults preferred more to settle on rice (BR3) than any of the weed species but settlement was observed on all the weeds tested (apart from *Hymenache* sp.). The highest number of beetles settled on *E. crusgalli* followed by *Hymenachne acutigluma* and then *D. sanguinalis*. Also, in this trial, many eggs were laid on the rice plants but only a few eggs were laid on *E. crusgalli*; these all hatched but none developed into pupae.

In the no-choice situation, the rice hispa females laid more eggs on rice (approximately 20 eggs were laid/ female /day) when compared to the rice field weeds (table 6.5). Among the rice field weeds, the highest number of eggs (10eggs/female/day) were laid on *Hymenachne acutigluma* followed *Digitaria sanguinalis*; egg hatching was also highest (approx. 80%) in *H. acutigluma*.

The data in table 6.6 shows that the rice hispa was able *to complete its life cycle on Echinochloa crusgalli, Digitaria sanguinalis and Hymenachne acutigluma* – the three species 'preferred' in the choice trials. However, the greatest overall survival was on *D. sanguinalis*; all the survival rates were lower than those recorded on the rice plants.

Thus, under the choice situation the rates of larva and pupa formation were zero in the rice field weeds, whereas under the no - choice situation the larva and pupa formation was achieved in three of the weeds tested.

Table 6.5. Ovipostion/egg hatch of rice hispa on different rice field weeds (and rice) at BRRI Greenhouse Gazipur, 2001. (mean values, no-choice situation)

Host plant	**Egg laid (no./female /day)**	**Egg hatched (no./female/ day)**
Echinochloa crusgalli	3.0 b*	1.5 b
Elusine indica	3.8 b	1.0 b
Digitaria sanguinalis	4.8 b	4.0 b
Hymenachne acutigluma	10.5 ab	8.0 ab
Hymenachne sp.	0.3 b	0.3 b
Rice	20.3 a	15.0 a

** In a column, means followed by a common letter are not different significantly (DMRT) at p< 0.05.*

Table 6.6. Survival of rice hispa on rice field weeds and rice, BRRI Greenhouse Gazipur, 2001. (mean values, no-choice situation)

Host plant species	Rice hispa survival (%)		
	Egg to larva	Larva to pupa	Pupa to adult
Echinochloa crusgalli	24.3	18.8	50.0
Elusine indica	14.3	0.0	0.0
Digitaria sanguinalis	60.3	37.5	75.0
Hymenachne acutigluma	57.6	10.8	37.5
Hymenachne sp.	25.0	0.0	0.0
Rice	66.4	44.2	71.7

6.3.2. Weeds recorded in the northeast during the BRRI surveys

Choice experiment

The settlement of adult rice hispa was also highest on rice in the experiment with this group of weeds (table 6.7). Settlement was observed on all the weeds tested but the numbers settled were low and there were no major differences between the weed species. Besides heavy feeding on the rice, the hispa adults also fed significantly on the *Orzya* sp., *Hygroryza aristata* and on *Hymenachne acutigluma*. Egg laying was also high on rice (table 6.6) but eggs were laid (in very small numbers) on all the weeds. The egg hatch rate was extremely low (table 6.7), even on rice and none of the larvae survived on the weeds. However, the hispa did complete its development on the rice. The low egg hatch rate calls into question the value of the results obtained in this experiment but there is correspondence between the overall results and that reported from the choice trials for the rice field weed species.

Table 6.7 Adult settlement, feeding and ovipostion of rice hispa in northeastern weed species, BRRI Gazipur, June, 2003. (mean values, choice situation)

Host plant species	**Hispa settled**		**Area fed on (mm^2/settled adultday)**	**Egg laid (no./settled female/day)**	**Egg hatched (no./settled female/day)**
	1st Day	2nd Day			
'Tamabil weed'	1.2	0.9	4.9	0.6	0.0
Hygroryza aristata	0.9	1.2	10.2	0.8	0.0
Hymenachne acutigluma	1.2	0.8	8.1	1.0	0.1
'Dhirasram narrow'	1.1	1.0	5.3	0.6	0.0
'Sylhet weed'	1.5	1.3	7.9	1.0	0.1
Echinochloa sp.	2.1	1.9	4.5	0.6	0.0
Oryza sp.	2.3	0.6	34.5	3.6	0.1
Rice	21.6	18.4	198.1	84.3	0.4

No-choice experiment

In the no - choice experiment, feeding again was heavy on rice (table 6.8) but also moderately heavy on *Orzya* sp. and *Hygroryza aristata*. This is similar to the choice experiment observation. In this experiment, the eggs laid on the rice were low compared with all the other experiments reported under this output but the mean number was still higher than on all the weed species (table 6.8); this may have been due to low humidity conditions at BRRI, Gazipur at the time the experiment was conducted. As with the choice experiment, eggs were laid on all the weed species with the highest numbers recorded from *Oryza* sp., *Hygroryza aristata*, *Hymenachne acutigluma* and 'Sylhet weed'. However, in contrast to the choice experiment, the rice hispa was able to develop and complete its life cycle on three of the weeds: Oryza sp., *Hymenachne acutigluma*, and ' Sylhet weed'; overall survival was greatest on the 'Sylhet weed'. Thus, in common with the no-choice experiment conducted on the rice field weeds, the results reported here show that under the 'forced conditions' of a no-choice set up, the rice hispa can survive and reproduce on several weed species. Also the results here support the early finding that *Hymennache acutigluma* is a suitable host under the no-choice situation.

Table 6.8. Feeding, ovipostion and the survival (immature stages) of rice hispa on some northeastern weeds and on rice, BRRI Gazipur, September 2003. (mean values, no-choice situation)

Host plant species	**Area fed on (mm^2/pair/day)**	**Egg laid (no./female /day)**	**Rice hispa survival (%)**		
			Egg to larva	Larva to pupa	Pupa to adult
'Tamabil weed'	62.8 d*	1.5 c	42.2	0.0	0.0
Hygroryza aristata	116.8 b	2.4 b	34.9	0.0	0.0
Hymenachne acutigluma	49.6 e	1.9 bc	32.3	9.7	16.7
'Dhirasram narrow'	37.0 f	1.3 c	32.2	1.9	0.0
'Sylhet weed'	60.8 d	1.8 bc	60.5	13.4	33.3
Echinochloa sp.	31.8 f	0.2 d	10.0	0.0	0.0
Oryza sp.	83.8 c	2.4 b	27.2	12.0	70.0
Rice	134.4 a	2.5 a	66.5	17.1	59.1

* In a column, means followed by a common letter are not different significantly (DMRT) at $p < 0.05$.

6.4 Conclusions

Several important points have arisen from the studies reported in this section which are important for the understanding of the population dynamics of the rice hispa:

- Under choice and no-choice conditions, the rice hispa will settle and reproduce on rice of a wide range of ages but will only feed and reproduce on an age group ranging from about 50 – 90 days old. This result has only been obtained for one rice variety but it is likely to apply more broadly. This aspect will need to be followed up researchers in Bangladesh.
- The application of high levels of urea does facilitate more intense feeding and higher survival rates – up to about 2g of urea/kg of soil.
- The studies on the alternative hosts suggests that all the weed species studied may act at least as an alternative food source for the rice hispa as the beetle will settle and feed even in under a host plant species 'choice' design that includes rice. The studies have also shown that under 'no-choice conditions' the rice hispa can complete its life cycle on three general weeds of rice fields and a further two species from the northeastern region. That the immature stages of the hispa have been recorded by BRRI in the field in the winter season from some of these weeds indicates that the hispa is, under some circumstances, breeding in the field on these weeds.

However, as mentioned under Output 5, field observations by BRRI indicate that most rice in the field, suitable for hispa reproduction (now confirmed by the results presented in this Output), at best, only has a low or patchy incidence of rice hispa. Together these observations and results strongly suggest that in most seasons, the standing rice crop (in terms of age and quality) is not a major limiting factor to the growth of hispa populations, at least in non-outbreak years. Thus other factors must be limiting hispa populations (e.g. like those identified in output 4) and these will be examined in the work reported in the next Output (no. 7).

7. Field Studies in Rice Hispa Survival and Mortality

7.1. Geographical and rice season patterns in rice hispa survival rates

The summaries (mean values) of the stage specific survival rates (and thus ‘apparent mortalities’) at Barisal, Gazipur and Habiganj are shown in table, 7.1; the data for the individual cohorts are shown in Appendix 7, tables 7.1 - 3. (The first row of the Appendix 7, table 7. 1 shows the sizes of the cohorts of eggs that were achieved. In all but a few cases these were of several hundreds in order of magnitude and this allowed reasonable estimates of survival to be made.)

Table 7.1. Schedule of survival of rice hispa immature stages, 2002, 03, 04, Barasal [1], Gazipur [2], and Habiganj [3] (mean values)

Rice hispa stage	**Percentage survival in relation to rice season**								
	Boro			Aus			T.aman		
	1 (6)*	2 (3)	3 (**)	1 (6)	2 (3)	3 (**)	1 (4)	2 (2)	
Egg	33.9	22.8	47.8	24.9	28.0	5	46.3	31.2	-
Larval	12.6	18.2	1.6	29.7	14.8	0	25.0	14.0	-
Pupae	59.4	100	66.7	83.9	74.3	0	73.7	78.2	-
Overall % Survival	3.7	1.8	0.5	11.1	3.4	0	6.9	3.6	-

** Number of cohorts that mean values represent*
***Only one cohort was set up at Habiganj in each season*

The values of survival from the individual cohorts across all sites and all seasons were very variable but some general trends in pattern did emerge:

- Overall survival rates in the three regions in all the rice seasons were very low (frequently less than 10%).
- Egg survival rates were usually much less than 50% but higher than larval survival rates that were frequently less than 20%. On the other hand pupal survival rates mostly very high; over 70%.
- No real differences in any of the survival rate values emerged between the three regions except that overall survival rates in all rice seasons in all years were higher in Barisal versus Gazipur.
- Of particular note were the low survival rates scored in Habiganj as this District lies in the northeast and where region wide small-scale population outbreaks of rice hispa have been a regular feature since about 2000. this point is returned to later.
- Overall survival rates did not differ between seasons at Barisal and at Gazipur (ANOVA F tests, $p>0.10$). Also, following the analysis under Output 4, a correlation analysis of overall survival rates (all regions pooled) in boro versus aus, and aus

versus t.aman were not significant (r = 0.7088 and 0.3561 respectively, $p>0.10$) (figures 7. 1 – 2) but a positive trend was evident between the aus and the boro seasons (figure 7. 1).

Figure 7.1. Relationship between rice hispa % survival in successive crops in three Upazillas

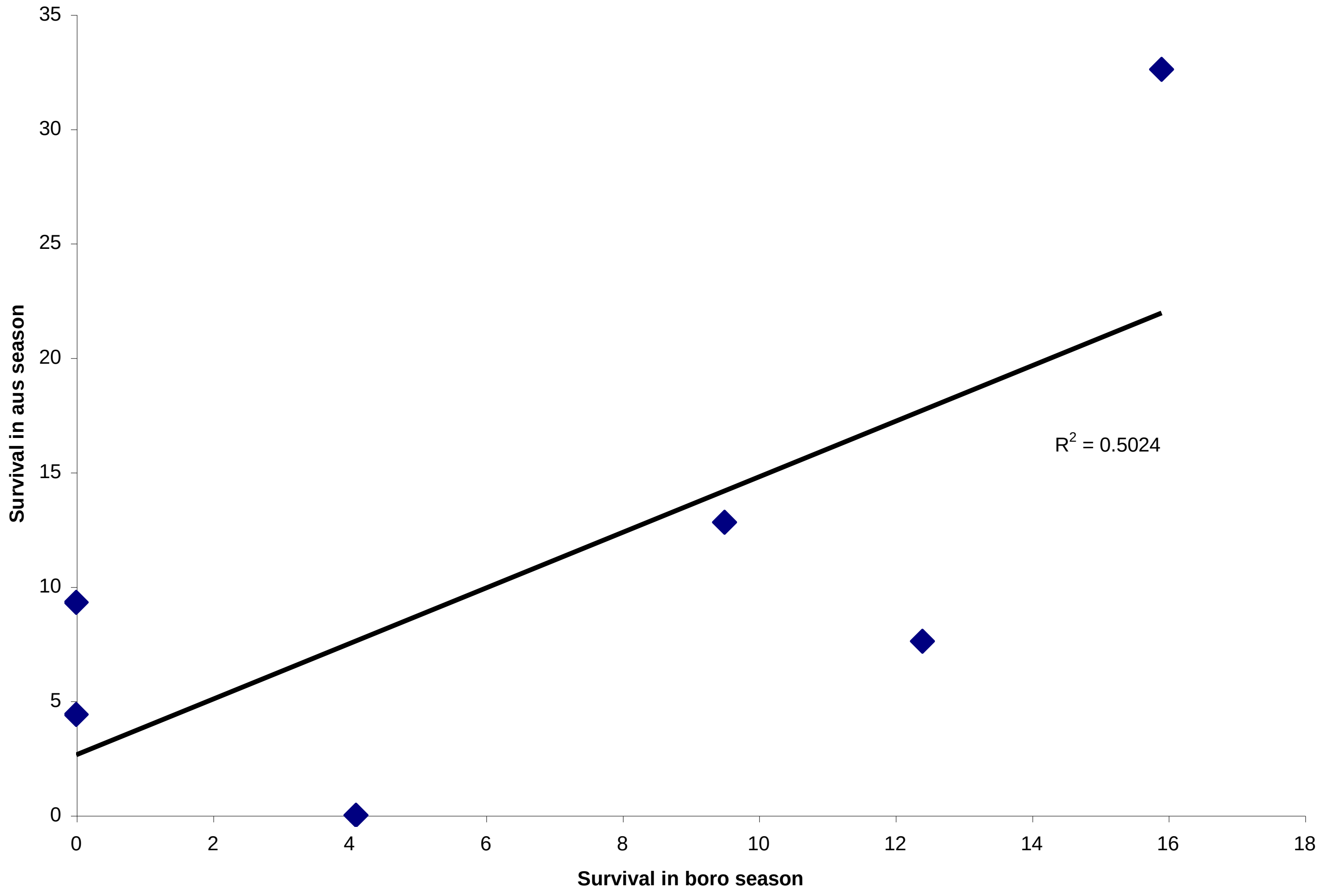
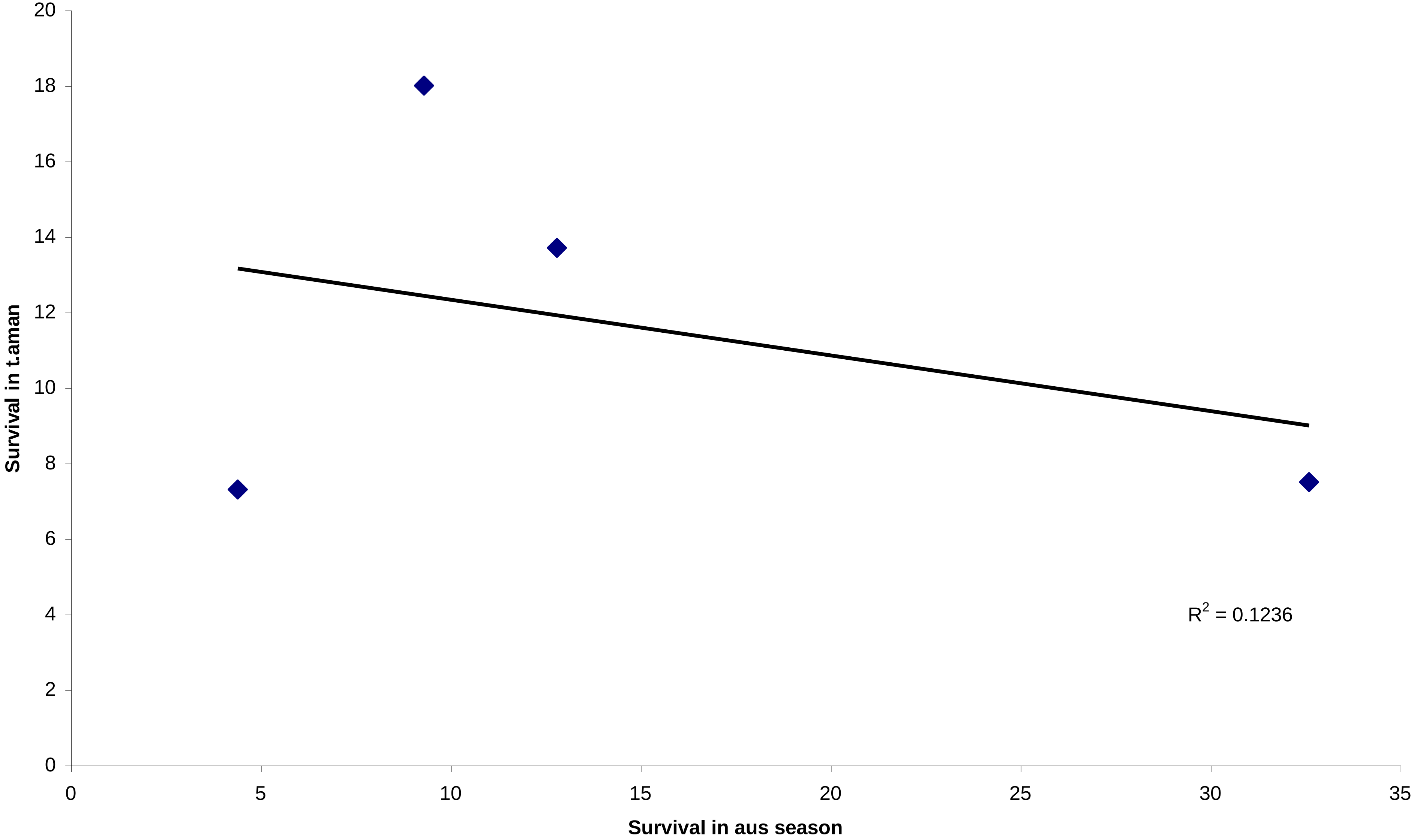


Figure 7.2. Relationships between rice hispa survival in successive crops in three Upazillas



A more detailed analysis was made of larval mortality from the cohort trials at Gazipur (2003) and Habiganj (2004) (table 7.2). Here the numbers 'dying' in each larval instar (L_1 – L_4) were counted during the censuses of the cohorts to see if mortality was more predominant at any particular instar; the expectation was that the greatest mortality was likely to take place at the early instar stages. However, as the data in table 7.2 shows, there is no discernable pattern either between seasons within sites or between sites. During the censuses it was noted that a significant number of larvae drop from the rice leaves, and presumably die. This occurs mostly at the L_2 – L_3 instars when some the larvae emerge from their mines to find new feeding sites on the leaves (P Sarker, pers. comm.). Thus, for these instars, larval mortality includes counts of dead larvae plus missing larvae, i.e. those that have fallen from the leaves.

Table 7.2. Survival of the different stages of rice hispa, Gazipur, 2003, Habiganj, 2004

Rice hispa stage *	Percentage survival in relation to rice seasons				
	Gazipur, 2003			Habiganj 2004	
	Boro	Aus	T. aman	Boro	Aus
Egg	15.2	10.9	24.8	47.8	5
L_1	70.2	76	30.1	45.5	0
L_2	11	18.9	54.4	36.5	0
L_3	0	100	51.9	22.6	0
L_4	0	90.5	97.9	42.9	0
L_T	0	13	8.2	1.6	0
Overall % survival of cohort	0	0.6	1.6	0.5	0

***** L_1 – L_4: successive larval instars*

L_T: survival rate for all larval instars

7.2. Relation of survival rates to relative humidity and flooding

7.2.1 Relative humidity (RH).

A regression analysis was conducted of the overall survival rates (transformed) for all seasons at Barisal against the mean minimum daily percentage RH values for the months the cohort trials were run (figure 7. 3); a similar analysis was done for Gazipur (figure 7. 4). Neither regression coefficient was significant. A further analysis was done, combining data from sites, using the greatest overall survival yearly survival against the mean minimum values of RH for the January to March period of the same year (figure 7 5);

these values from these months were used as these months tend to have some of the lowest RH values recorded during the year (see Output 4). Here the relation between these variables was positive and the regression coefficient was significant ($t = 2.6461$, $p < 0.10$) thus supporting the finding in Output 4 that rice hispa population growth appears to be related to winter humidity values. Experimental studies would need to be conducted to confirm the direct impact of RH on rice hispa survival.

Figure 7.3. Relationship between rice hispa % survival and mean minimum % relative humidity (RH) for the month, Barisal

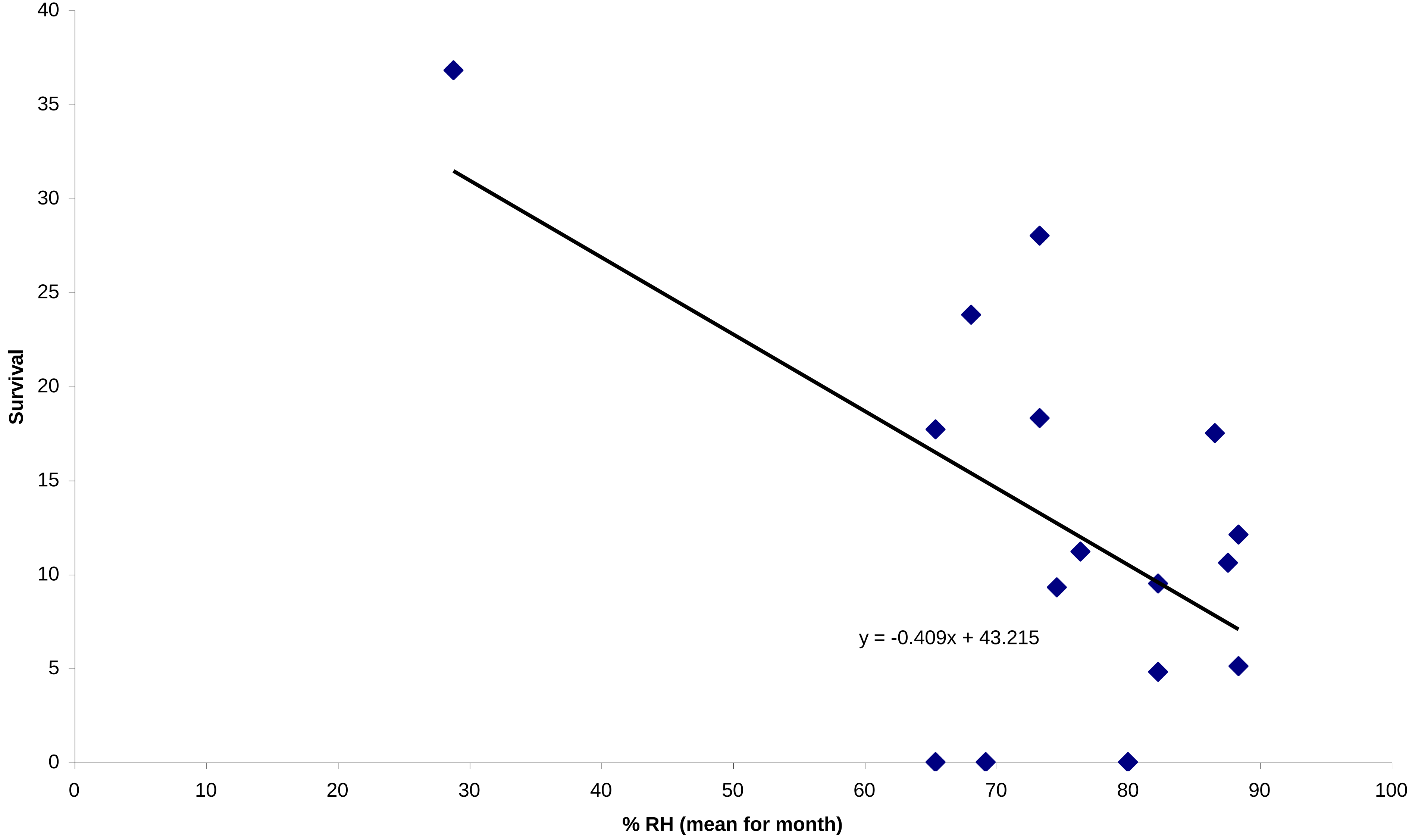


Figure 7.4. Relationship between rice hispa % survival an mean minimum % relative humidity (RH) for the month, Gazipur

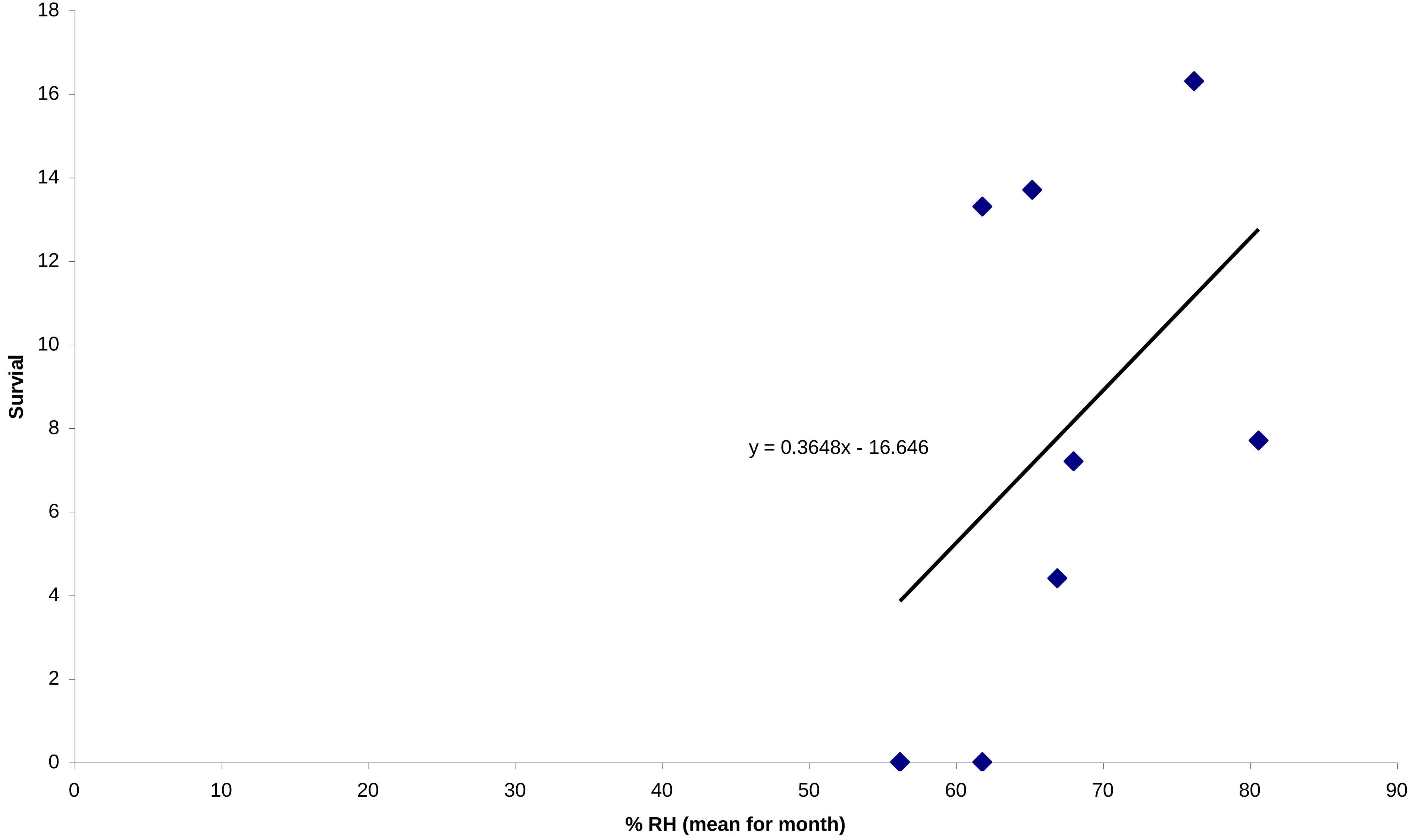
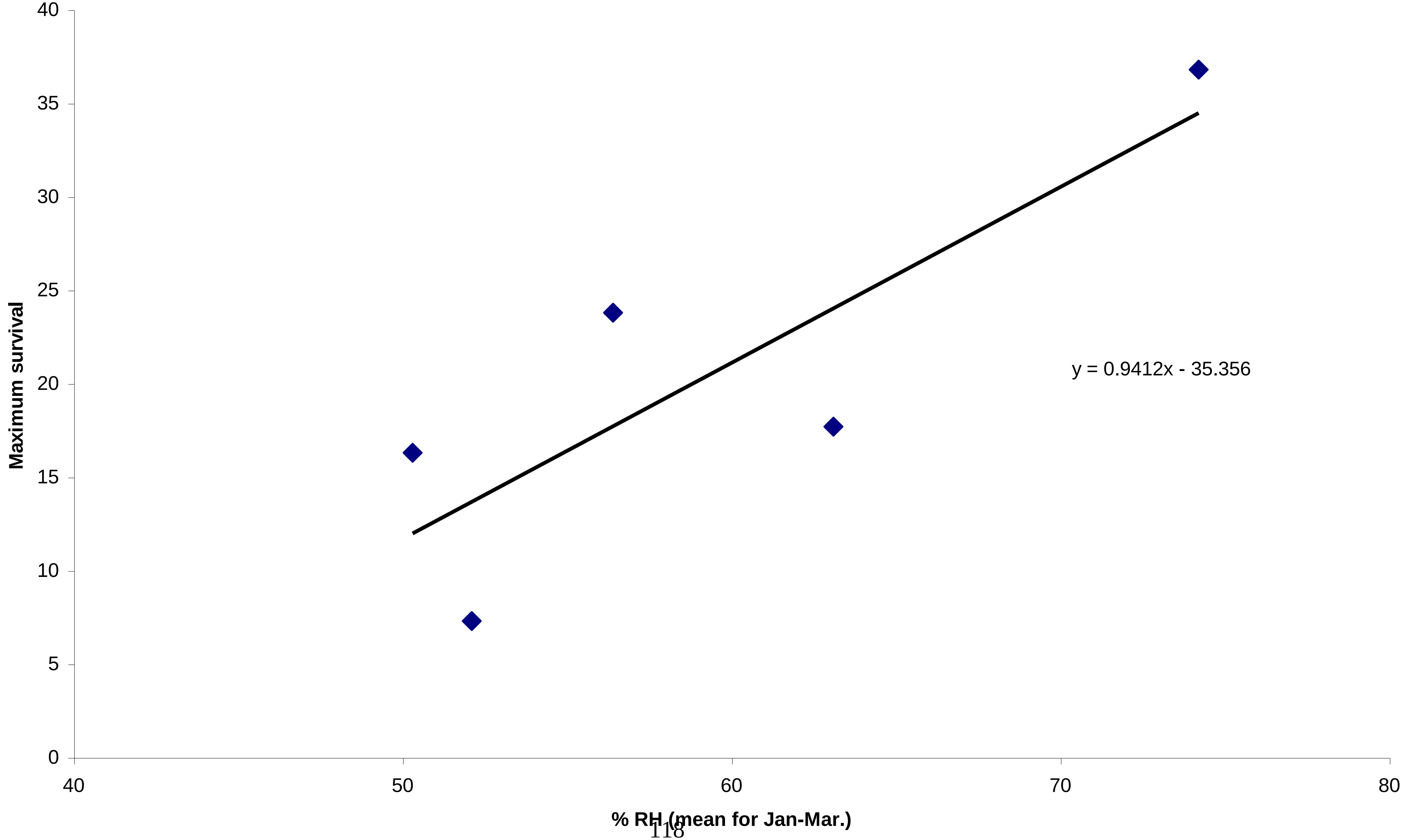


Figure 7.5. Relationship between yearly maximum rice hispa survival and mean minimum % relative humidity (RH) for Jan-Mar of the same year (all sites combined)



7.2.2. Flooding

Combining the overall survival rates of the cohort trials during the flooding prone rice seasons (aus and t.aman) at Barisal for all years the trials were run showed that rice hispa survival was significantly less when the trials were flooded (table 7.3; t = 2.1786, $p< 0.05$). This result is significant in that much of the southern and northeastern regions are flooded by fresh water from the vast river systems during the aus and t. aman rice seasons on a yearly basis, and this must put a ‘break’ on hispa population growth in these regions during years that flooding is significant.

Table 7.3. Overall survival of rice hispa under non-tidal vs tidal conditions, Barisal

Rice season/ date	Percentage survival	
	Non-tidal	**Tidal**
Aus:		
13/08/02		4.4
25/08/02		0.8
27/05/03	22.1	
17/06/03	35.8	
7/06/04		0.7
19/06/04	2.7	
T. aman:		
22/10/02	2.6	
19/11/02	16.3	
8/07/03		3.4
30/09/03		5.4
Mean ± SE (of transformed data)	**21.5 ± 5.5**	**9.2 ±1.8**

7.3. Natural Enemy Community and Relation of Rice Hispa Survival to Parasitism

7.3.1. Parasitoid community and other natural enemies.

Taxonomic identification and training for BRRI staff

Dr A T Barrion, Insect Taxonomist, IRRI, Philipinnes, made a visit to BRRI, Gazipur in August 2002 to work with BRRI staff to review past specimens of parasitoid and insect predator material collected in relation to the rice hispa. Dr Barrion also conducted a training course on parasitoid/insect predator taxonomy and identification. Dr Andrew Polaszek, private consultant on insect parasioids (but based at the Natural History Museum, London, UK), confirmed the presence of a new parasitoid of rice hispa not reported in Bangladesh until this project; this was *Pnigalio soemius* (Eulophidae). Dr Polaszek also formally named the egg parasitoid , *Trichogramma* sp.,(table 7.4) long reported from rice hispa (Polaszek et al., 2002) and is currently naming the larval parasioid, *Closterocerus* sp., as this species appears to be an important member of the parasitoid community (see below). Finally, Dr Polaszek has produced an illustrated key to the parasitoids listed in table 7.4 for use by BRRI researchers and by other organisations (e.g. DAE and workers in India) (Polaszek, 2005).

Table 7.4. Parasitoids recorded from the rice hispa

Insect parasitoids	**Family**	**Site**		
		Barisal	**Gazipur**	**Habiganj**
Trichogramma zahiri (egg)	Trichogrammatidae	√	√	√
Scutibracon hispae (larval)	Braconidae	√	√	√
Closterocerus (larval)	Eulophidae	√	√	√
Pnigalio soemius (larval)	Eulophidae	√	√	?
Trichomalopis anpanteloctena (hyperparasitoid)	Pteromalidae	√	√	?

Results of studies on natural enemy communities

The parasitoid species reared from the trap plants at the three sites during the three years the rice hispa cohort trials were run are shown in table 7.5. The main finding was that the community of parasitoids is more or less uniform across all three sites and this implies that this applies across the whole of the rice growing belt in Bangladesh. All species, apart from *Pnigalio soemius* and the hyperparasitoid were relatively common at all times. The last two species were found infrequently and in very low numbers.

The egg and two principal larval parasitoids (*Scutibracon* and *Closterocerus*) were all semi-gregarious in nature; i.e. one or more individuals can develop on one host individual. Recent work at BRRI (Islam and Rabbi, 1998; BRRI, 2001) has been conducted to determine the mean number of parasitoids, for each of these species, that emerge per host, for a range of large samples. This data can then be used to calculate a ‘correction factor’ for each species that is useful for the estimation of percentage parasitism figures. It should be noted that these correction factors are only useful for large samples or a broad range of parasitism data; the latter is the situation for the current project. The correction factors used were:

Trichogramma zahiri: 1.34 (BRRI, 2001)
Scutibracon hispae: 1.45 (Islam and Rabbi, 1998)
Closterocerus sp. (= Neochrysocharis sp.) : 1.15 (BRRI, 2001)

Regular sweep netting to record the presence of insect predators in rice fields (but not where the cohorts were run) was also conducted by BRRI entomologists at the Research Stations during the course of project; this was activity was not part of the project. Many species were recorded (spiders etc.). However, observations made during the cohort trials by the project staff suggested that insect predators are not significant mortality factors acting on the immature stages. Insect predators may, however, attack rice hispa larvae that emerge from the leaves (see earlier).

No fungal pathogens were recorded during the studies but some species have been recorded during previous surveys.

7.3.2. Impact of natural enemies on the immature stages of rice hispa

The percentage survival rates of the immature stages of rice hispa for the net house and field trials are shown in table 7.5. In almost all cases, and in all rice seasons, the stage-specific survival rates were much higher in the net house than in the field and were in excess of 75 –80 % (for the overall survival rates $p < 0.05$; $t = 2.4192$). These estimates show that natural enemies were making the following reductions in survival rates: boro - 49%, aus – 38%, and t. aman – 80%. As mentioned above, the main natural enemies of the rice hispa immature stages appear to be parasitoids. Thus, at Barisal at least, the combined impact of the parasitoids appears very significant across all the rice seasons. Further analysis is being conducted on the independent measures of parasitism to validate this.

Table. 7.5. Comparison of survival of rice hispa stages, field and net house conditions, Barisal, 2003

Rice hispa stage	Percentage survival in relation to rice seasons					
	Boro		Aus		T. aman	
	Net house	Field	Net house	Field	Net house	Field
	27/3	27/3	24/5	27/5	29/9	29/9
Egg	81.3	58	80.6	37.5	92.4	18.1
Larvae	76.9	30.6	75.3	70.2	91	0
Pupae	84.8	21.7	100	83.9	94.6	0
Overall % survival	53.1	3.8	60.7	22.9	79.6	0

7.3.3. Relation of parasitism to rice hispa stage-specific survival.

Summaries of the mean values of percentage parasitism for all the groups of trap plants put out at the time of the cohort trials are shown in tables 7.6-7 and table 7. 9 (mono crop figures). Figures for the parasitoid Pnigalio soemius have been left out as this species only occurred very rarely in the samples. Points that emerged were are follows:

- Percentage parasitism figures for the egg and two main larval parasitoids were variable and generally quite low. This is consistent with several earlier studies reported in the literature. But the figures in the tables represent spot estimates of parasitism and these may be much lower than the total parasitism of all individuals passing through a stage.
- Egg parasitism was higher in boro, aus and t.aman seasons in Gazipur than either Barisal or Habiganj. Larval parasitism was marginally higher in Gazipur than in Barisal; no figures were collected from Habiganj.
- Egg parasitism tended to lower in the boro season compared with the aus season - this was particularly noticeable in Gazipur.
- The data indicated that neither of the two main larval parasitoids predominated at any site.

Table. 7.6. Seasonal parasitism of rice hispa, 2002 – 03-04, Barisal*

Rice hispa stage & parasitoid	**Percentage parasitism**															
	Boro						**Aus**						**T.aman**			
	Date of cohort															
	2002		2003		2004		2002		2003		2004		2002		2003	
	15/4	2/5	22/2	27/3	4/3	20/3	13/8	25/8	27/5	17/6	7/6	19/6	19/10	16/11	8/7	29/9
Egg: *Trichogramma Zahiri*	6.1	6.1	0	0	-	0	3	3	4.6	14.9	-	-	1	-	-	-
Larval: *Scutibracon hispae*	6.5	6.5	-	3.8	-	0	1.4	1.4	3.8	0	0.3	-	-	-	-	-
Larval: *Closterocerus sp.*	5.8	5.8	-	25.7	-	0	0.2	0.2	0.7	0	6.3	-	-	-	-	-

**** Mean values for period of the cohorts of rice hispa***

Table. 7.7. Seasonal parasitism of rice hispa, 2002-03, Gazipur*

Rice hispa stage & parasitoid	**Percentage parastism**							
	Boro			**Aus**			**T. aman**	
	Date of cohort							
	2002		2003	2002		2003	2002	2003
	01/4	16/4	9/4	28/6	13/7	20/7	30/9	1/10
Egg: *Trichogramma zahiri*	14.9	28.1	10.5	32.1	44.3	29.9	41.6	34.3
Larval: *Scutibracon hispae*	5.4	5.0	2.3	18.4	11.5	5.8	12	-
Larval: *Closterocerus* sp.	6.9	6.3	11.6	4.3	12.2	16.0	11.3	-

* *Mean values for period of the cohorts of rice hispa*

The higher egg parasitism figures recorded in Gazipur may be a consequence of the lower risk of flooding at that site compared with the other two sites. Also, the higher overall rice hispa survival rates observed at Barisal compared with Gazipur, despite the impact of flooding from the rivers, might indicate that egg parasitism at least has a significant impact on rice hispa populations.

7.3.4. Parasitism in relation to rice hispa stage-specific densities

The potential impact of the three parasitoids was further investigated by examining the percentage parasitism figures in relation to the rice hispa egg or larval densities established on the trap plants. To do this, data on parasitism and host densities were collated from several cohort trial periods but this was kept to within an order of a month. Some of the data for egg parasitism is shown in figures 7.6-7 and that for the two larval parasitoids in figures 7.8-10. The data was investigated using linear regression to examine any trends; this analysis ignores small values of parasitism and small host densities.None of the regression coefficients were significant at the $p < 0.10$ level but strong trends in the data sets were evident: egg parasitism appeared to be density dependent, while that of the two larval parasitoids appeared inversely density dependent. Thus there is an indication that Trichogramma zahiri may be regulatory factor.

Figure 7.6. Egg parasitism, Gazipur, boro 2002

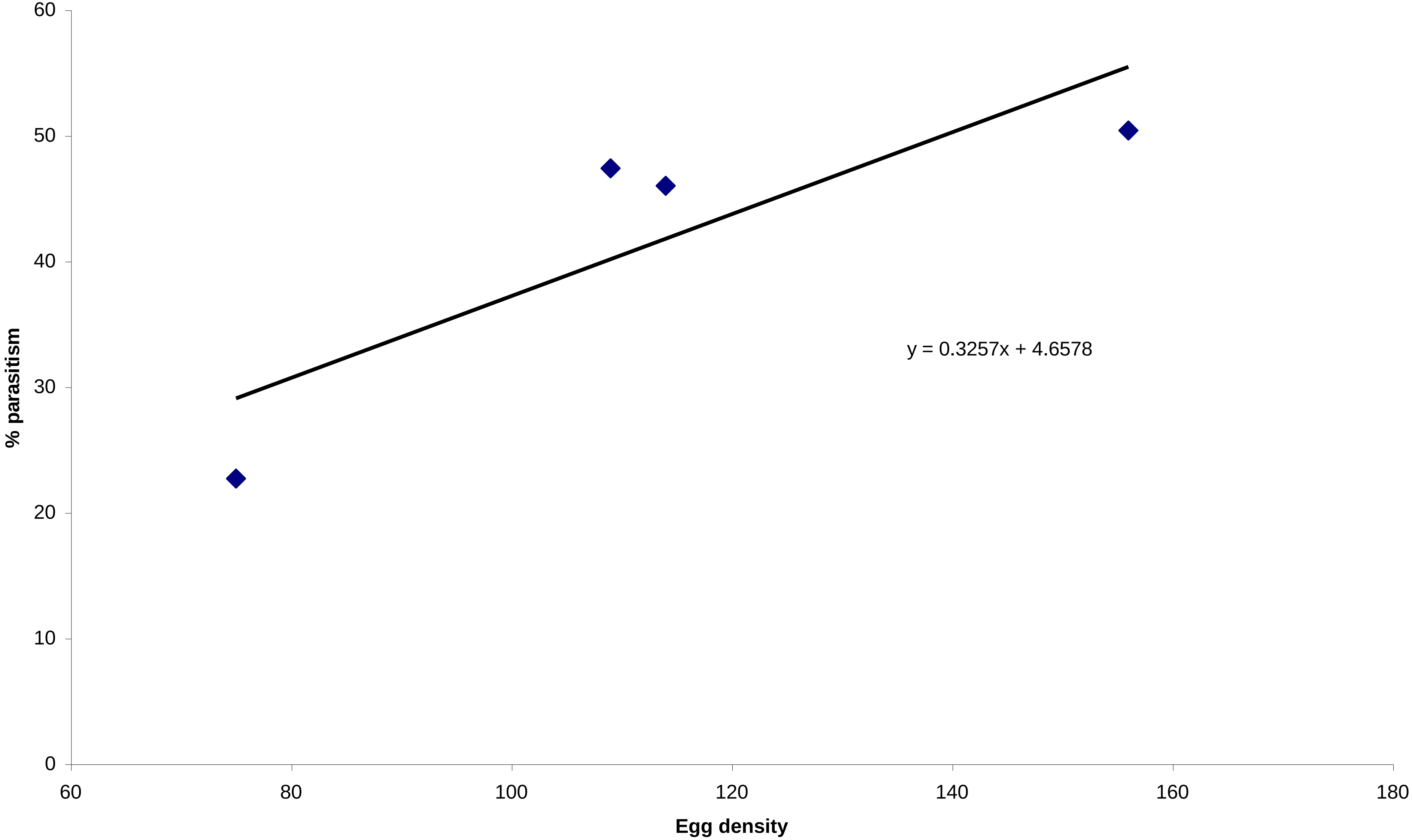


Figure 7.7. Egg parasitism, Barisal, aus 2002

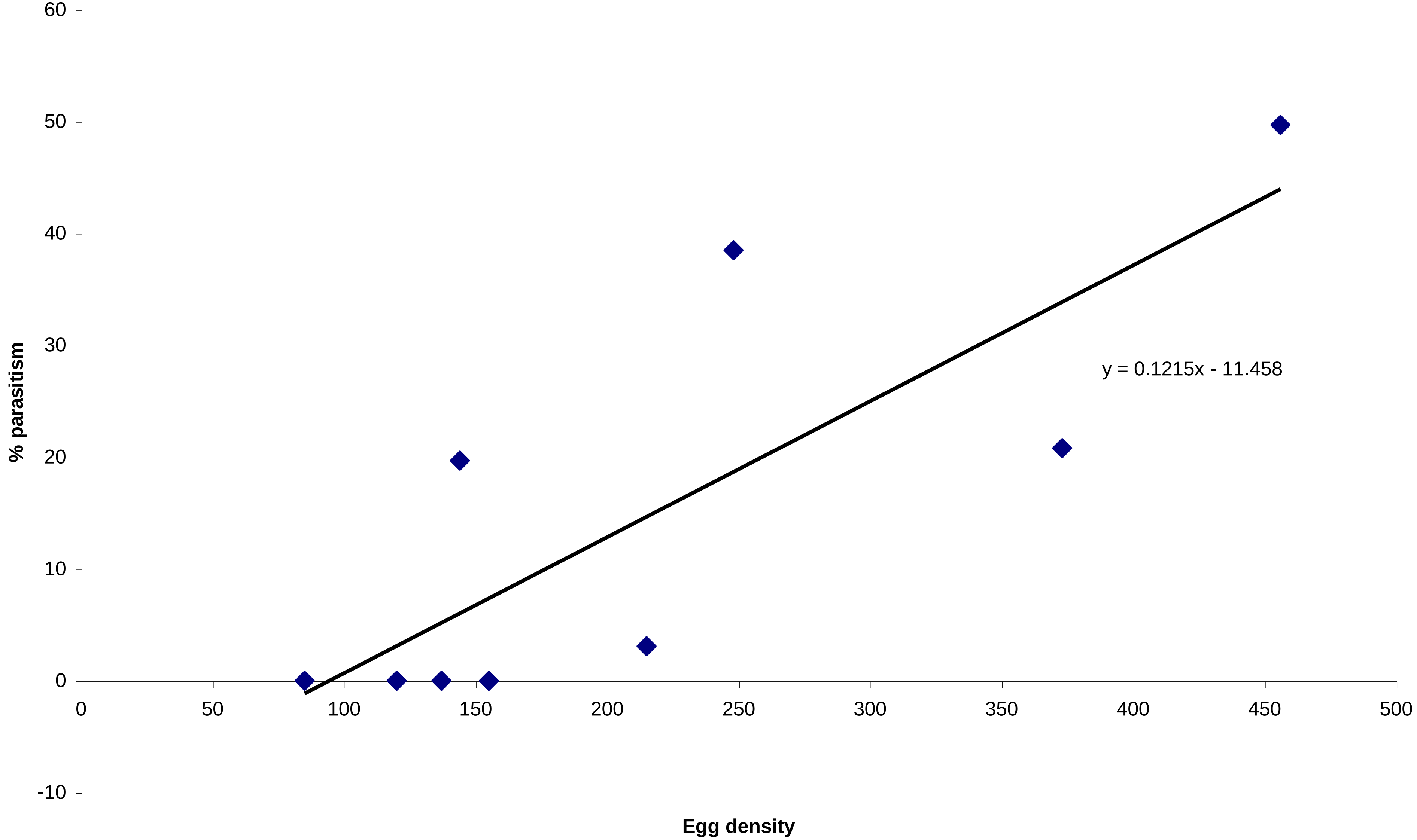


Figure 7.8. Larval parasitism, Scutibracon hispae, Barisal, boro, 2002

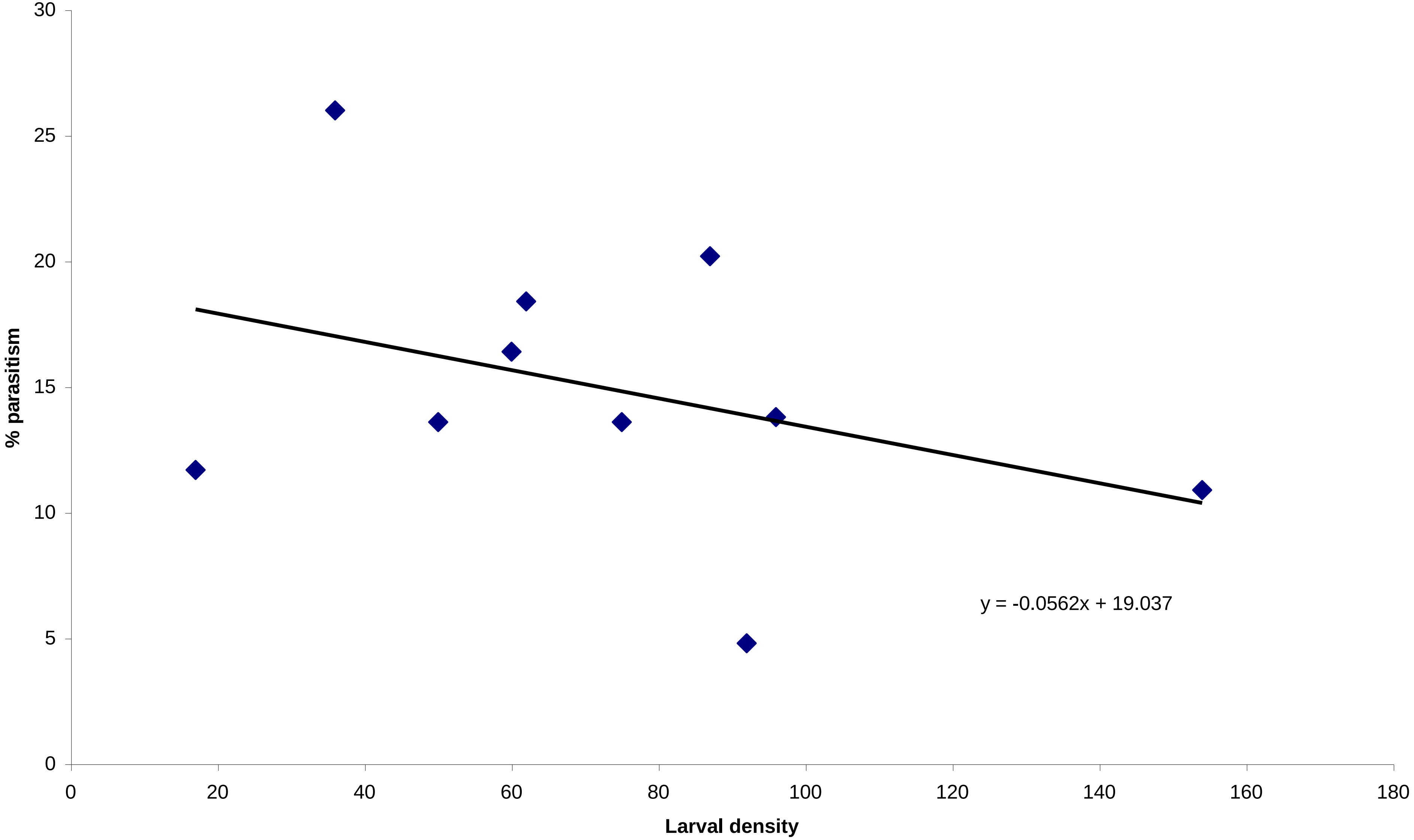


Figure 7.9. Larval parasitism, Scutibracon hispae, Barisal, aus, 2002

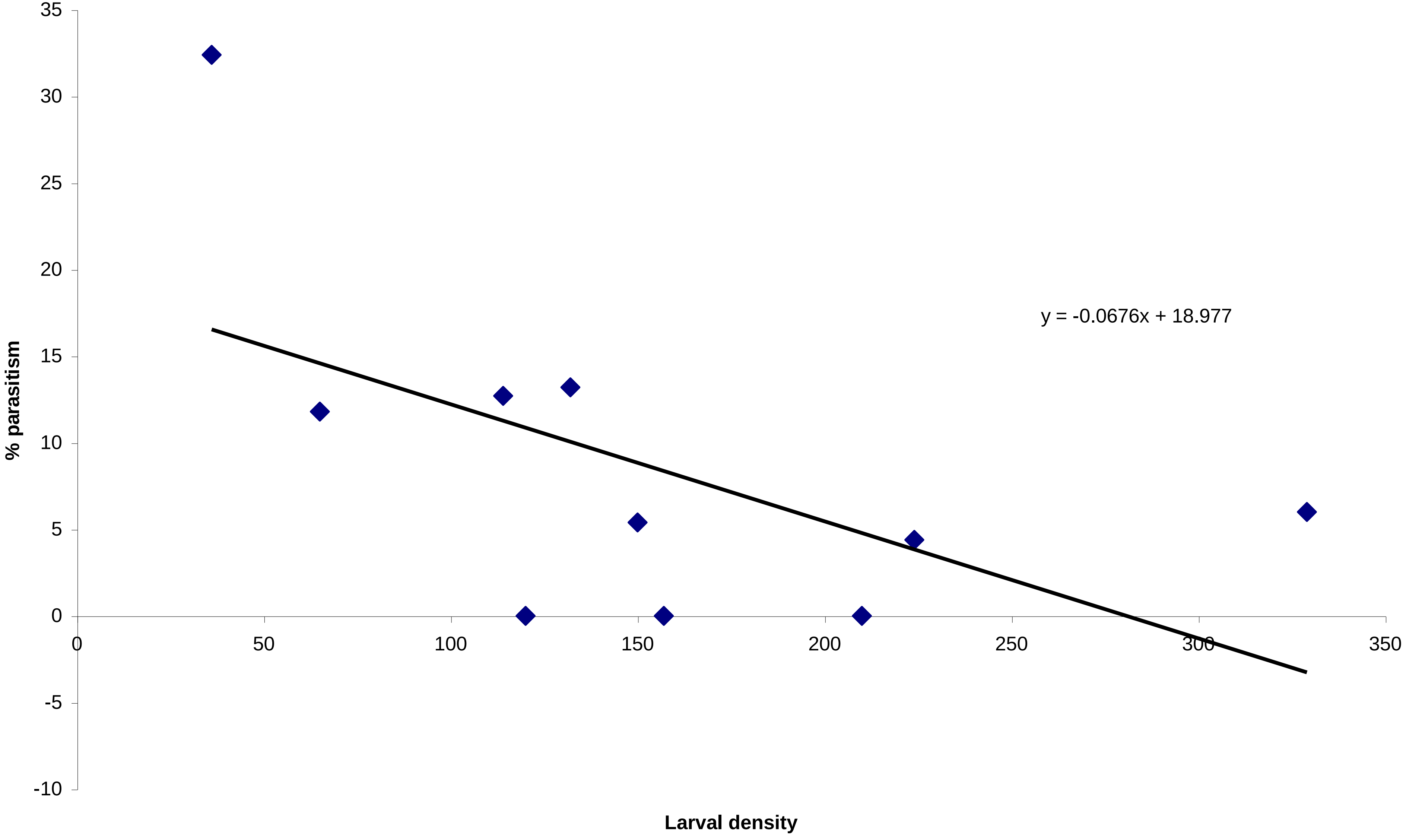
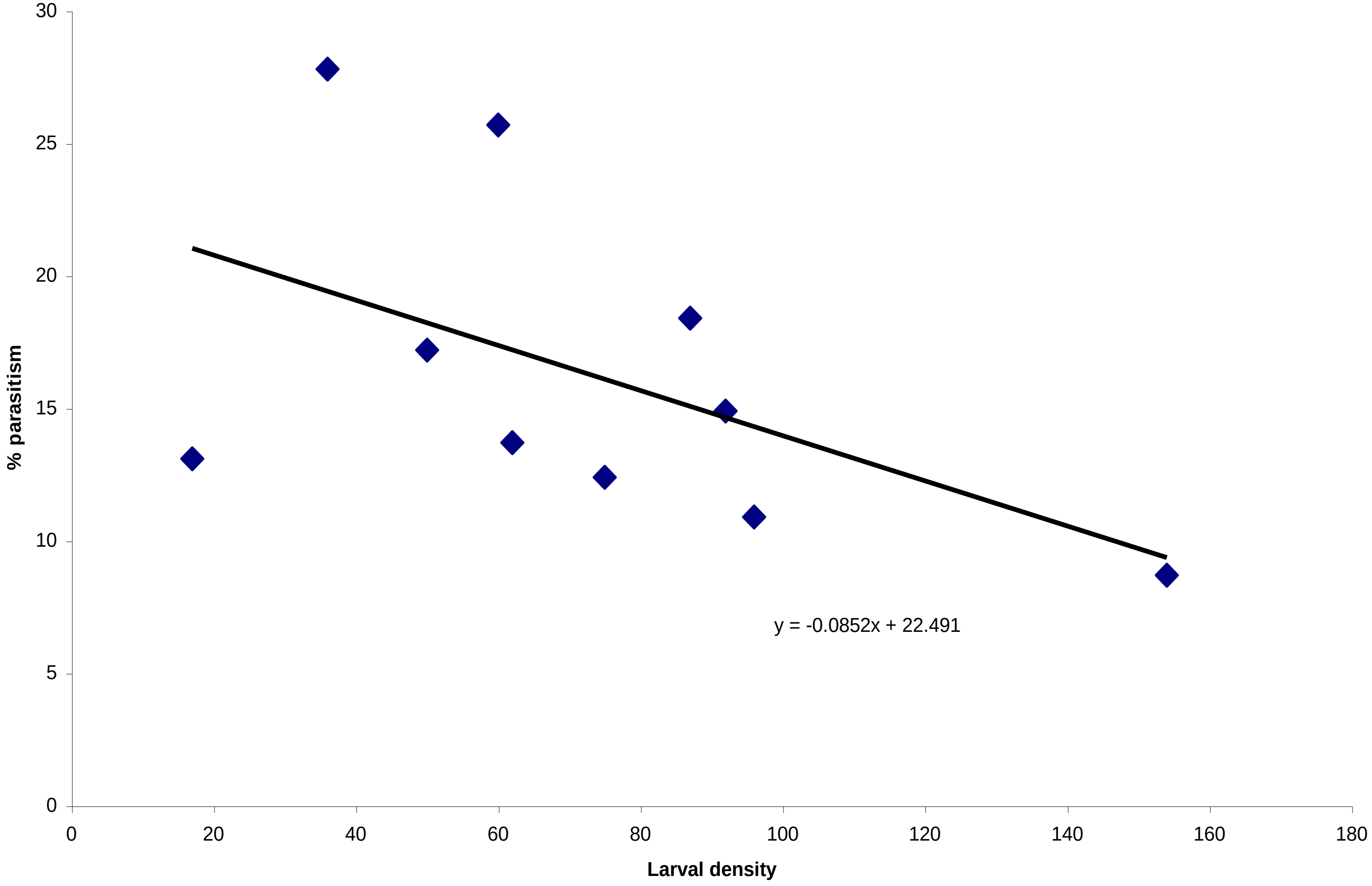


Figure 7.10. Larval parasitism, Closterocerus sp., Barisal, boro, 2002



7.4. Crop diversity study

The stage specific and overall survival rates for the cohort trials in the two different cropping systems in the boro and aus seasons are shown in table 7.8. In virtually all cases, survival rates were higher in the mixed crop systems although overall rates were only marginally so. Egg mortality was high in both cropping systems in the aus season because of high pre-monsoon temperatures and possibly low humidity levels (BRRI, pers comm.). An assessment of egg parasitism (table 7. 9) in both crop systems suggested that this approximately the same in both systems. Thus the higher survival rates observed for rice hispa in the mixed crop may be due to other factor/s such as micro - climate. The results do not support the notion that mixed crops reduce rice hispa population survival but these type of crop systems may reduce the rate at which rice hispa adults settle on rice plants.

Table. 7.8. Survival of the different stages of rice hispa for individual cohorts in rice mono vs mixed crop farms, Habiganj, 2004

Rice hispa stage	**Percentage survival in relation to rice seasons**			
	Boro		**Aus**	
	Mono-crop	**Mixed-crop**	**Mono-crop**	**Mixed-crop**
Egg	47.8	57.2	5	8.4
Pupae	66.7	33.3	0	100
Overall % survival of cohort	0.5	3.1	0	0.7

Table. 7.9. Seasonal parasitism of rice hispa in different cropping systems, 2004, Habiganj.

Rice hispa stage & parasitoid	**Percentage parasitism**			
	Aus		**T. aman**	
	Mono-crop	**Mixed-crop**	**Mono-crop**	**Mixed-crop**
Egg: *Trichogramme zahiri*	11.9	14.9	14.9	9.3

7.6. Conclusions and implications for management

Several important points emerge from the ecological studies. The generally low overall survival rates throughout the endemic range of rice hispa indicate that strong mortality factor/s are acting on the immature stages, particularly on the egg and larval stages. The survival rates do not differ significantly when rice is grown in mixed crop situations. That survival rates were also low in Habiganj, which is currently in an 'outbreak zone', suggests that mortality factors might be breaking down at a local level rather than at a broad scale. The patterns in seasonal survival did provide some support to the hypothesis that high survival in the boro is followed by high survival in the aus (see output 4)..

Several important mortality factors were identified from the studies. The positive relation of minimum levels of RH in the winter months with rice hispa survival do suggest that RH is limiting to rice hispa development and this supports the results of output 4. The flooding of rice fields from the rivers in the aus and t aman seasons is also clearly an important mortality factor that likely acts on a regional scale given the vast network of rivers that run through the south and northeast of Bangladesh.

The parasitoid community that attacks rice hispa has now been clarified and it is evident that almost all the parasitoid species identified in this project are ubiquitous throughout the rice growing zone. Insect predators, although known to have an important impact on rice hispa adult populations, do not appear to be important predators of the immature stages. In contrast, the egg and larval parasitoids do appear to have an important impact and this is regional in effect. In particular, the egg parasioid, Trichogramma zahiri may have a positive density dependent effect on rice hispa populations.

The lower values of egg parasitism at Barisal and Habiganj (and possibly larval parasitism) might be the result of the impact of flooding that occurs in the aus and t aman seasons. As the effects will be patchy throughout the regions (depending on the level of the water in the rivers), the impacts on the action and survival of parasitoids will be variable - this hypothesis would explain the apparent localized nature of outbreaks that are currently taking place in the northeast.

No fungal pathogens were recorded during the studies but previous surveys have shown these can be significant on adults. Researchers in India in Assam, have developed a mycoinsecticide based on Beauvaria bassiana which is proving to have a significant impact on hispa populations.

Another factor found to be contributing to the mortality of the immature stages was the loss of larvae when they exit their mines in pursuit of new feeding sites.

The methods used in this project to study survival and mortality do not allow an easy estimation of the relative magnitudes of the different mortality factors studied; to do this would require more detailed studies at individual sites.

The studies reported here on the apparent relation of rice hispa survival and RH/flooding supports the idea that the development of forecasting models (as suggested in output 4) could provide a strong tool for predictive and planning purposes. Also the ecological studies support the current efforts by DAE to promote the conservation of natural enemies of rice hispa. However, it is unlikely that efforts to mass rear and release some of parasitoids would be effective (in terms of impact in the field) as the hispa rice outbreaks occur very rapidly in the field.

8. Recommendations for Integrated Pest Management (IPM) Technologies and their Dissemination

The workshop was opened by the Director General of BRRI, Dr M Maniul Haque. The workshop was consisted of two major sessions: a formal presentation session covering the research results (first day/early part of the second day); and then discussion groups sessions (facilitated by BRRI) that considered some major themes identified during the formal presentations (most of the second day).

As already mentioned, the project partners had not completed some research activities, so preliminary findings had to be used in some discussions. The major points and conclusions arising from the discussions about the project outputs are listed below. The recommendations linked to these discussions and endorsed by all the national participants are shown in Box 1. Thus, some important points arising were:

- It is recognized by all that rice hispa outbreaks are episotic in nature and (currently) unpredictable; this is in contrast to other native pests of rice.
- The current IPM efforts by farmers and DAE are generally sound and that the DAE IPM training programme for farmers (under the SPPS) should be increased. It was noted that the economic basis of some cultural controls needed clarification but these studies were planned under the project (see output 2 for the conclusions on this).
- The importance of State level interventions (e.g. the DAE IPM training, loan of sprayers and sweep nets etc. – see output 2)
- The project research to date has provided some new key information (see outputs 4, 5, 6, and 7). Most of this does have several implications for hispa IPM; e.g., on how and where the State is currently focussing effort on hispa management, on the type of additional management interventions and also on IPM policy. Thus:

1. That rice hispa is present throughout most of the lowland rice growing area (and also present on some weeds) at very low incidence in what appears most years, means that all areas are probably at risk from local outbreaks as well as outbreaks from remote areas. Thus greater vigilance is needed in areas outside the southern region of Bangladesh – assumed by most to be the winter endemic range.
2. Insect natural enemies do seem to have an important impact on the rice hispa and at least one species seems to density dependent. Thus the need for the conservation of natural enemies takes on even greater significance in the case of rice hispa and needs incorporating in IPM training. But the episotic nature of rice hispa outbreaks makes augmentation technologies for parasitoids (that have been under discussion at BRRI and DAE) difficult to implement. (This point was not resolved but see the next point).
3. There are probably high possibilities for the development of a mycopesticide, e.g. based on *Beauvaria bassiana*. (This point is also discussed in output 3). BRRI have tried this approach in the past but do not have the full expertise; also the strains of *B. bassiana* in Bangladesh may not be the most effective (BRRI pers comm.). In contrast, India (Assam Agricultural University) have made good progress with mycopesticide technolgy, so this provides an opportunity for information and technology exchange between the two countries. This was endorsed at the workshop. There was general agreement that a study would also need to be

conducted to understand how a mycopesticide technology would be implemented, i.e. who would use and how would it be applied but unlike insect natural enemies, there is a potential to mass produce and stock pile a mycopesticide agent.

4. The studies on the historical rice hipsa data (see output 4) and the relation of hispa numbers to some abiotic parameters (particularly the previous winter humidity levels) attracted much interest in the workshop. There was strong agreement that it would be profitable to further this work with the aim of developing better monitoring schemes and possibly forcasting models. One important point that came out of the historical data collation for this project was that DAE need a strengthened capacity to handle and process rice pest information currently being routinely collected at the rice block and Thana (=Uppazilla) levels.

- The dissemination of the project results fall into several categories:

1. There is a need for follow –up within DAE to ensure all key senior personnel are aware of the outcomes of the project. For this purpose a popular booklet summaring the key findings and messages should be produced.
2. The same booklet could be used to inform NGOs
3. There is a need to follow through on the mycopesticide idea by connecting the project with workers in India.
4. BRRI and DAE need to formulate a concept for the development of rice pest monitoring and forcasting.

A proceedings of the workshop is to be produced by the BRRI Entomology Division.

Box 1. Recommendations from the Rice hispa workshop, April, 2004

1. *Life tables of rice hispa should be constructed on natural population in outbreak areas. Effect of crop diversity may also be considered.*
2. *Beauvaria sp. and other micro-organisms should be evaluated for rice hispa control.*
3. *Effective management practices for alternate host plants of rice hispa should be developed.*
4. *DAE in collaboration with BRRI should develop a format for data collection on rice hispa and other rice insect pest and their natural enemies (for monitoring and possibly forcasting). CABI and NRI may be consulted for this purpose.*
5. *To establish a surveillance and early warning system, both BRRI and DAE should prepare a project proposal and submit it to the government. and donor agencies for funding.*
6. *Measures should be taken to obtain meteorological data electronically from the Department of Meteorology (for the development of forcasting models). A memorandum of Understanding (MOU) may be signed among BRRI, DAE and the Meteorological Department.*
7. *The DAE SPPS project should continue with their training of farmers in rice hispa IPM, as some cultural measures may be effective.*
8. *The duration of the project should be extended to enable concrete recommendations for farmers to be developed.*
9. *As the rice hispa is a major pest in many counties neighbouring Bangladesh, regional co-operation may be strengthened by arranging an agreement between India, Nepal and Bangladesh for the effective management of rice hispa.*

9. Preparation of Publications

A summary of progress is as follows:

1. Project report and workshop proceedings. The latter is still in preparation by BRRI but they expect to have this completed in the next couple of months. It will be produced by BRRI.

2. The guide to the main parasitoids has been produced:
   Polazszek, A (2004) Identification guide to the common insect parasitoids of the rice hispa beetle, *Dicladispa armigera*, in Bangladesh. 12pp.

3. Popular booklet. This will be done after the completion of the final technical report (after March 2005). This will be led by BRRI.

4. The following paper has been published:
   - Polaszek, A; Rabbi, M F; Islam, Z; Buckley, Y M (2002). *Trichogramma zahiri* (Hymenoptera: Trichogrammatidae) an egg parasitoid of the rice hispa *Dicladispa armigera* (Coleoptera: Chrysomelidae) in Bangladesh. **Bulletin of Entomological Research** 92, 529 –537.

5. The following papers are in preparation for referred journals:
   - Zhu, C-D; Polaszek, A; Murphy, S T; Rabbi F; Gumovsky, O. Morphological and molecular characters defining a new species of *Closterocerus* (Hymenoptera: Eulophidae) - a parasitoid of rice hispa (*Dicladispa armigera*) in Bangladesh. Probably be submitted to the '**Bulletin of Entomological Research'.**
   - Stonehouse, J (and other authors from BRRI). Costs, benefits and perceptions of farmer level management options for rice hispa in Bangladesh. Will be submitted to **'Crop Protection'**

Besides these a number of other papers will be produced as specified in the Project Memorandum Form (PMF) document. These will cover:

6. Studies on the endemic range of rice hispa

7. Studies on the effects of the host plant on rice hispa settlement, oviposition and survival

8. Studies on the survival and mortality of rice hispa in the field.

CONTRIBUTIONS OF OUTPUTS TO DEVELOPMENTAL IMPACT

1. Contribution to Developmental Goal

The project goal (Land/water interface programme purpose) is: 'yields of rice based systems in the floodplain areas increased by application of environmentally benign pest control'.

The outputs have contributed to this goal in that the building blocks for the project purpose are now in place. More specifically, contributions of the outputs to the project goal are shown in Box 2.

Box 2. Contribution of the outputs to the project goal

Output no.	Major Results	Contribution to Project Goal
1	• Farmers confirmed that insects are worst production problem and hispa is second only to stem borer • Acceptability of different controls to farmers and other stakeholders now understood	• Farmer perception of importance of hispa in Bangladesh confirmed • Options for control defined – farmers and State 'agreed' on IPM approach. Importance of cultural contols confirmed and rational insecticide use.
2	• Economic costs of farmer level controls now understood, particularly the value of different cultural controls • Ditto, State level interventions	• Extension have a better basis for which IPM components (particularly cultural controls) should be promoted in the farmer training programme • Value of State level interventions for hispa control confirmed
3	• Options and acceptability of additional State level interventions now determined (and the implications for policy)	• The key government organisation responsible for IPM (the DAE) now understand the additional measures that could improve hispa management and are taking steps to develop and implement the new measures
4	• Major collation of historical rice pest information (focus on hispa) in centralised database • The needs for better rice pest incidence information management and processing identified • Some major abiotic and cropping factors associated with hispa outbreaks determined • Basic forecasting models developed	• The options for improving State level monitoring of rice hispa populations understood and now being actioned (see above) • The options for forecasting understood and being actioned (see above)
5	• The geographical range of hispa now understood, particularly the range in the winter season	• Basis of hispa population dymamics now better understood • Now clear that most rice areas are at risk from local based outbreaks • DAE and other stakeholders will use this information to direct their altert/IPM training

		programme for farmers • GIS will be explored as an additional tool for monitoring and forecasting
6	• Researchers now have a clearer understanding of the range of host plants (rice age, plant quality, alterantive host plants) that the hispa can use for feeding, ovipostion and for completing its life cycle.	• The information contributes to the understanding of hispa population dyanamics. Overall, in the field situation, host plants of a suitable age and quality do not seem to a limiting factor to population growth. The work has confirmed that hispa can/does exploit alternative host plants. BRRI/DAE will now use this information in the IPM training programme for farmers.
7	• Studies on the overall survival of the immature stages of hipsa indicate that these are very low in all rice seasons; even in a region where outbreaks were occurring. • Natural enemies, particularly parasitoids do seem to have a significant overall impact on hispa survival; at least one species of parasitoid may be density depenedent. • The species important species of parasitoid have been clarified and are being named. A guide has been produced for researchers. • Winter ambient relative humidity values appear to have an impact of hispa surival later in the year (this is in agreement with output 4). Flooding is also an important moratlity factor. • No differences in overall hispa survival could be found in rice mono-cultures versus mixed crop systems.	• Greater understanding of hispa population dynamics - the survival data illustrates that major mortality factors are operating on hispa in non-outbreak years and natural enemies, winter relative humidity values and flooding are all significant factors. • The low survival values obtained in the region of outbreaks (in the northeast) suggest outbreaks are local and patchy in any one area – at least in the initial stages. • Greater efforts need to be made to conserve insect natural enemies; this will be incorporated in to the IPM training programme. • The results on the abiotic factors support the move to develop monitoring and forcasting tools; this is being followed through by DAE/BRRI.
8	• National workshop involving important research and extension stakeholders to review project results and agree implications for hispa IPM	• Implications of the project results consolidated and plans for future actions agreed. Current IPM ‘package’ to be developed and modified using: 1. New results to add to farmer training programme (e.g. streamlining of cultural controls; conservation of natural enemies)) 2. Develop State support through developing monitoring and forcasting tools • The potential of mycopesticides to be followed up by connecting with hispa workers in India. If successful, this could form another component of State support to farmers.

2. Promotion Pathways to Target Institutions and Beneficiaries

The Government of Bangladesh gives strong support to IPM and the main country – wide implementation thrust is through the Department of Agricultural Extension (DAE). Within the Plant Protection Wing of DAE, there has been a long standing IPM programme of farmer training through the ‘Strengthening of Plant Protection Services

Project', a joint effort supported by the Government of Bangladesh and DANNIDA. Some NGO's also work locally with farmers on IPM. The hispa prject has made strong links with DAE, SPPS and some NGOs (PETRA, CARE) nand has sought advice from these stakeholders on promotion and uptake issues. Nonetheless, all groups, and also farmers, have emphasized the importance of the SPPS Project as a focal point for building IPM initiatives in Bangladesh. Most other groups take their lead from the SPPS Project, especially farmers.

3. Follow – up Action/Research

These include:

Further dissemination of project results. The type and list of these were covered under Output 9.

Development of the existing DAE - SPPS IPM training programme for hispa. These are part of on-going discussions with DAE, mainly through BRRI. An important step will be the summary of the project findings in the popular booklet that DAE can use to develop its training programme.

Research. The main focus will be on:
- Monitoring and forcasting models for hispa/rice pests – BRRI with DAE
- An assessment of the potential for the development of a mycopesticide – BRRI and DAE. The first step will be to make a connection with India researchers at Assam Agricultural University.

REFERENCES

Alam, MZ., 1967. Insect pests of rice in East Pakistan. In: *The Major Insect Pest of the Rice Plant.* Baltimore, USA: The Johns Hopkins Press, pp. 643-655.

Anon. 2003. *Modern Rice Cultivation.* (In Bangla). Textbook. 2003 edition.

Biswas, AK, Mandal, SK. 1992. Field efficacy of several insecticides against rice hispa. *Journal of Maharashtra Agricultural University* **17**: 169.

BRRI (2001). Mass rearing, cultivation and application of biocontrol agents for control of rice hispa. BRRI, Gazipur, Dhaka unpublished report. 45 pp.

Budhraja, K, Rawat, RR, Singh, OP 1980. Extent of recuperation from attack of *Dicladispa armigera* after insecticidal control in some rice varieties. *IRRN* **5**(**2**): 6.

CABI 1999. *Crop Protection Compendium*, Global Module.

Chand, R, Tomar, JB 1984. Screening for resistence to rice hispa. *IRRN* **9**(**2**): 6.

Chatterjee, PB, Bera, PK 1990. Rice grain yield loss due to rice hispa damage. *IRRN* **15**(**15**): 21.

Courshee, RJ, Ireson, MJ 1961. Experiments on the subjective assessment of spray deposits. *Journal of Agricultural Engineering Research* **6**: 175-82.

Deka, KC, Bhagowati, AK, Baruah, UK. 1994. Effect of monocrotophos application in rice-fish farming. *JASS* (India) **7**: 26-30.

De Kraker, J. 1997. The potential of natural enemies to suppress rice leaffolder population. *Wageningen Agricultural PhD dissertation* 257pp.

Dhaliwal, GS, Shahi, HN, Gill, PS, Maskina, M. 1980. Effects of different levels of nitrogen and varieties on the incidence of hispa and leaf folder in rice. *Pestology* **IV**(**7**): 14-6.

Dutta, BC, Hazarika, LK. 1994. Screening some rice cultivars for resistance to rice hispa, *Dicladispa armigera* (Coleoptera: Chrysomelidae). *JASS* (India): **7**:31-4.

Gladwin, RW, Christina H. 1983. Contributions of decision-tree methodology to a farming systems program. *Human Organisation* **42**: 146̣57.

Grimmett, R, Inskipp, C, Inskipp, T. 1999. *Pocket Guide to the Birds of the Indian Subcontinent.* New Delhi, India: Oxford University Press. 384pp.

Grist, DH. 1986. *Rice –6th ed. – (Tropical Agriculture series)*. Longman Singapore Publishers (Pte) Ltd.

Haque, S S, Islam, Z, Kundu, R. 2002. Relationship betweenrice hispa, *Dicladispa armigera* (Oliver), damage and grain yield. Unpublished report, BRRI, Gazipur, Bangladesh. 21pp.

Hazarika, LK, Puzari, KC. 1995. White Muscardine Fungus (*Beauvaria bassiana*) pathogenic to different stages of riche hispa (*Dicladispa armigera*). *Indian Journal of Agricultural Sciences* **65**: 368-72.

Hazarika, LK, Puzari, KC 1997. Field efficacy of White Muscardine Fungus (*Beauvaria bassiana*) on rice hispa (*Dicladispa armigera*). *Indian Journal of Agricultural Sciences* **67**: 643-5.

Heinrichs, EA (Ed.) 1988. *Plant Stress-Insect Interactions*. John Wiley & Sons, New York. 492 pp.

Horsfall, JG, Barratt, RW. 1945. An improved grading system for measuring plant diseases. *Phytopathology* **35**: 655.
Islam, S. 1997. *Unpublished PhD thesis,* Asian Institute of Technology.
Islam, Z 1989. Crop losses due to hispa beetle damage in deepwater rice. *IRRN* **14**(**6**): 33.
Islam, Z; Rabbi, MF. (1998). Parasitism of rice hispa, *Dicladispa armigera* (Oliver) grubs in Bangladesh. *Bangladesh Journal of Entomology* **8**, 127-129.
Islam, Z. 1999. DFID/CPP Rice Crop Protection Workshop, *Abstracts of presentations,* pp. 4-5. Bangladesh Rice Research Institute, Gazipur, 6-8 April, 1999.
Islam, ZM. 1973. Notes on the biology of rice hispa *Dicladispa armigera* (O1.) (*Coleoptera, Hispidae*) in Bangladesh. *Bangladesh Journal of Biological and Agricultural Sciences,* **2: 2,** 14-16.
Johannson, SA. 1964. Feeding and nutrition in the reproductive progress in insects. Royal Entomological Society of London Symposium **2,** 43 – 55.
Johnsen, S; Islam, S, and Hassain, MB. (1997). Rice hispa in Bangadesh: Dansih Internatioanl Development Assistances (DANIDA). Unpublished report. 22pp + 5 appendices.
Karim, ANMR. 1986. The Hispa Episode. A paper presented at the 12th workshop on Modern Rice Cultivation in Bangladesh jointly sponsored by BRRI and DAE, 5-7 April 1986, BRRI, Joydebpur, Gazipur.
Khan AR., 1989. Rice hispa: A threat to Bangladesh Agriculture. In: *Proceedings of the SAARC Workshop on Rice Hispa*. Bangladesh Rice Research Institute Publication, **94**: 28-29.
Khan, MQ, Murthy DV. 1954. A preliminary note on a larval parasite on the rice hispa. *Indian Journal of Entomology* **16**: 299 -300.
Kranz, J. 1988. Measuring plant disease. In: Kranz, J, Rotem, J, Eds. *Experimental Techniques in Plant Disease Epidemiology*. Berlin: Springer Verlag.
Lindow, SE. 1983. Estimating disease severity of single plants. *Phytopathology* **73**: 1576-81.
Maxwell-Lefroy, H. 1909. *Indian Insect Life: A Manual of the Insects of the Plains, Tropical India.* Calcutta and Simla, India: Thacker, Spink. xii+786+lxxxiv pp.
Mazunder, D, Puzari, KC, Hazarika, LK. 1995. Mass production of *Beauvaria bassiana* and its potentiality on rice hispa. *Indian Journal of Phytopathology* **48**: 275-8
McCracken, JA, Pretty, JN, Conway, GR. 1988. *An Introduction to Rapid Rural Appraisal for Agricultural Development.* London, UK: IIED. iv+81pp.
Nath, RK, Dutta, BC. 1997a. Assessment of yield loss due to rice hispa (*Dicladispa armigera* Oliv.). *Journal of the Agricultural Science Society of North-East India* **10**: 268-70.
Nath, RK, Dutta, BC. 1997b. Economic injury level of rice hispa, *Dicladispa armigera* (Oliv.). *Journal of the Agricultural Science Society of North-East India* **10**: 273-4.
Nur-E-Elahi, Khan, AH, Siddique, MR, Saha, A, Nasim, M, Mollah, MIU, Shahidullah, SM. 2001. Existing cropping patterns of Bangladesh, potential technologies and strategies for improving systems productivity. In: Proceedings of thye workshop on modern rice cultivation in Bangladesh, 14-16 February 1999, BBRI, Gazipur, Bangladesh pp 107 – 169.

PETRRA (Poverty Elimination Through Rice Research Assistance) 2000. *Stakeholder Analysis Report: An Initial Prioritisation of Rice Production Issues within the Context of the Livelihoods of Resource-Poor Farm Households.* Dhaka, Bangladesh: PETRRA. In ten volumes (South West Coast - November 1999, 37pp; South Central Coast - February 2000, 41pp; Central West, Kushtia - May 2000, 24pp; Chuadanga - May 2000, 39pp; Comilla - May 2000, 28pp; Bhanga, Faridpur - June 2000, 28pp; Rajshahi, High Barind - June 2000, 23pp; Hobiganj - June 2000 26pp; Rangpur - June-July 2000, 30pp; Noakhali, Maijdi - July 2000, 39pp).

Polaszek, AP, Rabbi, MF, Islam, Z, Buckley, YM. (2002) *Trichogramma zahiri* (Hymenoptera: Trichogrammatidae) an egg parasitoid of the rice hispa. *Dicladispa armigera* (Coleoptera: Chrysomelidae) in Bangladesh. *Bulletin of Entomological Resarch* **92**, 529-537.

Polaszek, AP. (2005) Identification guide to the common insect parasitoids of the rice hispa beetle, *Dicladispa armigera*, in Bangladesh, Unpublished manual, BRRI, Gazipur, Bangladesh.

Prakasa Rao, PS. 1977 *Dicladispa armigera* (Oliv.) In: Kranz J Schumutherer, Koch W., eds. *Disease, Pests and Weeds in Tropical Crops*. Panl Paney, Berlin, Germany: Verlag, pp 401-403.

Puzari KC., Hazarika LK. 1991. Efficacy of *Beauveria bassiana* combined with various stickers or spreaders against rice hispa (RH). *International Rice Research Newsletter*, **16(6)**: 21

Puzari, KC, Hazarika, LK. 1992. Entomophagous fungi from North-East India. *Indian Phytopathology* **45**: 35-8.

Rao, VG. 1977. Outbreak of rice hispa in Nellore District, Andhra Pradesh, India. *IRRN* **2**(**5**): 18-9.

Rao, VP c.1964. *US-PL-48 Project: Survey for Natural Enemies of Pests of Paddy; Final Technical Report covering the Period 15 July 1961 to 14 July 1964.* Unpublished report, CIBC Bangalore. 15pp.

Rawat, RR, Singh, OP, Budhraj, K. 1980. The effect of leaf-clipping of infested rice crop on the incidence of *Dicladispa armigera* (O) and yield. *Oryza* **17**: 247.

Razzaque, QMA, Karim, ANMR, Kamal, NQ. 1989. Studies of some bio-ecological aspects of rice hispa *Dicladispa armigera* (Oliver) (*Hispidae: Coleoptera*) In: *Proceedings of the SAARC Workshop on Rice Hispa*. Bangladesh Rice Research Institute Publication, 94.

Rhoades, Robert E. 1982. *The Art of the Informal Agricultural Survey.* Centro Internacional de la Papa (CIP) Social Science Department Training Document 1982̣2. Lima, Peru: CIP. 40pp.

Sahu, S, Singh, R, Kumar, P. 1996. Host preference and feeding potential of spiders predaceous on insect pests of rice. *Journal of Entomological Research* **20**: 145-50.

Sen, PC. 1921. Rice hispa. *Bengal Agricultural Journal*, **1**: 13-15.

Settle, WH., Hartjaho, A., Endah, TA, Widyastama, C, Arief, LK, Dadan, H, Alifah, SL. & Parjarningsih 1996. Managing tropical pests through conservation of generalist natural enemies and alternative prey. *Ecology* **77**: 1975-1988.

Shahjahan, M, Taludker, FZ. 1995. Influences of major pests of rice on yield in Bangladesh. *Pakistan Journal of Scientific and Industrial Research* **38**: 88-93.

Sharma, AK, Parshad, B. 1961. Bracon sp. (*Braconidae: Hymenoptera*) parasitized grubs of *Discladispa armigera* (Oliv.) (*Chrysomelidae: Coleoptera*) on paddy in Eastern Madhya Pradesh. *Indian Journal of Entomology*, **23 (3):** 238-239.

Sherwood, RT, Berg, CC, Hoover, MR, Zeiders, KE. 1983. Illusions in visual assessments of stagonospera leaf spot of orchardgrass. *Phytopathology* **73**: 173-7.

Sokal, RR,. Rohlf, FJ. (1995) *Biometry*. Third Edition. W H Freeman and Company, New York.

Sontakke, BK, Rath, LK. 1998. Pink stemborer and hispa on hybrid rice in Western Orissa. *Insect Environment* **4**(**1**): 8.

Southwood, TRE. (1978). Ecological Methods. Second Edition. Chapman and Hall, London.

Stonehouse, JM. 1994. Assessment of Andean bean diseases using visual keys. *Plant Pathology* **43**: 519-27.

Stonehouse, JM, Gbongboui, C, Ly, S, Maiga, I, de Groot, A, Tijani. 1997. Grasshopper control in the Sahel: Farmer perceptions and participation. *Crop Protection* **16**: 733-41.

Subbratnam, GV, Perraju, A 1976. A note on the chemical control of (*Dicladispa armigera* O) in a rice nursery. *IRRN* **1**(**2**): 15-6.

Thakur, AK, Kashyap, NP, Hameed, SF, Suri, SM 1979. Unusual occurrence of rice hispa on rice in Himachal Pradesh, India. *IRRN* **4**(**6**): 7.

Van Driesche, RG; Bellows. Jr. TS. (1996). *Biological Control*. Chapman and Hall. New York.