Biodiversity of insects associated with rice (*Oryza sativa* L.) crop agroecosystem in the Punjab, Pakistan

By

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To

The Controller of Examinations,
University of Agriculture,
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We, the Supervisory Committee, certify that the contents and form of thesis submitted by Mr. Muhammad Asghar, Regd. 92-ag-1261 have been found satisfactory and recommend that it be processed for evaluation by the External Examiner (s) for the award of degree.

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To

My

Affectionate Parents

Loving Brothers, Sisters

and

Wife
ACKNOWLEDGEMENTS

All praises are for “Almighty Allah” who is the creator of this multifaceted and beautiful universe. I consider it as my foremost duty to acknowledge the omnipresent kindness and love of Almighty Allah who made it possible for me to complete the writing of this thesis. I think it is also my supreme obligation to express the gratitude and respect to Holy Prophet Hazrat Muhammad (SAW) who is forever a torch of guidance and knowledge for humanity as a whole.

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<td>AT</td>
<td>Action threshold</td>
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<td>ATL</td>
<td>Application threshold level</td>
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<td>BLB</td>
<td>Bacterial leaf blight</td>
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<td>BLS</td>
<td>Brown leaf spot</td>
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<td>CNV</td>
<td>Conventional</td>
</tr>
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<td>D</td>
<td>Simpson’s index</td>
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<td>DAP</td>
<td>Diammonium phosphate</td>
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<td>DAT</td>
<td>Days after transplanting</td>
</tr>
<tr>
<td>DH</td>
<td>Dead heart</td>
</tr>
<tr>
<td>DMRT</td>
<td>Duncan’s multiple range test</td>
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<tr>
<td>E-E</td>
<td>Entertainment-education</td>
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<tr>
<td>ETL</td>
<td>Economic threshold level</td>
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<td>FFS</td>
<td>Farmers’ field school</td>
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<td>FYM</td>
<td>Farm yard manure</td>
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<td>GDP</td>
<td>Gross domestic products</td>
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<td>Guj_H</td>
<td>Gujranwala high input</td>
</tr>
<tr>
<td>Guj_L</td>
<td>Gujranwala low input</td>
</tr>
<tr>
<td>H</td>
<td>Shannon’s index</td>
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<tr>
<td>Ha</td>
<td>Hectare</td>
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<td>HIP</td>
<td>High inputs</td>
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<tr>
<td>IRRI</td>
<td>International rice research institute</td>
</tr>
<tr>
<td>IBBL</td>
<td>Insect biodiversity and biosystematic laboratory</td>
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<td>J</td>
<td>Evenness</td>
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<tr>
<td>Kg</td>
<td>Kilogram</td>
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<tr>
<td>LIP</td>
<td>Low input</td>
</tr>
<tr>
<td>LISA</td>
<td>Low input sustainable agriculture</td>
</tr>
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<td>LISRF</td>
<td>Low input sustainable rice farming</td>
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<td>MRA</td>
<td>Multiple responses were allowed</td>
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N1  Hill’s diversity number 1
N2  Hill’s diversity number 2
NIAB  Nuclear institute of agriculture and biology
NS  Non significant
OR  Organic
OM  Organic matter
PCA  Principal component analysis
RCBD  Randomized complete block design
RCGM  Rice crop growth stage model
RH  Relative humidity
RF  Rainfall
RLF  Rice leaffolder
RSB  Rice stem borers
Sheik_H  Sheikhupura high input
Sheik_L  Sheikhupura low input
Sial_H  Sialkot high input
Sial_L  Sialkot low input
SNS  Standard net sweep
SPSS  Statistical program for social studies
UAF  University of Agriculture Faisalabad
WH  White head
WSB  White stem borer
ABSTRACT

In this study, factors regarding the excessive use of pesticides and those particularly involved in the cultivation of high input and low input rice crop were investigated. Farmers’ sources of Basmati rice seed acquisition and perception of pest insects’ incidence and their management practices in rice crop were also evaluated. Results indicated that the main reason for farmers’ adoption of high input rice farming was to get better yields and profit. The main sources of rice seed acquisition were the home retained, local market and seed companies. Farmers were well aware of major pest insects of rice and reported moderate incidence of rice stem borers and high incidence of rice leaffolder but little was known about natural enemies and diseases. The most common reason for excessive use of insecticides was the misconception that pesticides were necessary to increase the yield. Farmers still relied to a great extent on chemicals to control the pests in rice crop and majority of them ignored economic threshold levels (ETL) recommended for the control. But the effective and economic suppression of insect pests in rice ecosystem by the judicial use of pesticides on the basis of ETL is utmost essential. Therefore, ETLs for the chemical control of rice stem borers (Scirpophaga incertulus Wlk. & S. innotata Wlk.) and rice leaffolder (Cnaphalocrosis medinalis Gn.) in the traditional Basmati rice growing area, the Kallar tract were also determined to be 5% dead-hearts (DH) and 3% folded leaves for stem borers and rice leaffolder respectively. The use of insecticides ignoring recommended ETLs along with higher doses of fertilizers is not only the cause of economic losses but also harmful to the insect biodiversity. So the effect of high inputs (HIP) farming practices on insect communities was also investigated. The higher number of species richness and abundance were measured for low input (LIP) systems. On the other hand some insects were abundant in HIP systems because of their adaptation to such kind of habitat. The insect species richness and abundance increased with rice crop age and showed close relationship with crop. All the major trophic guilds, except non rice pest (NRP), were also in abundance for LIP systems. Some species of insect were found sensitive to agrochemical pollution and were regarded as bioindicators. The higher Shannon’s value in some cases for HIP farms suggested that agrochemicals had a significant impact in eliminating the rare species and hence increased the Shannon’s and evenness values among the species. The overall effect of HIP rice farming on insect species richness and abundance was significantly negative. The LIP systems were found having greater diversity along with supporting a good number of rare species.
SECTION 1

Farmer’s knowledge and perception about pest insects and their management practices in rice crop in the Kallar tract, Punjab, Pakistan
1.1 INTRODUCTION

In Pakistan agriculture engages about half of the work force and contributes about one fourth of GDP (Anonymous, 2006a; Arshad et al., 2009). Rice is the second major cereal food and cash crop of Pakistan after wheat (Anonymous, 2003a). It is grown on an area of 2 million hectares chiefly in the Punjab and Sindh followed by NWFP and Balochistan (Provinces of Pakistan) (Anonymous, 2007a).

In the province of the Punjab there is a special rice area called “Kallar tract” well known all over the world for fine aromatic “Basmati” rice production. This area is classified as rice-wheat zone where rice and wheat are grown in rotation. It is worth to mention that all the rice grown in this zone is irrigated and transplanted. The Basmati rice varieties grown in this area possess highest quality and are considered as national treasure and hold monopoly in international markets (Shohab, 2006; Sheikh et al., 2006; Suhail et al., 2007). Rice and wheat are grown in continuous in Indo-Pak subcontinent on more than 12 million hectares. In many areas, especially where a continuous rice-wheat system predominates, there system diversity and productivity is reported to be declined and stagnant respectively. As a result of combined effect of yield reducing and limiting factors including improper time of rice transplantation, low plant population in rice fields, imbalance use of fertilizers, excessive use of pesticides, practices of monoculture, crop residues burning and energy, labor and other input shortages have contributed to the decline in productivity and sustainability of this system beside affecting insect biodiversity associated with rice crop (Ahmad and Iram, 2006a, b).

In order to achieve sustainability in agriculture through integrated farming system there is a need to maintain and conserve biodiversity. As farmers are the stewards of biodiversity and their management and farming practices can help to guess about the health and diversity of a farming system which in turn serve as litmus test for their ability to conserve species (Wood and Lenne, 1999). Much has been written on the land use pattern and practices’ affecting biodiversity but only a little work has been done on the custodian of biodiversity ‘the farmers’ who manage and
Introduction

utilize their resources to sustain and enhance. This is the reason that in recent years agricultural scientists are being encouraged to build their research plans on farmers’ knowledge, perception and practices (Fujisaka, 2005; Robinson et al., 2007) who closely watch their crops throughout the growing season and are helpful to evaluate any technology. This is the reason that the acceptance or rejection of a technology depends upon the eventual users of the products of agricultural research, the farmers (Joshi, 2006).

In the Kallar tract only a few studies have been carried out to know the farmers’ attitude towards the adoption of certain technologies. The first step towards understanding the reasons for adoption of a technology by the farmers can be evaluated only by a clear understanding of farmers' knowledge, attitudes and practices regarding particular technology or practice.

So, there was a need to conduct a survey study to execute that excessive use of agrochemicals and mal-cultural practices which are not only affecting insect biodiversity but also cause a loss of resources and their exploitation ultimately could lead to decrease in yields in the long run. It is therefore, the present study was, thus, undertaken to evaluate the farmer’s knowledge and perception of pest insects’ incidence in rice crop and the associated management and farming practices in the Kallar tract to address the following issues:

1. Farmer’s views about the low input (LIP) and high input (HIP) rice farming.
2. Farmers’ perception of pest insects’ incidence and their management in rice crop.
3. The factors motivating the farmers to excessive use of pesticides.
4. Crop management practices being used in rice farming.
5. Causes of low rice yield in the Kallar tract.
6. Farming practices harming the insect biodiversity of rice crop agroecosystem.
1.2 REVIEW OF LITERATURE

Rubia et al. (1996a) conducted field surveys in Java to determine the importance of white stem borer (WSB) and its current control practices and to assess farmers’ knowledge in connection with its outbreak. The largest percentage (85%) of farmers perceived WSB as important and difficult to control (22%) and considered other pest insects as less problematic in rice crops. Most of the farmers applied control actions for stem borers just by observing moths or their damage symptoms in their fields. Application of insecticides was found a common practice for stem borer control. The majority of farmers used insecticides (including those banned by the Government against white stem borers) when they saw stem borers’ moths, dead hearts and white heads.

Heong and Escalada (1997a) suggested that in order to improve pest management, farmers’ activities should be understood by the researchers. The most common method, among the other methods used to obtain such information, was farmers’ survey. The farmers’ survey comprised of problem identification, questionnaire development, sampling, field work, data processing and analysis, which could be used to improve problem definition, answer some questions and raise further questions.

Kartaatmadja et al. (1997) carried out survey studies in Java to evaluate the farmers’ knowledge, attitudes and pest management practices for rice pest control. Farmers ranked white stem borer and brown plant hopper as the most important rice pests and bacterial leaf blight (BLB) as the most common disease in rice fields. Farmers’ reliance on insecticides was found to be very high for control of rice pests.

Jahn et al. (1997) interviewed rice farmers about their knowledge, attitude and practices in rice pest management in Cambodia. An awareness of natural enemies was common but their importance in the rice ecosystem was usually not grasped. Majority of the farmers (59%) thought that pesticides could increase rice yield but some of them (19%) believed that insecticides could kill natural enemies and thus resulted into pest outbreak. Decisions about pesticides application were based on observation of
pests or their damage and sprays on a schedule basis were rare. Average ages, education level and farming experience did not differ significantly among pesticide users and non-users. The rice yields of pesticide users and non-users did not differ significantly.

Moody et al. (1997) in order to understand the farmers’ perceptions and practices in weed management conducted a survey of rice farmers in Iloilo Province, Philippines. Most of the farmers planted IR-64 seeds obtained from other farmers, their own seed stock, the Department of Agriculture and private seed growers. Herbicide application, water management and hand weeding were the most common measures practiced by the farmers to reduce weed problems.

Normiyaha and Chang (1997) in Malaysia compared farmers’ pest management practices and showed that most of the farmers were aware of major pest insects of rice and natural enemies but not sure about their role. Chemical control was the main pest management practice. However, they did not know the health hazards associated with insecticides.

Nugaliyadde et al. (1997) interviewed farmers in Sri Lanka to determine their pest management practices and knowledge of pest insects and natural enemies. Most of the farmers interviewed were aware of rice leafhoppers, rice bugs, brown planthopper, stem borers, thrips, cutworm, gall midges and army worm and majority of them applied insecticides to control these pests. A good number of the farmers knew about natural enemies of rice pests and also knew their role in rice ecosystem.

Li et al. (1997) conducted a survey of rice farmers to assess their knowledge, attitude and practices of integrated pest management in China. Most of the farmers applied pesticide 9.9 times per year on an average and believed that they could not control insects without using pesticides. Only a few farmers were aware of natural enemies and their role. Majority of the farmers obtained information about pest management from local technology extension station, but while making a pest control decision about half relied on their own experience or got help from their neighbours.

Rapusas et al. (1997) conducted a survey in Lao PDR and reported that stem borers, grasshoppers, rice bugs, gall midges and lepidopterous larvae were the most common pests observed by the farmers. Some farmers were aware of the natural enemies but were not sure about their roles. Only 23% of respondents used pesticides
for pest control while 75% did nothing. Pesticide were applied only once and mostly within the first forty days after transplanting (DAT). Yields of the farmers who did not apply pesticides were higher than those who treated their field.

Sivakumar et al. (1997) conducted a survey study in order to know farmers’ pest monitoring, assessment, control practices and the constraints in their adoption of integrated pest management (IPM) practices. Most of the farmers were familiar with rice pests: leaffolders, stem borers, ear head bug and beneficials like dragonflies and damselflies. Major source of pest control information was Agriculture Department. All the farmers used insect-resistant varieties, cleaned bunds and synchronized planting for pest management.

Mai et al. (1997) conducted a survey and reported the farmers’ perception that brown planthoppers, sheath blight and rice leaffolders were most important pests. These insects were perceived to be very damaging and causing heavy yield losses in rice. Farmers often sprayed pesticides to control them. Organophosphates, such as methamidophos, monochrotophos and methyl parathion were the popular insecticides used and believed to be necessary to control the leaf feeders in early season. They suggested that farmers’ participatory farming approach, strategic extension campaigns and pest management training should be increased because these could help farmers to realize that these early insecticide sprays were not advantageous.

Heong and Escalada (1998) in Philippines explored the use of farmers’ participation in pest management exercise in order to change their misperceptions about the rice leaffolder’s damage during early stages of crop. The farmers were asked not to spray against leaffolders for the first 30 DAT or 40 days after sowing to test a simple rule-of-thumb or ‘heuristic’. After participating in this exercise, 77% of the participating farmers reported that yields of rice in their test plots were not significantly different from yields in their control plots. Majority of the farmers gave up to spray during first 30 DAT, reduced number of insecticide use and their attitudes towards sever damage and huge yield losses by leaffolders were also changed.

Heong and Escalada (1999) in Philippines analyzed farmers’ decisions in stem borer management and reported that farmers spent different amounts of expenditure to control stem borer with the belief that a more yield loss would occur if they did not
control it. They further found that farmers’ decisions were guided by histories of worst attacks. Farmers believed that insecticide could destroy natural enemies but placed only moderate importance to conserve them. Health was considered to be very important but often farmers did not correlate a poor health to insecticides. Their studies also provided evidences that farmers’ spray decisions and concepts were directly influenced by perceived benefits from sprays.

Joshi et al. (2000) surveyed rice farmers in Philippines to assess their knowledge, attitude, practices of rice crop and pest management. Their survey revealed that majority (54%) of the farmers was in the age range of 31-50 years, having long (11-30 years) rice farming experience with average literacy rate. The majority of farmers followed traditional cultivation practices and had very little knowledge of IPM and new rice technologies. Drought, Zinc deficiency, earthworms, rats, golden apple snails and house sparrows were identified as major production constraints in rice crop.

Berg (2001) conducted a survey in major rice producing area of Mekong Delta, Vietnam, to know the pest management practices and perception of problems related to pest and pesticides in order to highlight the importance of IPM in farming system among farmers adopting IPM and non-IPM methods in rice and rice-fish farming. During survey 64 different pesticides were identified used by the farmers. Out of which approximately 50% were insecticide, 25% herbicides and 25% fungicides. Non-IPM farmers used twice as many pesticides as IPM farmers. The application frequency and amounts of active ingredient were used 2-3 times higher per crop than IPM farmers. During the last three years IPM farmers decreased pesticides use by approximately 65%, while non-IPM farmers increased pesticides use by 40%. As pesticides adversely affected the fish culture so farmers who were culturing fish in rice fields used less pesticides than the farmers growing only rice crop. Majority of the farmers (>80%) thought that pesticide were problem for their health and almost all the farmers regarded insecticides as most problematic pesticides. Despite this, application of pesticides was the main method (>90%) used by the farmers to control pests.

Wilson and Tisdell (2001) examined the paradox “despite the high costs associated with pesticides, farmers continue to use pesticides” by emphasizing ‘lock-
in’ aspects of pesticide use. They described that economic ‘locking in’ occurred as a result of the adoption of unsustainable economic techniques and the prevailing pest control technology had resulted ‘locked in’ farmers in ‘entrapment’ of pesticides.

Bandong et al. (2002) surveyed irrigated rice areas in Philippines and focused on farmers’ insecticide decision making protocol before formalized farmer field school (FFS) training programs. Decision protocols were largely site specific and farmer specific and based on different pest complexes and outbreak histories. A large proportion of prophylactic application was timed with fertilizer application during early crop stages. Decisions were also made while walking along the field borders and observing flushed moths or patches of damage. Farmers’ action thresholds were found always lower than those of researchers. They suggested that researchers should test some of the innovative farmers’ pest assessment methods.

Haefele et al. (2002) conducted surveys with rice farmers in Senegal. Farmers’ knowledge of recommended cropping practices was relatively poor. It was concluded that the rice production may leap forward rapidly if farmers were given better access to information, improved rice technologies, inputs and decision making.

Escalada and Heong (2004a) evaluated the knowledge, attitudes, concerns and practices with regard to stem borers’ management decisions which were often based on biased heuristics relied mainly on spraying of insecticides. The unnecessary sprays of insecticides were due to overestimation of losses from pest attack (a loss aversion behavior). The farmers were found having high beliefs that insecticides help to increase yield. They found that a participatory exercise was effective to help rice farmers to make adjustments to their biases. After participating in the exercise, farmers reduced their insecticide sprays for stem borer control by 22%. Their intended insecticide expenditures were reduced 45% and estimated loss from white head by 27%. The control farmers on the other hand did not reduce their sprays, however, reduced their intended expenditures by only 14% with no reduction in the estimation of losses from white heads. There was also a decline in farmers’ attitudes towards ‘insecticide spraying would increase yields’ in the experimental group, but the difference was not significant. They concluded that in order to motivate rice farmers in managing stem borers more efficiently the participatory exercise had the potential of being implemented in extension, training and mass communication programs.
Huan et al. (2005) in Vietnam evaluated the farmers’ participatory approach to the reduction of pesticide sprays, seed rates and nitrogen fertilizer in rice production. All the participated farmers found that the reduced inputs had little effect on yield. The highest (80%) contribution to increase farm income was due to pesticide reduction. This was also because sprays reduction mean reduction in labor and exposure to pesticide poisoning. This participatory exercise modified farmers’ attitudes that more spray, seed and fertilizer inputs would give higher yields. On the basis of these results a national mass media campaign, locally called ‘Ba Giam Ba Tang’ (Vietnamese for three reductions, three gains) to scale up the adoption of these practices in Vietnam was launched.

Saka et al. (2005) and Joshi (2006) interviewed the farmers to examine the status of adoption of improved rice varieties among small holding farmers with a view to assess the impact of technology transfer on rice production. The results showed that the farmers responded appreciably to intervention programme which promoted the use of the improved rice varieties. Farm size and frequency of extension contacts with farmers were found the significant factors influencing the decision of farmers to adopt the improved rice varieties.

Baloch et al. (2006) in Pakistan revealed that information sources, extension services and credit had a role in explaining rice production. Most of the farmers got information from their nearby growers due to uncertain and insufficient knowledge provided by other sources. A big portion of farmers was devoid of effective extension service. Farm visits by extension workers were considered as the most effective channels of information dissemination.

Sheikh et al. (2006) in Pakistan studied the adoption level of farmers for new production technologies of rice crop and revealed that most (>70%) of the farmers were aware of new technologies, while majority (90-97%) of them were fully aware of agronomic practices. They concluded that traditional technologies (variety selection, raising paddy nursery, land preparation, paddy transplanting and irrigation) based on indigenous knowledge had widely been adopted by the farmers than non traditional technologies (seed treatment, chemical weed control and use of pesticides).
Karami and Mansoorabadi (2007) in Iran compared the attitudes of male and female rice growers towards environmentally sustainable agriculture. Results of the survey indicated that women farmers’ attitudes were more positive toward sustainability. They also revealed that religious and spiritual beliefs, access to information, labor and education had a significant impact on the attitudes towards sustainability.

Robinson et al. (2007) in Bangladesh identified the reasons that many farmers did not follow recommended pest management practices. They proposed that in order to improve training approaches and knowledge of farmers about IPM, the farmers should be classified according to their motivations for pesticide use and constraints rather than observed pesticide use. The results of survey showed that from the farmers’ perspective, pesticides were easy to use, easy to access and economically rational. The farmers considered the precautionary use of pesticides as an insurance policy against future pest attack. Pesticides mostly were sold by fertilizer dealers who also offered advice to farmers and such farmers were less likely to seek advice from the extension services and neighbours. It was found that both the trained and untrained farmers used pesticides despite knowing the harms of these chemicals to human health. Farmers usually overestimated the benefits of pesticide use. They suggested that involvement of farmers in the development of research activities and during training emphasizing about health and environmental problems associated with pesticides use could make the research findings and training more fruitful and relevant to the farmers for adoption.

Yamota and Tan-Cruz (2007) in Philippines studied the different factors affecting farmers’ adoption of organic rice farming. According to socio-demographic profile of the adopter and non-adopter farmers, the attributes like age, educational level, number of seminars attended, number of family members involved in farming and tenure exhibited a positive relationship. On the other hand credit availability and family income were negatively related to the rate of organic adoption.

Edeoghon et al. (2008) in Nigeria examined the awareness and use of sustainable agricultural practices of farmers and showed that majority of the respondents either had primary or secondary educational qualification or even had no
formal education. Information on sustainable practices were mostly obtained from fellow farmers and a very few of the respondents were aware of sustainable farming practices. The major barriers to the use of sustainable agricultural practices were lack of Government support, funds and cost of the sustainable practices.

Heong et al. (2008) in Vietnam used the entertainment-education (E–E) process through a radio soap opera to create favourable attitudes and to change practices in rice farmers’ pest management. Between pre- and post-launch of this programme, insecticide sprays by farmers dropped 31%, seed and nitrogen by 9% and 7%, respectively. Besides farmers’ attitudes, the pesticides could affect their health, changed from 61.6% to 86.1% and leaf damages means yield loss, changed from 59% to 38%. In the post-test, farmers had not listened had less reduction in their attitudes. But those had listened to the soap had higher reduction in insecticide sprays (60%), nitrogen (9%) and seeds (33%). There were also similar changes in their beliefs and attitudes favouring judicious use of pesticides, fertilizers and seeds.

Huan et al. (2008) in Vietnam developed and used a media campaign to motivate rice farmers by a participatory planning process to reduce seed and fertilizer inputs and to modify pest management practices. Most of the farmers believed that high inputs would increase yield. The farmers also had perception that rice leaffolders could cause serious damage and necessarily be sprayed in the early crop stages. As a result of these campaigns farmers’ practices changed significantly i.e., use of seed rates dropped by 10% and nitrogen rates 7% and use of insecticides by 11%. Their belief was increased significantly that the rice crop could easily recover from leaf damage. These modifications were supported by practices in belief attitudes that favoured high inputs and unnecessary sprays. Farmers also changed their perception of yield loss significantly after reductions in the three inputs.
1.3 MATERIALS AND METHODS

The survey was conducted in the year 2004 in traditional rice zone, the Kallar tract spreading over the boundaries of districts: Sialkot, Gujranwala and Sheikhupura. All the farmers in this zone mostly follow rice-wheat cropping system (Sheikh et al., 2006). However, some farmers also practice rice-maiz-wheat or rice-vegetable-wheat. This rice-wheat zone (Zone-II) covering an area of 1.5 million hectare lies in the broad strip of land between rivers Ravi and Chenab and is also called Rachna Doab (Ra: Ravi & Chna: Chenab; Doab: two water’s land); here, aromatic Basmati rice is grown (Sheikh et al., 2006; Suhail et al., 2007). The climate is sub-humid, sub-tropical ranging from 400 to 700 mm of monsoon rainfall mostly in July-August. Rice growing season is fairly long and well suited for aromatic as well as IRRI varieties. All the rice grown in this area is irrigated and transplanted and management practices applied in this area are nearly same. The water for irrigation comes from canals or underground water is pumped out for this purpose and only one crop of rice is grown per year (Shohab, 2006; Anonymous, 2007b).

The survey was carried out in three districts of the Kallar tract i.e., Sheikhupura, Gujranwala and Sialkot. The detail description about each district is given in fig 1.1 and table 1.1.

Climate of all the districts is hot and humid during the summer which starts from April and continues till October. June, July and August are the hottest months of the year. Rainy weather alternates with oppressive weather. The land is generally plain and fertile.

A preliminary survey was made by meeting with farmers in order to develop a questionnaire with suitable information about farming and pest management practices. The questionnaire was pre-tested by interviewing some farmers (not included in this study). After this, some important changes were made in the questionnaire and tested again on additional farmers. Some minor changes were made again before giving it the final format (Appendix-I).
Materials and Methods

Section 1

Fig. 1.1 Maps (a) Kallar tract (b) Research localities in the Kallar tract. Source: Suhail et al. (2007)
Table: 1.1 Some characteristics of the districts of Kaller tract.

<table>
<thead>
<tr>
<th>Name of the districts</th>
<th>Sheikhupura</th>
<th>Gujranwala</th>
<th>Sialkot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location (N Lat.)</td>
<td>31.420</td>
<td>32.100</td>
<td>32.300</td>
</tr>
<tr>
<td></td>
<td>73.590</td>
<td>74.100</td>
<td>74.320</td>
</tr>
<tr>
<td>Height from sea level (m)</td>
<td>209.57</td>
<td>226.31</td>
<td>255.10</td>
</tr>
<tr>
<td>Area of the district (km²)</td>
<td>5,960</td>
<td>3,198</td>
<td>3,016</td>
</tr>
<tr>
<td>Population size (M)</td>
<td>3.3</td>
<td>4.3</td>
<td>3.5</td>
</tr>
<tr>
<td>Crops per year</td>
<td>2-3</td>
<td>2-3</td>
<td>2-3</td>
</tr>
<tr>
<td>Annual rainfall (mm)</td>
<td>400-500</td>
<td>500-600</td>
<td>600-700</td>
</tr>
</tbody>
</table>

Lat. = Latitude, Long. = Longitude  

During survey, face to face interviews of 150 farmers were conducted in cooperation with Agricultural Extension and Plant Protection officers in each district. All interviews were conducted between noon and afternoon when farmers mostly were available at their farm houses. Some farmers, however, were also interviewed when they were in their rice fields. Each interview took about 30-60 minutes. The theme of interviews was to obtain a clear picture of the farmers’ knowledge, perceptions of pest insects’ incidence and control practices in rice crop.

As most of the farming community was illiterate to low educational level so the questions were asked in local (Punjabi) language in simple words and answers were translated into English and finally the questionnaire was filled accordingly.

During interviews, technique of triangulation was followed strictly (Patton, 1990). That was looking at farmer’s responses to not just one, but several questions, and compared these responses with each others. After that it was possible to get the picture of internal consistency and completeness of the thinking of each respondent about the rice ecosystem and the concerned agronomic practices followed by them.

1.3.1 Data analysis:

The coded data obtained from the filled questionnaires was entered into EXCEL worksheet and analyzed to find out frequencies and percentages.
1.4 RESULTS AND DISCUSSION

1.4.1 Socio-Economic conditions of the farmers

Socio-economic conditions included educational level, age and land holding of the farmers which have strong influence on the farming practices of the farmers. The integration of social, ecological and economic factors help in the process of goal setting and decision making which is also called holistic resource management (HRM) (Stinner et al., 1997). Socio-economic conditions are also expected to have impacts on farmers' perceptions of LIP organic farming or HIP modern farming, pest and pesticides management. According to Heong and Escalada (1999) insecticide use is also a social norm among farmers and there is need to re-establish this norm with the preferred norm (McAlister, 1981). Actually these all factors are the driving forces leading to the general trends in land use, biodiversity and environment management (Anonymous, 1999). Some important aspects of socio-economic conditions of farmers of the Kallar tract are discussed below:

1.4.1.1: Educational level of the farmers

Out of the 150 farmers, 35.3% had not even formal education, 49.3% had attained education up to middle school level while 15.3% had undergone matriculation or above education (Table 1.2).

Previous survey studies also showed similar trend of education among rice farmers (Heong and Escalada, 1999; Joshi et al., 2000; Escalada and Heong, 2004a; Mironga, 2005; Sheikh et al., 2006; Heong et al., 1998, 2002, 2008). The results are, however, different from those of Jahn et al. (1997) and Shegun et al. (2002) stating that average number of years of schooling was only 3.7 and 1.03 years respectively.

It is very easy to make understand an educated farmer about ecofriendly pest management techniques as compared a farmer having a little or no education because illiteracy increases communication barriers.
As most of the farmers in the study area were either illiterate or had average literacy level so during making policies regarding future of agriculture and farmers training about pest management in the country this factor should be given due importance because education level significantly affects the adoption of particular type of farming practices (Yamota and Tan-Cruz, 2007).

**1.4.1.2: Different age groups of the farmers**

Among the 150 farmers interviewed, 14.7% of the farmers were of young age (upto 30 years), 32.0% were of middle ages (30-45 years old), while 53.3% were old (above 45 years) (Table 1.2).

<table>
<thead>
<tr>
<th>Educational levels</th>
<th>Frequency</th>
<th>% age</th>
<th>Age groups</th>
<th>Frequency</th>
<th>% age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illiterate</td>
<td>53</td>
<td>35.3</td>
<td>Young (upto 30 years)</td>
<td>22</td>
<td>14.7</td>
</tr>
<tr>
<td>Upto Middle (8 years)</td>
<td>74</td>
<td>49.3</td>
<td>Middle aged (30-45 years old)</td>
<td>48</td>
<td>32.0</td>
</tr>
<tr>
<td>Matriculation and above (10 years or more)</td>
<td>23</td>
<td>15.3</td>
<td>Old (above 45 years)</td>
<td>80</td>
<td>53.3</td>
</tr>
</tbody>
</table>

It is clear that most (85.3%) of the farmers in the present survey were above the age of 30 years, which showed that a big number of farmers belonged to middle or old age group. These results are similar to those of Heong *et al.* (1998), Huan *et al.* (1999), Joshi *et al.* (2000) and Mironga (2005), who revealed as results of their surveys that majority of the farmers (upto 84.17%) fall within a narrow age range (31-50 years). Similarly, the results of present study are also supported by the findings of Jahn *et al.* (1997), Heong and Escalada (1999), Heong *et al.* (2002), Shegun *et al.* (2002), Escalada and Heong (2004a), Anonymous, (2007c), Heong *et al.* (2008) who reported that ages of most of the farmers were between 40-54 years.

These results indicated increasing ages of farmers, reflected less trends in young and able bodied population (even in rural areas) towards land farming (Mironga, 2005). The results also showed that the number of entrants into farming had fallen over time with fewer younger people than in the past. This could be due to decline in farm size, numbers, industrialization and consequently the immigration of young generation towards cities in search of jobs, relative attractiveness of farm
versus non-farm earning opportunities especially when the non-farm economy is robust, as it has been for the past many decades, so the young people choose the option for the higher, more stable incomes available off the farm for a better livelihood (Anonymous, 2007c). These trends explained that young generation could be dissatisfied from farming occupation, which is very alarming for the future of agriculture of an agricultural based country. As age of farmers significantly affects the adoption of various agricultural practices by the farmers (Shegun et al., 2002; Ogunwali, 2005) therefore a new policy for agriculture in Pakistan must address the increasing average age of farmers and discover ways to persuade and encourage young people to choose farming as an occupation.

1.4.1.3: Land holding

The results (Table 1.3) indicate that most (73.3%) of the farmers had small land holdings (less than 5 hectares), while 17.3% were those having land from 5-15 hectares and 9.3% of the farmers belonged to big land owner category having land more than 15 hectares.

<table>
<thead>
<tr>
<th>Farm size</th>
<th>Frequency</th>
<th>% age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small (&lt; 5 ha)</td>
<td>110</td>
<td>73.3</td>
</tr>
<tr>
<td>Medium (5-15 ha)</td>
<td>26</td>
<td>17.3</td>
</tr>
<tr>
<td>Big (&gt; 15 ha)</td>
<td>14</td>
<td>9.3</td>
</tr>
</tbody>
</table>

These results are similar to those of Sheikh et al. (2006) indicating that in the Kallar tract, the average land holding of 75% farmers was less than 10 hectare and only 25.0% farmers had land more than 10 hectare.

The results are different from those of Rubia et al. (1996a), Huan et al. (1999), Heong et al. (1998), Heong and Escalada (1999), Shegun et al. (2002) Escalada and Heong (2004a) and of Mironga (2005).

Actually the fixed asserts and land per person has strong impact on farmer's rice yield loss perception. Small family farms are the backbone of a community, a nation and of a society as a whole. The agricultural economists now accept that there is an ‘inverse relationship between farm size and output’ (Peterson, 1997). It is also reality that in order to maintain social status the big/progressive farmers are more
careful about plant protection measures and yield losses which ultimately lead to excessive use of agrochemicals. The present study showed that a good number (26.6%) of the farmers was medium and big land owners, so a vigorous pesticides and fertilizers use tendency among them could be expected.

1.4.2: Farmers’ concepts about organic farming

In this section farmers knowledge, about safety of organic farming, reasons for non-adoption of organic farming, knowledge about harmful affects of HIP, favour towards a particular type of farming and best method of farming in the present situation of food demands, was investigated.

1.4.2.1: Knowledge about the safety of organic farming

Majority of farmers (>82%) accepted that organic farming was safe for humans and animals (Table 1.4). On the other hand only a small fraction (6.6%) of sampled population stated that it was safe for beneficial organisms but a major portion (91.3%) of farmers did not answer this question. Similar was the case with their knowledge about safety of organic farming to the environment where 65.3% respondents did not respond and only 33.3% agreed that organic farming was safe for environment (Table 1.4).

Table 1.4: Knowledge about the safety of organic farming.

<table>
<thead>
<tr>
<th>Organic farming is</th>
<th>Yes</th>
<th>No</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>% age</td>
<td>Frequency</td>
</tr>
<tr>
<td>Safe for humans</td>
<td>127</td>
<td>84.7</td>
<td>3</td>
</tr>
<tr>
<td>Safe for animals</td>
<td>123</td>
<td>82.0</td>
<td>2</td>
</tr>
<tr>
<td>Safe for beneficial insects</td>
<td>10</td>
<td>6.6</td>
<td>3</td>
</tr>
<tr>
<td>Safe for environment</td>
<td>50</td>
<td>33.3</td>
<td>2</td>
</tr>
</tbody>
</table>

Multiple responses were allowed

These results indicate that farmers were well aware about harms of HIP and benefits of organic farming as majority of them considered organic farming safe for human and animals as well. But at the same time they had little concept about beneficial organisms and environmental pollution as caused by agrochemicals and hence paid less attention to save them from hazardous effects of agrochemicals.
1.4.2.2 Reasons for non-adoption of organic farming

The majority (34.7%) of surveyed farmers were of the view that organic farming had more weed problem, among the other reasons mentioned by the farmers for non-adoption of organic farming were; pest insects attack (36%), disease problem (24%), takes more water and time to mature (2.0%), difficult to harvest (1.3%) while 5.3% farmers had no confidence that organic rice will grow. A large number of the farmers (72.3%) were of the view that organic rice could be grown but with lower yield. Among the surveyed farmers 38.0% were ready to grow rice crop organically. However, farmers mentioned no restriction from Government to grow rice crops organically (Table 1.5).

Table 1.5: Reasons for non-adoption of organic farming.

<table>
<thead>
<tr>
<th>Reasons for not adopting organic farming</th>
<th>Frequency</th>
<th>% age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Govt. restrictions</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>More weeds</td>
<td>52</td>
<td>34.7</td>
</tr>
<tr>
<td>Non availability of organic market</td>
<td>57</td>
<td>38.0</td>
</tr>
<tr>
<td>Insect pest problem</td>
<td>54</td>
<td>36.0</td>
</tr>
<tr>
<td>Disease problem</td>
<td>36</td>
<td>24.0</td>
</tr>
<tr>
<td>Take more time and water to mature</td>
<td>3</td>
<td>2.0</td>
</tr>
<tr>
<td>Lower yield</td>
<td>107</td>
<td>72.3</td>
</tr>
<tr>
<td>Difficult to harvest</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>Have no confidence to grow</td>
<td>8</td>
<td>5.3</td>
</tr>
</tbody>
</table>

Multiple responses were allowed

From the table 1.5 it is quite clear that a handsome number of farmers thought that there would be more weed, insect and disease problems, if no pesticide will be used in case of organic farming. Some farmers also revealed that organic produce would be difficult to harvest because due to reduced amount of inputs the straw becomes stiff. A big segment of the farmers considered that in case of organic production the yield will be much lower. Some farmers also considered that organic crop could not grow under present pest scenario and hence farming will be not feasible because of much reduced or no profit.

However, majority of sampled population was ready to grow rice crop organically provided availability of organic markets to sale out their produce at better
prices and otherwise they will not adopt the organic technology. These results are in agreement with those of Yamota and Tan-Cruz (2007).

1.4.2.3: Knowledge about the harmful effects of HIP farming

Table 1.6 indicates that a big segment of interviewed farmers were well aware of the harmful affects of HIP in causation of diseases in human (88.0%) and in animals (78.0%). Many of respondents (68.0%) also considered HIP farming a big reason of pest problem. However, only 33.3% considered it as a cause of environmental pollution. A few (0.7%), (4.0%), (23.3%) and (4.7%) farmers also denied to the role of HIP farming in causation of diseases in human, in animals, environmental pollution and pest problem respectively.

Table 1.6: Knowledge about the harmful effects of HIP.

<table>
<thead>
<tr>
<th>HIP farming is a cause of</th>
<th>Yes</th>
<th>No</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>% age</td>
<td>Frequency</td>
</tr>
<tr>
<td>Diseases in human</td>
<td>132</td>
<td>88.0</td>
<td>1</td>
</tr>
<tr>
<td>Diseases in animals</td>
<td>117</td>
<td>78.0</td>
<td>6</td>
</tr>
<tr>
<td>Environmental pollution</td>
<td>50</td>
<td>33.3</td>
<td>35</td>
</tr>
<tr>
<td>More pest Problem</td>
<td>102</td>
<td>68.0</td>
<td>7</td>
</tr>
</tbody>
</table>

Multiple responses were allowed

The results indicate that farmers were very well aware of the harms of modern agriculture. A large number of farmers interviewed stated that conventional farming was the mother of diseases in human and animals and was the major cause of environmental pollution in contrast to organic farming which enhances the health of agricultural ecosystem, material circulation in agroecosystem and crop production with minimum load on the environment (Young-Hwan et al., 2002; Otto, 2003; Yamota and Tan-Cruz, 2007). Majority of farmers believed that insecticides had resulted into more pest problem. The results are similar to those of Heong and Escalada (1999) and Berg (2001) that majority of the farmers (>70%) thought that pesticides had increased the number of pests in their fields.

1.4.2.4: Favour towards a particular type of farming

Out of 150 farmers interviewed 22.7% fully favoured HIP while 58.0% favoured it partially. There were 19.3% of the farmers who were totally against HIP.
farming. As for organic farming was concerned 64.7% farmers fully favoured it while 24.7% partially favoured this system. There were also some farmers (10.7%) who were against organic farming (Table 1.7).

**Table 1.7: Favour for high inputs/ organic farming.**

<table>
<thead>
<tr>
<th>Type of Farming</th>
<th>Full favour</th>
<th>Partially favour</th>
<th>No favour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>% age</td>
<td>Frequency</td>
</tr>
<tr>
<td>High inputs farming</td>
<td>34</td>
<td>22.7</td>
<td>87</td>
</tr>
<tr>
<td>Organic farming</td>
<td>97</td>
<td>64.7</td>
<td>37</td>
</tr>
</tbody>
</table>

The results showed that a reasonable number of farmers fully favoured HIP reasoning that crops could not be grown without agrochemicals. However, a large number of farmers favoured partially this type because they thought there was no way to feed the world except this sort of farming and giving up HIP farming will mean just famine. Some of the farmers were totally against HIP. In case of organic farming a big segment of sampled population favoured it, giving reason that in the ages of such type of farming human were free from such enormous diseases. Whereas, many of the farmers partially favour it because at one end it was safe for human and on the other end due to certain concerns about low yield and un-availability of markets where such produce can be sale out. However, only a few of farmers were against organic farming and mentioned that it was not practicable in the present situation of food demands and the prevailing rice verities, which did not respond good without agrochemicals and it would be hard to grow crops without agrochemicals.

**1.4.2.5: Perception about the best method of farming**

The best method of farming according to most of the farmers (53.3%) was LIP farming followed by organic farming (16.0%) and HIP (11.3%) while 19.3% of the farmers did not respond to this question (Table 1.8).

**Table 1.8: Perception about the best method of farming.**

<table>
<thead>
<tr>
<th>Farming methods</th>
<th>Frequency</th>
<th>% age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic</td>
<td>24</td>
<td>16.0</td>
</tr>
<tr>
<td>LIP</td>
<td>80</td>
<td>53.3</td>
</tr>
<tr>
<td>HIP</td>
<td>17</td>
<td>11.3</td>
</tr>
<tr>
<td>No answer</td>
<td>29</td>
<td>19.3</td>
</tr>
</tbody>
</table>
1.4.3: Perception about pest insects, diseases and beneficial organisms in rice crop

The farmers were asked to rank: attack of pest insects and diseases, occurrence of different beneficial organisms in rice crop, based on a five-level scale (no attack/present, low, medium, high and no response).

1.4.3.1: Perception about pest insects in rice crop

Rice crop is attacked by various pest insects and farmers rank them according to the population intensity and losses caused by them. In case of rice stem borers 27.3% of the farmers declared their attack as high, 34.0% as medium, 29.3% as low and 7.3% mentioned no attack, while only 2% did not respond to this. In case of rice leaffolder 43.3% farmers declared its attack as high, 37.3% as medium, 16.0% as low and 2.7% said that there was no attack of leaffolder in their crops while only 0.7% did not respond to this. Similarly, in case of rice leaf and plant hoppers 53.3% claimed that their crops were free from these insects while 9.3% indicated their low attack, 3.3% medium and only 1.3% pointed out their high attack. At the same time 32.7% did not respond to this question. As for as rice grasshoppers were concerned 12.7% farmers declared them as occurring in high intensity, 16% as medium, 56.7% as low and 8.0% declared that this pest did not attack their crops. However, 6.7% farmers did not respond to this question (Table 1.9).

Table 1.9: Perception about pest insects attack in rice crop.

<table>
<thead>
<tr>
<th>Name of insect pest</th>
<th>No attack</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>% age</td>
<td>Frequency</td>
<td>% age</td>
<td>Frequency</td>
</tr>
<tr>
<td>Stem borer</td>
<td>11</td>
<td>7.3</td>
<td>44</td>
<td>29.3</td>
<td>51</td>
</tr>
<tr>
<td>Leaffolder</td>
<td>4</td>
<td>2.7</td>
<td>24</td>
<td>16.0</td>
<td>56</td>
</tr>
<tr>
<td>Leafhopper &amp; plant hopper</td>
<td>80</td>
<td>53.3</td>
<td>14</td>
<td>9.3</td>
<td>5</td>
</tr>
<tr>
<td>Grasshoppers</td>
<td>12</td>
<td>8.0</td>
<td>85</td>
<td>56.7</td>
<td>24</td>
</tr>
</tbody>
</table>

It is evident from the table 1.9 that farmers were aware about almost all the major pest insects of rice crop. From this, it is also clear that according to ranking by rice farmers, leaffolder and stem borers were the major pest followed by grasshoppers and leaf & plant hoppers respectively. This could be due to the reasons that while walking along rice field’s bunds the moths of rice stem borers & leaffolders and
their damages and grasshoppers which flush up in big number are easily visible
(Bandong et al., 2002). So, these pests are noticed by farmers easily and most of the
insecticidal applications are directed against them.

Although survey results recorded that, farmers had sufficient knowledge about
stem borers and leaffolder but had little knowledge about leaf and planthoppers. It
was commonly observed that the moths of stem borers and leaffolder were
collectively called by the farmers the ‘pumbhat’ while leaf & plant hoppers were
called by the farmers ‘taila’ (in local language). Most of farmers were not able to
distinguish between leaf hoppers and plant hoppers thus lump them under the term
‘hopper’ or taila. Most interestingly the farmers also called ‘attack of taila’ to the
attack of bacterial leaf blight (BLB). So, they often used insecticides for the control of
BLB instead of using fungicides to control it. Such types of wrong sprays of
pesticides were very common among the farmers of the Kallar tract. Anyhow, the
results are in accordance with those of Mai et al. (1997) and Bandong et al. (2002).

1.4.3.2: Perception about diseases in rice crop

Out of the total (150) surveyed farmers’ community, a large number (69.3%) of
farmers indicated that attack of BLB was high, 10.7% as medium, 10.7% as low and
3.3% of the surveyed farmers said that there was no attack of BLB on their rice crop
while 6.0% farmers did not respond. In case of brown leaf spots (BLS) 8% farmers
declared its attack as high, 27.3% as medium, 39.3% as low and 12.0% said that there
was no attack of BLS on their rice crops. In this case 13.3% farmers did not answer.
But in case of rice blast only a small number of farmers (2.7%) pointed out its attack
as high, 3.3% as medium, 10.0% as low and 33.3% claimed that their crops were not
attacked by rice blast. In this case a big segment (50.7%) of farmers’ community did
not answer. Whereas, in case of bakanae (foot rot) none of the farmers claimed its
attack as high or medium. Only 12.0% of the farmers declared its attack as low and
86.7% claimed no attack of bakanae, also a small portion of farmers 7.3% did not
answer to this question (Table 1.10). So, it is clear that the most prevalent disease in
the Kallar tract was BLB followed by BLS and rice blast. Whereas, bakanae was very
uncommon and most of the farmers declared that there was no attack of Bakanae on
Super basmati.
Table 1.10: Perception about diseases’ attack in rice crop.

<table>
<thead>
<tr>
<th>Name of the diseases</th>
<th>No Attack</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>No Response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>% age</td>
<td>Frequency</td>
<td>% age</td>
<td>Frequency</td>
</tr>
<tr>
<td>Bacterial leaf blight</td>
<td>5</td>
<td>3.3</td>
<td>16</td>
<td>10.7</td>
<td>16</td>
</tr>
<tr>
<td>Brown leaf spot</td>
<td>18</td>
<td>12.0</td>
<td>59</td>
<td>39.3</td>
<td>41</td>
</tr>
<tr>
<td>Rice blast</td>
<td>50</td>
<td>33.3</td>
<td>15</td>
<td>10.0</td>
<td>5</td>
</tr>
<tr>
<td>Bakanae</td>
<td>121</td>
<td>86.7</td>
<td>18</td>
<td>12.0</td>
<td>0</td>
</tr>
</tbody>
</table>

The present position of pest insects and diseases in rice area could be mainly due to the change in varietal pattern in which Super basmati was a dominant variety, which was resistant to pest insects but susceptible to diseases, especially to BLB. It was the bakanae disease, which has pushed out almost completely Basmati-385 from rice area and as a result Super basmati, dominated other basmati rice varieties in the Kallar tract. This is one of the most important reason that pest insects and diseases’ attack scenario has changed entirely in this tract.

1.4.3.3: Perception about beneficial organisms in rice crop

It is quite clear from table 1.11 that most of the farmers were quite unaware about the beneficial organisms found in rice crop.

In case of green lace wing 4.0% respondents refused the presence of these beneficial organisms in rice crop, whereas 1.3% said their presence at low levels. A major portion (94.7%) of farmers did not answer.

About lady bird beetle 6.7% of farmers indicated that no such organism was present in rice crop, whereas only 1.3% claimed that these were present but at very low level. in this case similar to lace wing, 92.0% of the farmers interviewed did not answer this question.

About the parasitizing wasps 51.3% farmers were of the view that these were not present in rice fields. There was none of the farmers claiming the presence of wasps in low, medium or high number while 48.7% did not respond to this question.

The results reveal that farmers were aware of dragonflies and damselflies among beneficial insects and indicated their presence at low (25.3%), medium (40.7%) and high (27.3%) levels while 6.7% did not answer. None of the farmers refused about their presence.
Table 1.11: Perception about beneficial organisms in rice crop.

<table>
<thead>
<tr>
<th>Name of the organisms</th>
<th>Not Present</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>No Response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>% age</td>
<td>Frequency</td>
<td>% age</td>
<td>Frequency</td>
</tr>
<tr>
<td>Lace wing</td>
<td>6</td>
<td>4.0</td>
<td>2</td>
<td>1.3</td>
<td>0</td>
</tr>
<tr>
<td>Lady bird beetle</td>
<td>10</td>
<td>6.7</td>
<td>2</td>
<td>1.3</td>
<td>0</td>
</tr>
<tr>
<td>Wasps</td>
<td>77</td>
<td>51.3</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>Dragon flies</td>
<td>0</td>
<td>0.0</td>
<td>38</td>
<td>25.3</td>
<td>61</td>
</tr>
<tr>
<td>Spiders</td>
<td>20</td>
<td>13.3</td>
<td>54</td>
<td>36.0</td>
<td>21</td>
</tr>
<tr>
<td>Birds</td>
<td>3</td>
<td>2.0</td>
<td>76</td>
<td>50.7</td>
<td>56</td>
</tr>
<tr>
<td>Frogs</td>
<td>101</td>
<td>67.3</td>
<td>33</td>
<td>22.0</td>
<td>0</td>
</tr>
</tbody>
</table>

As for as spiders were concerned 13.3% farmers indicated their absence in rice crop, 36.0% indicated that they were present at low level, 14.0% at medium, 6.7% at high level, whereas 30.0% did not respond to this.

The presence of birds was declared at low (50.7%), medium (37.3%) and high (4.0%) levels. According to 2.0% of the farmers birds were not present in their rice crops while 6.0% farmers did not answer.

In case of frogs 67.3% of the farmers pointed out that these were not present, 22.0% pointed out their presence as low in number while 10.7% did not respond to this.

According to farmers the birds were more at the time of land preparation or at the time of crop maturity, where they feed upon insects and on maturing rice grains.

Most of the rice farmers use more and more quantities of agrochemicals, which no doubt pollute the environment. Odonata are the predators of rice pest insects. They also function as indicators of ecosystem quality. Because of their sensitivity to the environmental degradation and their trophic position they are potentially useful in habitat conservation and management. A significant negative correlation exists between cattle grazing and Odonata species richness in wetlands. Due to excessive use of agrochemicals the abundance of dragonflies in rice fields is decreasing and the farmers claimed occurrence of dragonflies in low number in their rice fields could be those used to graze their cattle on harvested rice straw in rice fields and also overused the agrochemicals (Clark and Samways, 1996; Samways et al., 1996; Takamura, 1996).
The reduction in frog population could be partially due to abuse of insecticides. However, their conservation is very important for the preservation of some insect species i.e., giant water bugs and for maintenance of biodiversity within rice field ecosystems (Hirai and Hidaka, 2002).

The important finding is that farmers had poor knowledge and recognition of beneficial insects. However, they could recognize well to spiders, birds and frogs, but were unaware about their roles in rice fields and consequently were unconscious that pesticides could decrease the number of natural enemies. Similar results are found in survey studies conducted by Heong et al. (1994), Bandong et al. (2002) and Berg (2001). According to Litsinger et al. (1980) farmers have deficiencies in recognizing natural enemies and thus apply 5.0% of insecticide spray against lady beetles thinking it as pest. Most of the farmers acknowledged the existence of natural enemies but these tend to note the larger and obvious ones such as dragonflies, spiders and birds.

The rice fields have potential in sustaining the biodiversity of many invertebrates and vertebrates like natural areas of wetlands. They are important in sustaining populations of several species of birds and frogs including many species of other taxas. Different farming practices can alter the sustainability of rice fields as a habitat for these species. Overuse of pesticides by the farmers may harm invertebrates and other wildlife as pointed out by the farmers that the number of frogs in rice fields had decreased too much lower levels, due to excessive use of pesticides. These chemicals have greater effects on insect predators’ population than on the pests (Lawler, 2001).

So, inauguration about a formal IPM training programme on national basis emphasizing about the recognition of pest insects and their natural enemies is suggested which is also recommended for rice farmers by Medina and Callo (1999).

**1.4.4: Farmers’ beliefs about pests**

In this segment various beliefs of farmers about pest insects’ attack, most problematic pest (insect, disease, weed, rats) and interaction between insects and weeds were determined.
1.4.4.1: Severity of pest insect’s attack after a certain time period

Most of the farmers (44.0%) thought that there was a cyclic rotation of 5 years in severity of pest insects’ attack. The proportion of the farmers explaining this cycle as of 10 years was 18.7%. There were 6.0% of the farmers who did not believe in this concept. However, there were 31.3% of the farmers who did not respond to this question (Table 1.12).

Table 1.12: Farmers’ views about number of years VS pest insect attack.

<table>
<thead>
<tr>
<th>Farmers View</th>
<th>Frequency</th>
<th>% age</th>
</tr>
</thead>
<tbody>
<tr>
<td>After each 5 years</td>
<td>66</td>
<td>44.0</td>
</tr>
<tr>
<td>After each 10 years</td>
<td>28</td>
<td>18.7</td>
</tr>
<tr>
<td>No such cycle</td>
<td>09</td>
<td>6.0</td>
</tr>
<tr>
<td>No response</td>
<td>47</td>
<td>31.3</td>
</tr>
</tbody>
</table>

The findings are supported by the results of Robinson et al. (2007) who indicated that rice farmers in Bangladesh typically reported that they expected no more than one severe pest attack per ten years.

This belief of farmers that pest attack is severe once after a certain time period also excited them to use insecticides not only as precautionary measures but also more excessively. Farmers call that year as a ‘hard year’. It was a matter of common observation that whenever there was an attack of pest insect or of a disease in farmer’s own or in neighbour farmers’ rice crop, farmers considered that attack was as a result of had year. In this sense each farmer had set its own criteria to declare a year as hard and in response to its perception farmers often became engage in insecticides arrangements to be used in that year.

1.4.4.2: Most problematic pest

Out of 150 farmers interviewed 47.3% stated that diseases were most problematic among the pests followed by insects (21.3%), weeds (6.7%) and rats (2.7%). However, 22.0% farmers did not respond (Table 1.13).

Table 1.13: Most problematic pest.

<table>
<thead>
<tr>
<th>Name of Pests</th>
<th>Frequency</th>
<th>% age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insects</td>
<td>32</td>
<td>21.3</td>
</tr>
<tr>
<td>Diseases</td>
<td>71</td>
<td>47.3</td>
</tr>
<tr>
<td>Weeds</td>
<td>10</td>
<td>6.7</td>
</tr>
<tr>
<td>Rats</td>
<td>4</td>
<td>2.7</td>
</tr>
<tr>
<td>No response</td>
<td>33</td>
<td>22.0</td>
</tr>
</tbody>
</table>
According to Rubia et al. (1996a) most of farmers believed that rats (89.0%),
diseases (77.0%) and pest insects (82.0%) caused sizeable yield losses to rice crop.
Overall, pest insects were seen as important but controllable. The results of present
study are partially supported by their findings in which farmers ranked diseases as
most important and difficult to control. Insects, weeds and rats were considered less
important as for as losses caused by them and the difficulties faced by farmers to
control them were concerned.

1.4.4.3: Most problematic pest insect

Out of 150 farmers 35.3% of the farmers considered stem borers as most
problematic pest, while 45.3% thought this about rice leaffolder. Small group (6.0%)
was of the view that grasshoppers were most problematic while only 2.0% claimed
this about rice planthopper and leafhoppers. However, 11.3% of the farmers did not
answer (Table 1.14).

From table 1.14 it is clear that most of the farmers thought rice leaffolder and
stem borers as most damaging pest insects. It means high proportions of insecticides
were used against these insects. Similar findings are of Bandong et al. (2002) in
which they mentioned stem borers, leaffolder, whorl maggot and defoliators as
targeted pests.

The findings of the present study are in accordance with those of Rubia et al.
(1996a) and Huan et al. (1999) who found stem borers and leaffolders as problematic
pests for farmers. Similar was the case in the Kallar tract, where farmers considered
stem borers and leaffolder as most problematic pest insects and ultimately used
maximum insecticides for their eradication.

In case of stem borers and leaffolder because of plant compensation, actual
yield losses are usually much less than expected (Rubia et al., 1996a, b). But farmers
overestimate the losses due to these pest insects by many folds and these
misperceptions influence management decisions. Hence a large proportion of
insecticides currently used against these insects may be unnecessary (Graf et al.,
1992; Lazaro et al., 1993; Heong et al., 1994; Way and Heong, 1994; Heong and
Escalada, 1999).
Table 1.14: Most problematic pest insect and disease.

<table>
<thead>
<tr>
<th>Most problematic insect</th>
<th>Frequency</th>
<th>% age</th>
<th>Most problematic disease</th>
<th>Frequency</th>
<th>% age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem borer</td>
<td>53</td>
<td>35.3</td>
<td>Bacterial leaf blight</td>
<td>76</td>
<td>50.7</td>
</tr>
<tr>
<td>Leaffolder</td>
<td>68</td>
<td>45.3</td>
<td>Brown leaf spot</td>
<td>6</td>
<td>4.0</td>
</tr>
<tr>
<td>Grasshopper</td>
<td>9</td>
<td>6.0</td>
<td>Rice blast</td>
<td>3</td>
<td>2.0</td>
</tr>
<tr>
<td>Hoppers</td>
<td>3</td>
<td>2.0</td>
<td>Bakanae</td>
<td>3</td>
<td>2.0</td>
</tr>
<tr>
<td>No response</td>
<td>17</td>
<td>11.3</td>
<td>No response</td>
<td>62</td>
<td>41.3</td>
</tr>
</tbody>
</table>

1.4.4.4: Most problematic disease

According to 50.7% of the farmers interviewed BLB was most problematic for them followed by BLS (4.0%) rice blast and bakanae each (2.0%) while 41.3% of the farmers did not answer (Table1.14).

It is quite clear that for farmers BLB was most problematic as it was difficult to control by them and was known by the farmers the disease of ‘lua’. The excessive application of nitrogenous fertilizers, a common practice among the farmers of the Kallar tract, makes the plant vulnerable to this disease. However, the farmers were generally not familiar with other rice diseases.

1.4.4.5: Weed-insect interaction

In a rice field, generally non rice plant and specifically the plants of other varieties could be regarded as weeds. Out of 150 farmers interviewed 16.0% were of the view that if weeds would be more the attack of insects would be less. However, many (74.3%) farmers believed that with the large number of weeds, the attack of insects would increase. There were 22.0% of the farmers who did not believe in weed-insect interaction. Only 14.7% of the respondents did not respond to this question (Table1.15).

Table 1.15: Weeds VS insect attack.

<table>
<thead>
<tr>
<th>Insect attack</th>
<th>Frequency</th>
<th>% age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less</td>
<td>24</td>
<td>16.0</td>
</tr>
<tr>
<td>More</td>
<td>71</td>
<td>74.3</td>
</tr>
<tr>
<td>No effect</td>
<td>33</td>
<td>22.0</td>
</tr>
<tr>
<td>Not known</td>
<td>22</td>
<td>14.7</td>
</tr>
</tbody>
</table>

The views of 16.0% farmers are supported by the fact that if weeds are allowed to grow in paddy fields they provide shelter to many beneficial insects and
Thus help in keeping pest population down (Anonymous, 2006b). So the perception of these of farmers could be true that in weedy rice fields insect attack would be less.

1.4.5: Farmers’ beliefs about pesticides

In this part, main reasons/effects of using insecticides, beliefs of farmers about the problems related to pesticides, average number of use of various insecticides and change in pesticides usage during the last five years were determined.

1.4.5.1: Reasons for using insecticides

Out of 150 farmers interviewed 54.7% said that they used insecticides to kill the insects, while 32.0% mentioned that the insecticides helped to protect the crop from future pest attack. There was also a big segment (54.0%) of sampled farmers who claimed that the insecticides not only killed the pest insects but also improved yield of crop. However, 16.0% of the farmers did not respond (Table 1.16).

<table>
<thead>
<tr>
<th>Reasons for using insecticides</th>
<th>Frequency</th>
<th>% age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kill the insects (make crop free from insects)</td>
<td>82</td>
<td>54.7</td>
</tr>
<tr>
<td>Protect the crop from insect attack</td>
<td>48</td>
<td>32.0</td>
</tr>
<tr>
<td>Increase the yield</td>
<td>81</td>
<td>54.0</td>
</tr>
<tr>
<td>No answer</td>
<td>24</td>
<td>16.0</td>
</tr>
</tbody>
</table>

It is clear that majority of the farmers used insecticides just to kill all the insects irrespective of their role in trophic guilds. It means that most of the farmers had no knowledge and identification about beneficial insects and this unawareness of farmers continued to encourage pesticide use and misuse (Berg, 2001).

Some farmers used insecticides as precautionary measures as they believed that by doing so they could be able to eliminate or lower the pest infestation. This is in accordance with the findings of Brunold (1981), Rola and Pingali (1993), Hu et al. (1997) and Robinson et al. (2007).

However, majority of the farmers considered that insecticides also acted as fertilizers and were necessary to increase the yield. Similar results have been shown in survey studies carried out by Heong et al. (1998), Huan et al. (1999) and Bandong et al. (2002). The increasing use of pesticides in rice crop (Table 1.19) could be due to this misconception about the effects of insecticides in increasing rice yield like fertilizers.
These were the more critical findings, which determined some of the factors forcing farmers to use insecticides even when there was no or negligible attack of pest insect in rice crop. As it is clear from the table 1.16 that excitement to make crop free from pest and zeal to increase the yield were the major motives for excessive use of insecticides and farmers in the Kallar tract were more confident about this belief while using granular insecticide the “Padan”. This wrong concept about insecticides association with increasing rice production could be changed by proper training of the farmers (Escalada et al., 1999) in farmers’ field schools (Mattson, 2000) or through carefully designed television programmes (Escalada and Heong, 2004b).

1.4.5.2: Problem related to pesticides

From previous table 1.16, it is clear that farmers’ main objective of using insecticide was just to kill pest insects altogether. They were however less concerned about harmful effects of this practice to health of human and environment. From table 1.17 it becomes even more clear that a major portion (54.0%) of farmers considered costs of pesticides as a big problem related to pesticides. As for health hazards were concerned with pesticides 22.0% farmers pointed out this problem, 8% claimed that pesticides had deleterious affects to the environment while 16.0% farmers did not answer.

The results showed that farmers were mainly concerned about the price of pesticides rather their effects on health or contribution to environmental contaminations. In spite of the fact that almost all pesticides related to rice crop were relatively cheap, yet the farmers seek further cheaper (low priced) pesticides so that they could use them more vigorously. The most important finding was that only a small fraction of farmers was conscious about health risks and about environment deterioration associated with pesticides usage.

Due to a little knowledge about the poisonous chemicals and with the greater market liberalization, there has been a tendency towards the application of cheaper and sometimes more hazardous pesticides, which has damaged the health of farmers and of farm animals and these health costs outweighed the benefits gained from pesticides, especially when pesticides are applied very close to harvest, these could also endanger the health of consumers (Beasley and Trammel, 1989; Rola and Pingali, 1993; Quyen, et al., (1995).
Table 1.17: Problem related to pesticides with specific reference to health.

<table>
<thead>
<tr>
<th>Problems related to pesticides</th>
<th>Pesticide most problematic to health</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmers’ view</td>
<td>Frequency</td>
</tr>
<tr>
<td>Cost of pesticides</td>
<td>81</td>
</tr>
<tr>
<td>Health hazards</td>
<td>33</td>
</tr>
<tr>
<td>Environmental effects</td>
<td>12</td>
</tr>
<tr>
<td>No answer</td>
<td>24</td>
</tr>
</tbody>
</table>

The results about the health risks associated with pesticides to farmers are supported by the findings of Heong and Escalada (1999) while partially supported by the studies of Berg (2001) and Heong et al. (2008). It was also observed that almost all the farmers did not use any protecting clothing during pesticides applications which could be due to hot whether of the area. It means that farmers were prepared to compromise health risks associated with pesticide use (Heong and Escalada, 1999).

A large portion of insecticides used in crops remains in surrounding environment, making it unhealthy for other organisms. But farmers do not care about this, as it is clear from the table 1.17 that only 8% of the farmers knew about this. The results are in accordance with survey results of Heong et al. (1998), Berg (2001) and of Mironga (2005) that a low number of rice farmers (6-13%) were of the view that high input agriculture including excessive use of insecticides polluted the environment.

In rice monoculture, the chance of pests to reach a population level that economically justifies control action is usually low. So, the farmers should be very careful in using these poisons. If costs associated with health and environmental effects, difficulties in performing the task, along with real costs also accounted for by farmers, their willingness to use pesticides could be decreased (Waibel, 1992; Halwarth, 1998; Heong and Escalada, 1999).

1.4.5.3: Pesticide most problematic to health

When the farmers were asked about the most dangerous pesticides they considered for their health, 74.7% pointed out that these were insecticides, while 4.7% thought this about fungicides. None of the farmers considered herbicides unsafe for health. However, 20.7% farmers did not respond to this question (Table 1.17).
These results are in accordance with those of Berg (2001) who indicated that almost all farmers (85-100%) regarded insecticides as the most problematic to their health. However, results are supported to some extent by the findings of Heong et al. (1998) that only 13.0% farmers considered that insecticides spray could be detrimental to one’s health.

1.4.5.4: Average number of applications of various pesticides

The frequency of insecticides usage by the surveyed farmers only once in rice crop was 54.0%, while 45.3% farmers used insecticides twice in single rice crop season. The number of farmers using herbicides once in rice was 88.0% and 6.7% farmers used herbicides either two times or used two types of herbicides at the same time by mixing them or one after the other. The frequency of fungicides usage once was found to be 30.7%, while 4.7% farmers used fungicides twice. On the other hand 0.7%, 5.3% and 64.7% of the farmers were those not using insecticides, herbicides and fungicides respectively in rice crop (Table 1.18).

<table>
<thead>
<tr>
<th>Name of pesticide</th>
<th>One time</th>
<th>Two times</th>
<th>Not use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>% age</td>
<td>Frequency</td>
</tr>
<tr>
<td>Insecticides</td>
<td>81</td>
<td>54.0</td>
<td>68</td>
</tr>
<tr>
<td>Herbicides</td>
<td>132</td>
<td>88.0</td>
<td>10</td>
</tr>
<tr>
<td>Fungicides</td>
<td>46</td>
<td>30.7</td>
<td>7</td>
</tr>
</tbody>
</table>

It is evident that the use of pesticides especially of insecticides and herbicides among the rice farmers was very high. This is because the farmers always choose those pest management options that appear best to meet their pest control practices, so they mostly rely on pesticides leading to misuse and overuse of insecticides. However, pest management decisions are mainly influenced by farmers’ perceptions of problem and related pest control actions (Heong and Escalada, 1999). These results are in conformity with the previous studies (Heong et al., 1994; Heong and Escalada, 1997b; Bandong et al., 2002; Berg, 2001).

Although there was high incidence of diseases (Table 1.10) in rice crop yet application of fungicides was low as compared to insecticides and herbicides. This probably was due to the difficulties in spraying the fungicide. Because at the time of disease incidence the rice crop usually has grown up and reached mostly near
maturity stages, which makes it difficult for a spray man to work in fully grown crop also having standing water or muddy soil in it, which ultimately encumber even the need base use of fungicides.

1.4.5.5: Change in pesticides usage

The farmers were enquired about any change in pesticide usage during the last five years. A big segment (78.7%) of the farmers answered that there was an increase in pesticides usage during this period. On the other hand 2.7% farmers claimed that there was decrease, while 4.7% claimed no change in pesticide usage. However, 14.0% farmers did not answer this question (Table 1.19).

One of the most important findings from this survey is the farmers' response to increased pesticide usage. This could be attributed to the lower costs of pesticides (especially insecticides and herbicides) and farmers dependence on pesticides as main pest control tactics (Heong and Escalada, 1997b; Berg, 2001). Due to this reason the pesticides has dominated pest management practices of rice farmers (Heong et al., 1998). The results of present study are in accordance with those of Berg (2001) that during the last three years majority of the farmers (90.0%) had increased their use of pesticides.

This increasing use of pesticides in fact is very alarming to health of farmers, environment and biodiversity associated with rice crop ecosystem (Berg, 2001). Efforts to convince farmers to reduce their pesticide use mainly rely on the factors that can significantly reduce the farmers' risk aversion. These include: education and training in improvement of pest management related information and extension services.

1.4.5.6: Increasing use of pesticides

Out of 150 farmers interviewed a big part (60.7%) declared that there was an increase in insecticides usage. It was followed by increased use of herbicides (16.0%) and fungicide (14.0%) while 9.3% of the interviewed farmers did not respond (Table 1.19).

The findings are exactly similar to those of Heong and Escalada (1997b), Heong et al. (1998), WRI (1998), Berg (2001) and Dawe (2008) who stated that rice farmers had adopted pesticides as major pest control strategy and were using insecticides more frequently than herbicides and fungicides.
Table 1.19: Change in pesticides’ usage during last five years.

<table>
<thead>
<tr>
<th>Farmer’s view</th>
<th>Frequency</th>
<th>% age</th>
<th>Name of pesticide</th>
<th>Frequency</th>
<th>% age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased</td>
<td>118</td>
<td>78.7</td>
<td>Insecticides</td>
<td>91</td>
<td>60.7</td>
</tr>
<tr>
<td>Decreased</td>
<td>4</td>
<td>2.7</td>
<td>Herbicides</td>
<td>24</td>
<td>16.0</td>
</tr>
<tr>
<td>No change</td>
<td>7</td>
<td>4.7</td>
<td>Fungicides</td>
<td>21</td>
<td>14.0</td>
</tr>
<tr>
<td>No response</td>
<td>21</td>
<td>14.0</td>
<td>No response</td>
<td>14</td>
<td>9.3</td>
</tr>
</tbody>
</table>

The overall impact from the changed insecticide use patterns is difficult to assess. However, these will most likely have a large and probably impact on shaping the future of rice farming systems (Berg, 2001).

1.4.6: Farmers’ beliefs and practices about pest management

In this section the farmers were asked about various practices of pest management which included practices of insecticides application, favour for aerial spray against rice pest insects, frequency of use of fungicides, herbicides and insecticides for control of diseases, weeds and insects respectively.

1.4.6.1: Practices of insecticide applications

For a better pest control program the proper timing of application of pesticide is of utmost important. This practice could reduce the costs of pesticides and their application as well as save the environment from these poisons by their inept and heavy-handed applications at improper times. From the table 1.20 it is clear that there was only a small fraction (0.7%) of farmers not using insecticides. But majority (46.7%) of the farmers applied insecticide just after looking at pest and 13.3% just looking their symptoms of damage. Only 9.3% farmers consult Agriculture Department before using insecticides, while 26.7% were those who applied insecticide after seeing their neighbours using insecticides or listening from peoples that the attack of a certain pest insect has started. The frequency of the farmers using insecticides on calendar/crop-stage base or routine wise schedules was somewhat high (36.7%). There was only 0.3% farmer out of 150 using insecticides at ETL.

It is quite clear from table 1.20 that farmers were much conscious about yield losses, which could occur as a result of pest insect attack. Due to this reason most of them applied unnecessary insecticides just looking insect pest/damage or on routine...
wise basis which is in agreement with the findings of Heong et al. (1995). The farmers observed these pest insects or their damage not by proper pest scouting methods but were monitored during weeding, irrigation & fertilizer application, bund cleaning or while walking along pathways on rice field’s bunds. However, this practice had been proved erratic even when pest/damage was high near field bunds (IRRI, 1988; Bandong et al., 2002).

Table 1.20: Practices of insecticide applications.

<table>
<thead>
<tr>
<th>Farmers' views</th>
<th>Frequency</th>
<th>% age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not use insecticides</td>
<td>1</td>
<td>0.7</td>
</tr>
<tr>
<td>After looking pest</td>
<td>70</td>
<td>46.7</td>
</tr>
<tr>
<td>After looking damage</td>
<td>20</td>
<td>13.3</td>
</tr>
<tr>
<td>After consulting Agri. Department</td>
<td>14</td>
<td>9.3</td>
</tr>
<tr>
<td>Following the neighbour</td>
<td>40</td>
<td>26.7</td>
</tr>
<tr>
<td>Routine wise</td>
<td>55</td>
<td>36.7</td>
</tr>
<tr>
<td>At ETL</td>
<td>1</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Multiple responses were allowed.

In routine wise application the farmers applied granular insecticides to nursery seedling a few days before uprooting (with a view that there would be insecticide residues carryover affect to the main crop) and to main crop when it had attained the age of 30-40 days along with fertilizers or alone and again at end of tillering-booting stage in the month of August. The results are confirmed by the previous survey studies by Kenmore et al. (1987) and Bandong et al. (2002) that most of the farmer applied insecticides based on crop growth stages or routine wise, just before pulling the seedlings, timed with fertilization and upon seeing a neighbour spraying.

A good number of farmers applied insecticides when their neighbour did so. These findings are in accordance with those of Rola and Pingali (1993), Hu et al. (1997) and Bandong et al. (2002).

Majority of the farmers also applied insecticides just by looking insects or their damage and ignored ETLs. The benefits of thresholds also included reduction in insecticides usage leading to reduce the cost of production (Bandong and Litsinger, 2005; Litsinger et al., 2005). But farmers were unaware about the utility of ETLs. Actually farmers had set their own ETLs for rice pest insects (Rajasekaran, 1993) and they applied insecticides when the insects reached at that ETL i.e., just observing the moths of stem borers or its damage/dead hearts (Lazaro et al., 1993; Rubia et al., 1996a; Bandong et al., 2002) or moths and damage symptoms of rice leaffolders in
fields (Graf et al., 1992; Heong et al., 1994; Heong et al., 1998; Heong and Escalada, 2005). The important thing was that, the farmers self-made ETLs were always lower than those recommended by researchers. Some times they became much worried when they saw only one live larvae of stem borer in a dissected rice plant stem or larvae of rice leaffolder. Hence, in most of the cases they applied control measure when it was not needed (Rubia et al., 1996a; Bandong et al., 2002). It means insecticide uses among rice farmers were based on perceived needs and perhaps fear, rather than real need and economics of the situation (Norton, 1982; Mumford and Norton, 1984).

A handsome proportion of farmers used insecticides on routine wise/calendar base/crop stage basis, irrespective of the infestation level of pest insects. This finding is in accordance with the findings of Berg (2001) that farmers applied pesticides according to scheduled spray, whether pest were present or not. This was partially because farmers innately prefer the simpler crop stage-based insecticide approach (Kenmore et al., 1987).

The results indicate that the insecticides were misused to a greater extent in the Kallar tract. These were the leaf or plant damage symptoms that stimulated the farmers to use insecticides. They believed that this leaf damage could cause yield losses and thus immediate action should be taken to control it- a loss aversion behavior.

This misuse of pesticides is common throughout Asia, especially in intensive irrigated system and may lead to secondary pest problem and can severely affect human health beside deteriorating quality of environment. So, there is dire need to educate the farmers about sustainable pest management strategies which are socially acceptable, effective against the target pests only, friendly to environment and economical condition of the farmers and to motivate the farmers to adopt ‘wait and see’ approach (Tait, 1977; Norton and Mumford, 1983; Waibel, 1986; Lazaro et al., 1993; Heong, 1997; Heong et al., 1998; Escalada and Heong, 2004a,b; Garg et al., 2004; Robinson et al., 2007).

1.4.6.2: Favour for aerial spray against pest insects of rice crop

From the table 1.21 it is much clear that a large portion (81.3%) of farmers was in favour of aerial sprays of insecticides for control of rice pest insects, while
only 5.3% of the farmers were against such type of spray programs. However, 13.3% farmers did not answer this question.

Table 1.21: Farmers’ favour for aerial spray against rice crop pest insects.

<table>
<thead>
<tr>
<th>Farmers’ Response</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>122</td>
<td>81.3</td>
</tr>
<tr>
<td>No</td>
<td>8</td>
<td>5.3</td>
</tr>
<tr>
<td>No response</td>
<td>20</td>
<td>13.3</td>
</tr>
</tbody>
</table>

It is evident that majority of the farmers was quite unaware of harmful affects of insecticides to the environment and beneficial organisms, which could result into secondary pests outbreak. In Indonesia as a result of aerial sprays against rice stem borers, brown planthopper *Nilaparvata lugens* (Stal), appeared as a pest far worse than stem borers (Rubia *et al.*, 1989). According to Barnes *et al.* (1987) crops could lost as a result of pesticides drift to neighbouring farms. This drift affects several kilometers away and when pesticides would be sprayed from aircraft this problem could become even worse (Mazariegos, 1985).

1.4.6.3: Seed treatment for rice crop

Out of 150 farmers the portion of the farmers treating their seeds with fungicides was quite high (74.0%). There were only 26.0% farmers who claimed that they did not treat seeds with any fungicide (Table 1.22).

Table 1.22: Seed treatment.

<table>
<thead>
<tr>
<th>Farmers’ Response</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>111</td>
<td>74.0</td>
</tr>
<tr>
<td>No</td>
<td>39</td>
<td>26.0</td>
</tr>
</tbody>
</table>

The reason given by farmers not treating seeds was due to giving up the sowing of Basmati-385 because it was heavily attacked by foot rot (Bakanae) disease and seed treatment was helpful to protect the crop against this disease. However, seed treatment is recommended by Government of the Punjab, Pakistan to reduce the attack of seed and soil born diseases in rice crop.

1.4.6.4: Fungicides used for seed treatment of rice crop

Out of 150 farmers 40.7% used Topsin-M, 32.7% Benlate, 0.7% Vitavax for seed treatment while the portion of the farmers not treating seeds was 26% (Table 1.23).
1.4.6.5 Fungicides used against diseases in rice crop

As the most prevalent disease in the Kallar tract was bacterial leaf blight (BLB), so, the use of copper based fungicide (copper oxychloride and Cupravit etc) against this disease was high (23.3%) followed by mancozeb (7.3%) against brown leaf spots (BLS). The use of fungicides difenoconazole against rice blast was very low i.e. 3.3% only. As it has been described earlier (Table 1.18) that the spray of fungicides is difficult in rice fields, hence the frequency of the farmers not using fungicide was very high (66.0%) (Table 1.23). The attack of rice blast was also reported to be increasing in this tract but the farmers were very less aware about this disease.

Table 1.23: Fungicides used by rice farmers.

<table>
<thead>
<tr>
<th>Fungicides used for seed treatment</th>
<th>Fungicides used against rice crop diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Name of Fungicide</strong></td>
<td><strong>Frequency</strong></td>
</tr>
<tr>
<td>Topsin-M (thiopenate methyl) 70WP</td>
<td>61</td>
</tr>
<tr>
<td>Benlate (benomyl) 50WP</td>
<td>49</td>
</tr>
<tr>
<td>Vitavax (carboxin) 200FF</td>
<td>1</td>
</tr>
<tr>
<td>No treatment</td>
<td>39</td>
</tr>
</tbody>
</table>

Note: Common names are given in parenthesis

1.4.6.6: Herbicides used by farmers in rice crop

From the table 1.24 it is evident that frequency of farmers using acetachlor was high (58.0%) followed by Butachlor (18.0%), Machete (9.3%) Rifit (2.7%) Sunstar (6.7%) and the farmers who did not use herbicides were 5.3%.

Table 1.24: Herbicides used by rice farmers.

<table>
<thead>
<tr>
<th>Name of Herbicides</th>
<th>Frequency</th>
<th>% age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetachlor (acetachlor) 50EC</td>
<td>87</td>
<td>58.0</td>
</tr>
<tr>
<td>Butachlor (butachlor) 60EC</td>
<td>27</td>
<td>18.0</td>
</tr>
<tr>
<td>Machete (butachlor) 60EC</td>
<td>14</td>
<td>9.3</td>
</tr>
<tr>
<td>Rifit (pertilachlor) 50EC</td>
<td>4</td>
<td>2.7</td>
</tr>
<tr>
<td>Sunstar (ethoxysulfuron) 15WG</td>
<td>10</td>
<td>6.7</td>
</tr>
<tr>
<td>Not use</td>
<td>8</td>
<td>5.3</td>
</tr>
</tbody>
</table>

Note: Common names are given in parenthesis

The results are in agreement with those of Sheikh et al. (2006) indicating that majority of the farmers adopted chemical control techniques for weed management. Acetachlor was cheaper weedicide so mostly the farmers used it. Butachlor and
Machete have the same active ingredient i.e. Butachlor but farmers preferred butachlor being low-priced than the branded Machete. The two herbicides i.e., acetachlor and butachlor were in excessive use by a large no of farmers.

However, it is unwise to use the same herbicides continuously without rotating several herbicides because using the same herbicides could induce resistance in some weeds (Shibayama, 2001; Sing et al., 1999). It is also apparent that chemical weed control method currently was the more popular method among the farmers of the Kallar tract because it had lowest labor input, but this substitution of chemicals for labor could affect the environment negatively (Huang and Rozelle, 1996; Shibayama, 2001).

1.4.6.7: Frequency of insecticides applications

From table 1.25 it is clear that mostly the farmers used granular insecticides for the control of rice pest insects. The highest use of granular insecticides (single application) was of cartap (36.4%) followed by Padan (10.1%), monomehypo (9.4%). The use of emulsifiable concentrated (EC) insecticides was very low. Among the EC formulated insecticides the use of Karate was 1.3% and that of chloropyrifos was 0.7% in case of single application of ECs insecticides. Although in case of two applications of granular insecticides the highest contribution was of monomehypo+cartap (21.5%) followed by monomehypo+monomehypo (12.1%) and cartap+cartap (2.0%). On the other hand the frequency of two insecticides among which one was granular and other was EC was relatively very low. In this group the highest use was of monomehypo+Karate (2.0%) followed by monomehypo+chloropyrifos, cartap+Karate and cartap+chloropyrifos, each (1.3%) and lastly 0.7% of Padan+Karate.

It is clear from table 1.25 that rice farmers mostly used granular insecticides in single application or in case of two applications the 2nd application in most of the cases was also that of granules. Padan (cartap) a branded product, being an expensive insecticides was used by a fewer farmers while cartap and monomehypo being economical were used abundantly. The overall use of granules in single or in double applications or in combination with EC formulations was 98.0% while use of EC alone was 2.0%. The reason for preference the granular insecticides was their easy application and satisfactory results in controlling pest insects of rice crop.
The granular insecticides i.e. cartap and monomehypo belong to carbamate group of insecticides. This showed that use of carbamates group by rice farmers was highest which is in accordance with the findings of Rubia et al. (1996a).

Table 1.25: Insecticides used by rice farmers

<table>
<thead>
<tr>
<th>Name of Insecticide</th>
<th>Frequency</th>
<th>% age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Padan (cartap hydrochloride) 4G</td>
<td>15</td>
<td>10.1</td>
</tr>
<tr>
<td>Cartap (cartap hydrochloride) 4G</td>
<td>54</td>
<td>36.2</td>
</tr>
<tr>
<td>Monomehypo (monomehypo) 5G</td>
<td>14</td>
<td>9.4</td>
</tr>
<tr>
<td>Karate (lamda cyhalothrin) 2.5EC</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>Chloropyrifos (chloropyrifos) 40EC</td>
<td>1</td>
<td>0.7</td>
</tr>
<tr>
<td>Padan+Karate</td>
<td>1</td>
<td>0.7</td>
</tr>
<tr>
<td>Cartap+Karate</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>Cartap+ chloropyrifos</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>Monomehypo+Karate</td>
<td>3</td>
<td>2.0</td>
</tr>
<tr>
<td>Monomehypo+ chloropyrifos</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>Cartap+Cartap</td>
<td>3</td>
<td>2.0</td>
</tr>
<tr>
<td>Monomehypo+ cartap</td>
<td>32</td>
<td>21.5</td>
</tr>
<tr>
<td>Monomehypo+monomehypo</td>
<td>18</td>
<td>12.1</td>
</tr>
</tbody>
</table>

Note: Common names are given in parenthesis

The granular insecticides are applied in standing water or field is irrigated after the application of these insecticides. The insecticide after dissolving in water is absorbed by rice plant where it ultimately kills the target pest insect. However, a large portion of applied insecticides is leached down along with water. Pesticides that find their way into soils become toxic to soil inhabiting arthropods, earthworms, fungi, bacteria and protozoa which are vital to the ecosystem functioning (Pimental et al., 1992). In this way the applied insecticides are affecting to the agricultural biodiversity which in turn affects the sustainability and productivity of this system.

1.4.7: Causes of low rice yields

Besides pest insects, weeds and diseases the other causes of low rice yield as identified during survey were; improper use of fertilizers, unreliable sources of seed and information, harmful effects of weedicide on rice plant, poor sources of irrigation and rice straw burning along with rice monoculture.

1.4.7.1: Improper/imbalance use of fertilizers

The table 1.26 shows that among 150 farmers, the farmers not using Urea, Diammonium Phosphate (DAP) and Potash were 3.3%, 16.7% and 73.3%.
respectively. The farmers using Urea, DAP and Potash up to 1 bag/acre were 36.7%, 68.0% and 26.7%, respectively. It is also clear that a big segment of the farmers (57.3%) used urea fertilizers @ upto 2 bags/acre. The farmers using DAP @ 2 bags/acre were 15.3%. There was a small portion (1.7%) of the farmers using Urea @ more than 2 bags/acre. However, none of the farmers interviewed was using Potash @ 2 bags or more than two bags per acre.

Table 1.26: Fertilizers used by rice farmers.

<table>
<thead>
<tr>
<th>Amount of fertilizer used @ Kg/acre</th>
<th>Urea</th>
<th>DAP</th>
<th>Potash</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>% age</td>
<td>Frequency</td>
</tr>
<tr>
<td>No use</td>
<td>5</td>
<td>3.3</td>
<td>25</td>
</tr>
<tr>
<td>0-50 (1 bag)</td>
<td>55</td>
<td>36.7</td>
<td>102</td>
</tr>
<tr>
<td>51-100 (up to 2 bags)</td>
<td>86</td>
<td>57.3</td>
<td>23</td>
</tr>
<tr>
<td>101-150 (&gt;than 2 bags)</td>
<td>4</td>
<td>1.7</td>
<td>0</td>
</tr>
</tbody>
</table>

From table 1.26 showing the use of fertilizers by rice growers, it can be said that among the other reasons of high attack of diseases and insects, the imbalance use of fertilizers was of utmost important, especially the excessive use of nitrogenous fertilizers (Urea, DAP).

Fertilizers are the quickest way of enhancing crop production but their cost and unavailability in time are the limitations frequently discouraging farmers from their use in the recommended quantities and in the balanced proportions (Ijaz, 2008). Farmers believed that high nitrogen application would produce healthier crop but the truth is that it tends to promote pest abundance and particularly invites the notorious rice pests i.e., leaf folder and BLB (Savary et al., 1995; Heong et al., 2008). The high nitrogen application, to get higher yields due to more food demands, has increased pest intensities, which demands for more pesticides (Heong et al., 1995). It is estimated that about 60% of fertilizers applied are left behind as residues and pollute the underground water, rivers, lakes and modify the soil bacterial ecology, affect the diversity of soil microflora and decrease long term soil fertility (Cassman et al., 1996; Tilman, 1998; Wilson and Tisdell, 2001; Bandong et al., 2002; Heong and Escalada, 2005; Khaskheli, 2008).

Although the farmers were using high doses of fertilizers to increase the rice yields yet they were of the view that fertilizers invited the pests. Therefore, high rates of chemical fertilizers lead to increase insect and disease infestation and ultimately
Results and Discussion

prompting the farmers to become reliant on pesticides (Borromeo and Deb, 2006). A few farmers, in the present study, not using synthetic fertilizers were also of the view that insects emerged as a consequence of using fertilizers. Similar beliefs of farmers have been shown by Bentley (1989) and Bandong et al. (2002).

The farmers who were not using synthetic fertilizers altogether were using farm yard manure which increases the yield and grain weight, softens the soil and changes its color necessary for sunlight absorption (Ijaz, 2008).

1.4.7.2: Unreliable sources of seed for rice crop

Out of the total 150 farmers interviewed 0.7% got seed from the research station, 12.7% from seed companies, 73.3% used self-produced/home retained seed, 15.3% obtained seed from neighbour farmers and 18.7% of farming community obtained seed from retailers in the local market (Table 1.27).

A good quality seed is the key component of crop production leading to higher yields by ensuring a uniform crop establishment with uniform vigor and population of seedlings per unit area of field. The seed should be pure, uniform in size, shape and color, free from weed seeds, seed born diseases and physiological disorders and contain a required amount of moisture (Anonymous, 2008a).

Table 1.27: Source of seed for rice crop

<table>
<thead>
<tr>
<th>Sources of seeds</th>
<th>Frequency</th>
<th>% age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research station</td>
<td>1</td>
<td>0.7</td>
</tr>
<tr>
<td>Seed companies</td>
<td>19</td>
<td>12.7</td>
</tr>
<tr>
<td>Home retained</td>
<td>110</td>
<td>73.3</td>
</tr>
<tr>
<td>Fellow farmers</td>
<td>23</td>
<td>15.3</td>
</tr>
<tr>
<td>Market</td>
<td>28</td>
<td>18.7</td>
</tr>
</tbody>
</table>

Multiple responses were allowed

It is quite clear that there was a high dependency on self produced seeds, which is often not cleaned and pure to its type, not stored and processed according to recommended procedures and contained seed of many weeds which compete with rice crop and ultimately reduce yield (Fujisaka et al., 1992; Anonymous, 2008b). According to an estimate good seed can increase yields by 5-15% or even more, hence recommended for use in order to fulfill increasing food demands (Shibayama, 2001; Anonymous, 2003b; Brandle, 2008).

It is evident that most of the farmers practice their own system of obtaining seeds by forming informal system of seed distribution network. Many farmer
especially small-scale farmers think that seed obtained in this way is more reliable than the other seed distribution systems (Rajasekaran, 1993; Almekinders et al., 1994). This system provides seed to farmers at relatively low costs and seed quality is not a major concern in this system. This is the reason that the informal seed system remains the main seed source as compared to formal system, in developing countries (Ndjeunga et al., 2000; Aw-Hassan et al., 2008). On the other hand formal seed services, mainly Government parastatal and private companies are not meeting needs of small farmers (Cromwell, 1990) because for them to business with small farmers is not attractive (Jones et al., 2001).

1.4.7.3: Low plant population

Plant population in most (26.7%) of the fields was low, in 45.3% fields was moderate, in 17.3% sufficient. On the other hand the proportion of farmers’ fields having recommended plant population, or near to that, was only 10.7% (Table 1.28).

A good crop stand leads to good yield (because plant productivity and soil nitrogen utilization increases with increasing plant population). This is in accordance with diversity–productivity and diversity-sustainability hypotheses (Tilman et al., 1996). However, in farmers’ fields plant population remained mostly low as compared to recommendations by Agriculture Department.

Table 1.28: Plant population in farmer’s fields

<table>
<thead>
<tr>
<th>Plant population in “000”</th>
<th>Frequency</th>
<th>% age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (upto 50)</td>
<td>40</td>
<td>26.7</td>
</tr>
<tr>
<td>Moderate (51-60)</td>
<td>68</td>
<td>45.3</td>
</tr>
<tr>
<td>Sufficient (61-70)</td>
<td>26</td>
<td>17.3</td>
</tr>
<tr>
<td>Good (71-80 and above)</td>
<td>16</td>
<td>10.7</td>
</tr>
</tbody>
</table>

It is clear from table 1.28 that plant population in most of the farmers’ fields was lower than the recommended one, which is one of the major causes of low rice production. These results are in full accordance with those of Akhtar (2006) who identified low rice plant population as one of the main constraints in improving rice yields. In case of low plant population the attack of yellow stem borer and weeds population also increases which contributes further towards low production (Rajasekaran, 1993; Balasubramanian, 1999; Shibayama, 2001; Srivastava et al., 2004).
The main causes of low plant populations were the absentee land owners and the shortage of labor during transplanting season. Also some farmers were of the wrong view that high plant population caused decrease in yield because of less tillering of rice plants as a result of close plant spacing. The farmers having plant population near recommended levels were mostly those using their family labor during transplanting. These farmers also claimed higher rice yields per season. Therefore, by increasing plant population up to recommendations (80,000 per acre) in rice fields, yield of rice crop can be increased.

1.4.7.4: Harmful effects of herbicides

Most (60.0%) of the farmers were of the view that application of herbicides retarded the growth of rice plant. Many (50.0%) of the farmers considered that these had adverse effects on yield. Some (21.3%) of the farmers claimed that herbicides had no bad affect on either crop growth or yield. Only 2.0% farmers did not respond (Table 1.29).

From table 1.29 it becomes clear that farmers were of the view that herbicides also had side effects i.e., after weedicide application the growth of crop is retarded for 10-12 days especially when acetachlor was used, whereas butachlor had negligible effect in retarding crop growth. However, it affects the population of aquatic invertebrates (Simpson et al., 1994a). It was a general concept among the farmers, especially using no herbicides, that the application of acetachlor affected the root penetration of rice plant and reduced the porosity of soils. The fact is that the herbicides change the chemistry and biology of soil (Malcolm, 1999), which could effect negatively to rice crop growth. However, the farmers were not willing to give up their use, especially of acetachlore because it was a cheapest weedicide available in the market.

<table>
<thead>
<tr>
<th>Herbicides have effect on</th>
<th>Frequency</th>
<th>% age</th>
<th>Source of irrigation</th>
<th>Frequency</th>
<th>% age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth</td>
<td>90</td>
<td>60.0</td>
<td>Tube well</td>
<td>81</td>
<td>54.0</td>
</tr>
<tr>
<td>Yield</td>
<td>75</td>
<td>50.0</td>
<td>Canal</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>No effect</td>
<td>32</td>
<td>21.3</td>
<td>Tube well +canal</td>
<td>67</td>
<td>44.7</td>
</tr>
<tr>
<td>Not known</td>
<td>3</td>
<td>2.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Multiple responses were allowed
Keeling et al. (1989) showed that when residues of some herbicides persist in soils, they have negative effects on crop planted in rotation. In rice-wheat zone (Kallar tract) the rice and wheat crops are grown in rotation and a number of herbicides are used in both crops which definitely have bad impacts on productivity of this system. Also herbicide application brings about water, soil and atmospheric pollution which are the most harmful by-products of commercial rice cultivation. The wide spread concerns about environmental side effects of herbicides and public awareness have resulted into banning of several herbicides in some countries and increasing pressure on farmers to reduce herbicide usage. So, the herbicides use in paddy rice production should be improved to be safer to the harvested crops (Shibayama, 2001).

1.4.7.5: Sources of irrigation

A big portion (54.0%) of farmers used water only from tube well, other (44.7%) used mixture of tube well and canal water, while only 1.3% used canal irrigation water alone to raise rice crops (Table 1.29).

The results are partially in agreement with those of Sheikh et al. (2006) indicating that in the Kallar tract about 44.4% of the farmers irrigated their land by tube wells while 55.6% used mixture of canal and tube wells water.

Pakistan has largest irrigation system in the world but low irrigation performance and irregular supply of irrigation water coupled with un-leveled fields are the causes of its low productivity (Bhatti, et al., 1991; Akhtar, 2006; Anonymous, 2008b). It is obvious that due to shortage in canal water farmers have to use tube wells to pump out underground water to fulfill the water shortage. In many cases this water is unfit for irrigation leading to lower production (Malik et al., 1984; Singh et al., 1992; Abid et al., 2001; Anonymous, 2003a). Also, as tube wells are run by either electricity or by using fossil fuel i.e., the diesel, so the expenses in raising rice crop have increased many folds. In order to save some water expenditures farmers sometimes tend to reduce number of irrigation. But as the rice crop requires larger amounts of water through out its growth so a reduction in numbers of irrigation may result in yield reduction.
1.4.7.6: Rice straw burning

A large number (68.0%) of the farmers burnt rice straw in harvested rice fields, 4.7% ploughed it in the field, 1.3% sold it out to market, while 52.7% feed it to cattle (Table 1.30).

Table 1.30: Rice straw burning.

<table>
<thead>
<tr>
<th>Action taken</th>
<th>Frequency</th>
<th>% age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burn</td>
<td>102</td>
<td>68.0</td>
</tr>
<tr>
<td>Plough in the field</td>
<td>7</td>
<td>4.7</td>
</tr>
<tr>
<td>Sale</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>Feed to cattle</td>
<td>79</td>
<td>52.7</td>
</tr>
</tbody>
</table>

Multiple responses were allowed

As big number of rice farmers disposed off rice straw by burning because after harvesting with combine harvester it was difficult for them to collect half cut and scattered straw from the field so they did the easy job of rice straw burning irrespective of its harmful effects not only to environment but also to the insect biodiversity.

There was only a small portion of farmers incorporating rice straw in the fields. This could be due to the difficulties faced during ploughing in the field.

The small percentage of the farmers’ selling rice straw to the market could be those who harvested their rice crop manually, mainly because of their small land holdings.

The farmers were feeding rice straw to their cattle either after collecting from fields or by grazing animals in harvested field. However, these farmers were also putting on fire to rice stubbles remained in fields after cattle grazing.

With the high-mechanized rice farming certain problems are taking their births alongside. The use of combine harvesters is a common practice in rice growing areas for crop harvesting, as agricultural labor is expensive and also not available in time. Resultantly almost all the farmers, instead of manual harvesting, used these harvesters to harvest their crops. In case of manual harvesting the straw is bailed out and used as cattle’s fodder or soled out in the market. But in case of harvesting with machines, straw is burnt in the fields as farmers think it an ‘easy solution’ to get rid off it. Due to burning despite the large losses of nutrients (upto 80% of N, 25% of P and 21% of K and 40-60% of S), this practice not only deprives soils of organic matter (OM) but also causes significant air pollution. The residues when burn instantly generate as
much as 13t of CO$_2$ per ha, thus contaminating the air, besides killing the beneficial soil insects and microorganisms (Raison, 1979; Mandal et al., 2004).

Along with several yield reducing and yield limiting factors (including delayed rice transplanting and shortages of labor, energy and other inputs) the crop residue burning has contributed to the declining or stagnant production, productivity, sustainability and the moisture holding capacity of the soil (Ahmad and Iram, 2006b). Straw burning in addition to killing biocontrol agents is also a big threat to the other insects inhabiting rice fields especially to soil inhabiting insects’ fauna (Swengel, 2001; Gallagher et al., 2002; Mann and Meisner, 2002; Meisner et al., 2002; Garg et al., 2004; Ijaz, 2008). The overall effect of such malpractices is that the world is becoming increasingly species poorer and more homogenous in its insect fauna (Samways, 1996).

So, the rice farmers should adopt alternative methods of straw disposal (Christopher and Chris 2002) and there should be a complete ban on rice straw burning (Mann and Meisner, 2002).

In Pakistan there is a need for implementing better environmental polices and a better system of monitoring and implementing the laws in rural areas. Enforcing the state framework of sustainable development and environmental protection by further legislative and institutional changes at local level is also suggested. Because the overall impact from this change in straw managing pattern is difficult to access; this will most likely has a large impact on shaping the future farming system of rice crop. Due to variability and complexity of invertebrate assemblages and their responses to fire, a much more rigorous approach to methodology must be adopted if optimal fire policies for invertebrate conservation in various habitat types are to be devised (Friend, 1994).

1.4.7.7: Source of information

Among the 150 farmers interviewed majority (44.7%) of the farmers used insecticides, based on their own previous experiences. A small section (9.3%) of the farmers got information from Agriculture Department. For a large portion (46.7%) of farmers the major sources of information were pesticides dealers/companies. The portion of the farmers getting information from their fellow farmers was 34.0%. Only
13.3% got information regarding plant protection of rice crop from various media (Table 1.31).

These are the information sources which determine the consistency of a certain action. The more one is confident about a certain source of information, the more it will rely upon it. Knowledge and information are the opportunities to which

**Table 1.31: Sources of information regarding plant protection measures against rice crop pest insects.**

<table>
<thead>
<tr>
<th>Sources of Information</th>
<th>Frequency</th>
<th>% age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own experience</td>
<td>63</td>
<td>44.7</td>
</tr>
<tr>
<td>Agriculture Department</td>
<td>14</td>
<td>9.3</td>
</tr>
<tr>
<td>Pesticide dealer/companies sales agent</td>
<td>70</td>
<td>46.7</td>
</tr>
<tr>
<td>Fellow farmers</td>
<td>51</td>
<td>34.0</td>
</tr>
<tr>
<td>Media (TV, Radio, Newspapers etc)</td>
<td>20</td>
<td>13.3</td>
</tr>
</tbody>
</table>

Multiple responses were allowed

farmers respond because these play a central role in improving their agricultural productivity.

As most of the farmers were of old ages (Table 1.2). It means they definitely had long experience about farming and their pest management practices could be based on their previous experiences including the high losses caused by pest insects in their outbreak periods resulting into ‘anchoring bias’. The results show that second important source of information regarding plant protection measures was farmers’ own experience which is in accordance with Escalada and Heong (2004a). Consequently most of the decisions were based on perceived prospects of incurring losses rather than actual need for control. As a result large proportions of the chemicals were misused because of poor knowledge and decisions (Tait, 1977; Norton and Mumford, 1983; Heong and Escalada, 1997b: Bandong et al., 2002).

The results regarding role of Agriculture Department in providing information about plant protection to rice farmers in the same area are similar to those of Sheikh et al. (2006). The results show that a good number of farmers obtained information from their neighbours, which are in agreement with those of Heong et al. (1998) and Shegun et al. (2002).

It is evident from table 1.31 that pesticide dealer/companies sales agents were the major sources of information for most of the farmers. The results of the survey carried out by Sheikh et al. (2006) in the study area are different from present findings.
indicating that share of pesticides and other input supplying companies in disseminating information about agricultural technologies in rice area was meager. However, the results are confirmed by the survey studies of Heong and Escalada (1999), Tjornhom et al. (1997) and Berg (2001) explaining that chemical company’s sales agents had the highest influence on the farmers’ decisions followed by extension technicians, neighbours and village heads, respectively. The pesticide dealers/sellers were the main sources, providing not only information to farmers but also fertilizers and often credit at start of season. In most of cases pesticide was sold in combination with fertilizers at time of crop sowing or even before season. Therefore, it is the need of time to train and educate the pesticides sellers in order to fulfill the information gaps and to improve their knowledge about current pest situations in order to enable them to be in a better position to guide the farmers (Escalada and Heong, 2004a).

Due to advancements in media especially the electronic one, the latest information regarding agriculture can be transmitted to a very wide range of farmers. But in study area only a small portion of farmers used media to obtain information about agriculture. The results are in agreement with those of Sheikh et al. (2006) in the same area who revealed that 3-15% farmers received information from media. The results, however, are partially similar to those of Shegun et al. (2002). The decisions about pesticides use by farmers can be improved by proper use of media. According to Escalada and Heong (2004b) farmers’ media exposure was negatively related to beliefs and insecticides used frequency, indicating that farmers with high media exposures had low beliefs about yield losses and thus sprayed less.

1.4.7.8: Area (acres) sown under different rice varieties

It is quite clear from the table 1.32 that about 80.4% area of the surveyed farmers was under Super basmati followed by 14.5% under 386 and 3.5% under super fine. An area of 1.0% was under IRRI types (Irri-6 and NIAB Irri-9), 0.4% under Basmati-385, 0.2% under Basmati-2000 and only 0.03% was under hybrid rice. All the Basmati rice varieties collectively contributed to 81.0% of total surveyed area.

<table>
<thead>
<tr>
<th>Rice variety</th>
<th>Basmati-Super</th>
<th>Basmati-385</th>
<th>Basmati-2000</th>
<th>IRRI type</th>
<th>Hybrid Rice</th>
<th>386</th>
<th>Super fine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>2913</td>
<td>13</td>
<td>6</td>
<td>36</td>
<td>1</td>
<td>526</td>
<td>127</td>
</tr>
<tr>
<td>% age</td>
<td>80.4</td>
<td>0.4</td>
<td>0.2</td>
<td>1.0</td>
<td>0.03</td>
<td>14.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>
The results are in accordance with those of Mann and Meisner (2002), who stated that almost 80% of rice area was under Basmati rice varieties.

The coverage of large area by a single variety or by a few varieties of the same crop adversely affects the biodiversity (Ahmad and Iram, 2006b). This has resulted in increased problems related to plant health, rapid multiplication of rice pest and diseases and loss of soil quality besides having serious implications for yield and long term sustainability of rice ecosystem (Anonymous, 1970; Thresh, 1989; Mattson et al., 1997; Borromeo and Deb, 2006). According to Heong et al. (1995) mixtures of varieties can provide functional diversity that limits pathogens and pests expansion. It also reduces the risks of resistance breakdown and stabilize yield and yield losses not only due to diseases but also from stresses of abiotic factors. The mixtures of varieties buffer in a better way than the pure stands having genetic uniformity (Finckh et al., 2000; Gallagher et al., 2002).
1.6 Summary and Conclusions

Summary

Most of the farmers were of low educational level, belonged to middle or old age groups and were having small land holdings. They were well aware of harmful effects of HIP farming on human and animal health, on the environment and on the productivity of the system and knew the benefits of organic farming. Therefore, they were ready to grow rice crop organically provided availability of organic markets.

The rice leaffolder, stem borers and bacterial leaf blight were the most important rice pests to the farmers. They however had least knowledge about beneficial organisms.

A total of 15 pesticides were under the use of farmers (in which fungicides, herbicides and insecticides were 40.0, 33.3 and 26.7%, respectively). Farmers ranked insecticides as the most problematic pesticides to their health. Even then there was an increasing trend in the use of pesticides especially of insecticides.

The sources of information for farmers were very poor and unreliable. Most of the farmers did not follow the recommendations by the Department of Agriculture or by experts in case of agrochemical usages as they had minimal contact with them compared to their contacts with pesticides dealers or their neighbour farmers. Among the various reasons of low rice yield improper uses of fertilizers, unreliable sources of seed and plant protection information, low plant population, growth retarding effects of herbicides on rice plant, rice straw burning were of major importance.

Conclusions and Recommendations

1. As many farmers were illiterate and a little or no education increases communication barriers. So, the extension programs should focus on training of the farmers about pest insects, diseases and beneficial arthropods identification, safe use and hazards of pesticides. A perspective planning aiming to increase the literacy rate is also needed.
2. Most of the farmers were poor having small holdings, so there is more need for investment in agriculture for sustainable rural development so that poor farmers may have better livings and come out of desperation because desperate farmers are less likely to care for long term sustainability of the agroecosystem. It is the result of this desperation that rural people are migrating to cities in search of jobs or for better livelihood. This migration has resulted into agricultural labor shortages, non-involvement of young people in farming occupation consequently increasing ages of farmers. This trend, if continues will have serious impacts on future of rice.

3. As most of the farmers were well aware about hazards of HIP farming but they were practicing it because of more profit and non-availability of organic markets to sale their produce at high price. It is, therefore, responsibility of the Govt. to assure the farming communities about purchasing their produce and make arrangements for its sale in national and international marketes. Therefore, the revival of more effective, long-term viable and sustainable rice farming practices can be achieved through policy measures securing income and providing organic markets and proper training to the farmers.

4. Among the various factors that motivate and determine farmers’ decisions about pesticide use; farmers’ very little knowledge about beneficial organisms and their role in rice crop, their own experience and perception about pest and over estimation of crop yield losses due to these pest, high risk aversion in pest control, costs of its control measures, inadequate training about pesticides use, misconception that insecticides increase yield and are necessary for higher yields, chemical companies selling the pesticides and promoting the fears about crop failure if no pesticide will be used were the most important determinants. The farmers must be internalized externalities of pesticide use and assured that there is wide gap between visible and actual damage.

5. Farmers' awareness of the pesticides' hazards to the environment, animal and human health should be included in the local extension activities. The approach of farmer first through informal education in FFS followed by IPM training to
farmers emphasizing on farmer-training-farmer and research by farmers can be helpful in attaining the goals of rational use of agrochemicals.

6. Methods of pesticide application, practices and handling by farmers were not safe. Many highly hazardous pesticides were still sold by dealers and used by farmers for pest control. Hence, more conducive and concrete policies, regulations, and enforcement system are required for pesticides as for as for rice straw burning.

7. The results of this study suggest that a sustainable seed supply should be achieved by some modification and supporting farmer to farmer seed system and discouraging monopoly for public seed companies so that farmers may have a relatively cheap seed supply. So the results and suggestions have important policy implications.

8. Weed control through chemicals was one of the drawbacks of HIP farming system. So, it is desirable to use those chemicals, which are economical, safe to crop and environment. It is also recommended that instead of keeping the field completely free of weeds, those should be kept at a safe threshold to conserve natural enemies, using weeds as shelter.

9. Mass media channels should be more effective as they can communicate information to a large number of audiences rapidly, lead to changes in some weakly held attitudes and also can avoid discontinuance.

10. The Extension Department should take into account the socio-economic conditions of the farmers for any extension-training program and to target only a specific category of people in extension work to obtain remarkable results.

11. The researchers should also take into consideration farmers-developed pest monitoring method, farmers’ practices that are used in making insecticide application decisions, which may result in developing new techniques of use to researchers. In future, flushed moths and grasshoppers’ numbers to larval infestations and leaf damages respectively in the rice field, should be tested for developing action thresholds.
Lastly it is suggested that there must be a positive change in attitude and philosophy among decision-makers, scientists and others stakeholder to acknowledge alternatives so that while formulating policies and extension training programs regarding agriculture, hazards of pesticides, benefits of LISA, increasing costs of rice farming, declining prices of farm products, increasing average age of farmers and encouraging young people to choose farming as a profession, promoting a sense of pride in farmers, consumer demands for safe, nutritious food produced locally in ways that maintain and protect the environment, making farming both environmentally and economically sustainable, proper use of media, food security and conservation of biodiversity should be addressed. Moreover this research will open the doors to analyze the existing farming practices in deep and the ultimate results will be helpful in changing methods and materials in extension and farmer training and in modifying those management practices and approaches of farmers which are harming the insect biodiversity.
SECTION 2

Determination of economic threshold level for the Stem Borers (*Scirpophaga* sp.) and Leaffolder (*Cnaphalocrosis medinalis*) of Rice (*Oryza sativa*) in the Kallar tract of the Punjab, Pakistan
2.1 INTRODUCTION

Rice yield is declining slightly at global level (Fernandez, 2005) due to diminishing land and water resources, increased pest insects and diseases, global climatic change, environmental pollution and erosion of agricultural biodiversity partially caused by agrochemicals. The rice production in traditional rice-wheat zone (Kallar tract) is also towards decline. Among the various factors contributing to low rice production, pest insects are among the most important ones. The control of these pest insects has often relied on the extensive use of insecticides, which disrupt the beneficial insects and other insect fauna besides causing environmental pollution (Drechsler and Settele, 2001; EJF, 2002; Heong, 2005).

The rice crop provides food to more than half of the world’s population and hosts to over 800 species of insect herbivores from nursery to harvest but only a few of them are of potential treat and have gained the major importance as for as losses in yields caused by them, are concerned (Cramer, 1967; Karim and Riazuddin, 1999).

Among the major pest insects, rice stem borers (Scirpophaga incertula Walker and S. innotata Walker) and leaffolders (Cnaphalocrosis medinalis Guenee, Marasmia patanalis Bradley and M. exigua Butler) are of much importance. Actually the stem borers were the only accepted terrors of this crop in the past but now rice leaffolders are also considered as major pest insects of rice throughout the rice growing areas in many Asian countries (Bautista et al., 1984; Inayatullah et al., 1986; Maragesan and Chellish, 1987; Khan et al., 1988; Panda and Shi, 1989; Bhatti, 1995). Rice stem borers (RSB), the most damaging pest species, feed inside the stem, when attack at early/vegetative stages, result in the formation of ‘dead hearts’. At the reproductive stage stem borer feeds inside the stem and results in panicles with unfilled grains called ‘white heads’ (Pathak, 1968; Pathak, 1968;)

Note: This portion of thesis is in press in International Journal of Agriculture and Biology, manuscript is attached as Appendix-II, Reprinted by the permission of Journal.
Rubia et al., 1997). During severe outbreak 70 to 90% of the crop may be damaged by RSB and in certain cases the crop had to be left unharvested due to high cost of harvesting compared to the yield obtained (Makhdoomi et al., 1976, Inayatullah et al., 1989).

With the widespread introduction and adoption of ‘Green Revolution’ technologies, rice leaffolders complex (C. medinalis, Marasmia spp.) which were considered as minor before, have assumed the status of major pest. A larva during its development consumes about 10 cm² leaf area. Rice leaffolders’ (RLF) larvae reduce photosynthetically active leaf area of rice plants not only by feeding but also by folding leaves which ultimately affect the yield. Among the three species of rice leaffolder the most common species is C. medinalis, which causes highly visible damage symptoms, but negligible yield loss. However, in certain cases yield losses of 60 to 80% have also been recorded (Dhaliwal et al., 1979; Fraenkel and Fallil, 1981; Fraenkel et al., 1981; Reissig et al., 1986; Graf et al., 1992; Islam and Karim, 1997; Heong et al., 2002; Alvi et al., 2003; Rani et al., 2007).

Effective crop protection is an integral component of efforts to increase and sustain yields. Farmers have been employing various methods to protect the rice crop from these economically important pests. Among the various methods of pest control, chemical control using insecticides remains the only major control tactic of economical and rapid method for suppression of pest insects’ infestation (Chelliah and Bharathi, 1994; Ponnusamy, 2003). However, if strategies to achieve high level of pest control are practiced, chemical pesticides can result in the development of serious agrobiological problems by damaging the agricultural lands and by harming to rice field biodiversity (Mangan and Mangan, 1998; Wilson and Tisdell, 2001; Borromeo and Deb, 2006).

So, it would be unwise to under- or over-estimate the significance of pesticides’ impact on biodiversity. Underestimation could cause unavoidable ecological damage. Overestimation could restrict to the judicious use of pesticides when appropriate (Roger et al., 1991). Therefore, pesticides should be considered as a last resort for pest control and only when pest has reached a certain population level at which its presence can no
longer be tolerated. Such a population level is called threshold, action threshold (AT) or economic threshold level (ETL). These levels stress that an immediate intervention mostly by insecticide use is needed to prevent further losses (Stern et al., 1959; Srivastava et al., 2004). Therefore the threshold levels are of due importance for rational use of insecticides. But the farmers use insecticides ignoring the ETLs to overcome the losses caused by pest insects.

ETL is a dynamic parameter which depends on several factors i.e., the crop variety, geographic area/region of production, monetary value of harvest, tolerance of plants, feeding of insects and changes in the cost of artificial control measures (Michael and Pedigo, 1974; Ahmad et al., 1985; Wood, 1996; Afzal et al., 2002).

The varietal pattern of rice crop in the Kallar tract of the Punjab has changed altogether with Super basmati as dominant variety grown over a vast area. The price of inputs to raise the crop and that of rice produce has also been changed.

So, it was the need of time to determine the economic threshold levels for most common and major lepidopterous pest insects of rice (rice stem borers and leaffolder), against which maximum insecticides were being used by rice farmers.

These ETLs would enable the farmers the rational use of insecticides by employing targeted rather than calendar-base use. This practice in turn will help protect the biodiversity and environment from being deteriorated by indulging poisons and lessening the weights of pesticides on country’s import along with savings of health and wealth of the farmer ‘the mechanic’ of agroecosystem.
2.2 Review of Literature

2.2.1 Stem Borers

Inayatullah (1984) carried out studies to determine threshold levels on Basmati rice using five infestations levels viz; 0, 1, 3, 5 and 10%, applied at 45 DAT. Clipping method was used to ensure the requisite damage level. The result indicated that the threshold level at which insecticides should be applied lies between 5 and 10%.

Catling et al. (1987a) revealed that low level of infestation i.e. one un-parasitized yellow stem borer (YSB) egg mass m⁻², at the reproductive stage did not reduce grain yield, but two or more egg masses m⁻² caused yield reduction. However, for YSB a tentative action threshold of 10% damaged stems at booting to flowering stage was proposed.

Viajante and Heinrichs (1987) during screen house tests indicated that Scirpophaga incertulas (Walker) development was most rapid on the tillering and flowering stages and lowest on the panicle initiation stage. Similarly plant damage and grain yield losses of rice cultivar IR46 under field conditions were highest when attacked by S. incertulas larvae in the tillering and flowering stages and lowest when plants were attacked at the panicle initiation stage of growth. They suggested an action threshold of one egg mass m⁻².

Rubia and Penning (1990) suggested that spraying against stem borers at early vegetative stage was often unnecessary, since the young plants could tolerate considerable damage. They used a rice crop growth model (RCGM) to simulate yield reduction caused by stem borers on irrigated rice. They produced artificial damage by clipping off the tillers. Predicted grain yield correlated well with yield obtained by clipping tillers in the field. The computer simulations predicted that up to 20% dead hearts at the vegetative growth stage would cause no significant reduction in the grain
yield because young plants could compensate for lost tillers. Damage at the grain filling stage resulting into white heads caused almost proportionate yield reduction.

Rubia et al. (1990) estimated the losses caused by stem borers and predicted that up to 33% dead hearts of 30 days old plant at vegetative stage did not influence the total number of productive tillers at maximum tillering stage and as a consequence had no effect on grain yield. But at grain filling stage, resulting into white heads, it caused significant yield reduction. However, less than 10% of white heads had no influence on yield.

Bhuiyan et al. (1992) conducted studies to examine the concept of ETL by farmer communities and concluded that IPM training and the use of ETL in decision making process about the use of insecticides was beneficial.

Rubia et al. (1997) conducted field experiments to investigate the impact of stem borer injury on physiology and yield response of irrigated rice. They investigated that compensating mechanism includes: increased tillering, increased percentage of productive tillers and increased grain weight. In stem borer injured tillers the photosynthesis rate of green leaves increased and plant translocated assimilates from injured tillers to healthy tillers. The results indicated that rice plant could employ all these mechanisms in response to stem borer injury. The need for breeding of cultivars tolerant to stem borer injury, application of nitrogenous fertilizers to encourage plant compensation and an increase in the economic threshold for stem borers’ control, for a better IPM of rice crop was stressed.

Afzal et al. (2002) conducted an experiment to determine ETL for chemical control of rice stem borers on Super basmati (Oryza sativa L.). The infestation levels (0-15%) were produced artificially by clipping the tillers. The economic analysis showed that cost of application of cartap (Padan) before 7.5% infestation level was more as compared to the monetary value of reduction in grain yield due to attack of RSB. They determined that cost of chemical control in between 7.5 and 10% infestation levels was equal or less than reduction in yield and this level was suggested as economic threshold level.
Anonymous (2002; 2003c) determined the ETL for the chemical control of rice stem borers and recommended that the control measures were more reasonable at infestation of 5% dead hearts.

Litsinger et al. (2006a) developed action thresholds (ATs) as insecticide application decision tools and tested against yellow stem borer and white stem borer of rice crop in four sites over 68 crops. Damage incidence was low with a mean over all crops and sites of 2% dead hearts (DH) and 3% white heads (WH) based on weekly sampling. Highest incidence reached 19% WH as a mean of one crop and 31% WH in an individual field in one week. The most effective ATs levels in each of the three growth stages i.e., vegetative, reproductive and the ripening, were 5, 25 and 10% dead hearts, respectively. These ATs resulted in 96-99% correct decisions about insecticide application, based on criteria involving DH and yield loss.

Reay-Jones et al. (2007) evaluated the insecticide application on infestation of stem borers, *Diatraea saccharalis* (F.) and *Eoreuma lotini* (Dyar) in rice (*O. sativa*). Rice yield and white heads per square meter were significantly affected by insecticide treatment in each year of the study. The injury was not significantly (P>0.05) reduced by biorational insecticides (diflubenzuron, novaluron and tebufenozide). Applications of diflubenzuron, novaluron at 14 days after flood were not as effective in reducing the injury as lambda-cyhalothrin. Application of methoxyfenozide at panicle emergence stage significantly (P<0.05) reduced injury but without detectable difference in the yield. The greatest reduction in white heads (14-fold) was achieved with two applications of lambda-cyhalothrin. Economic analysis showed that foliar application generally resulted in net increased benefit for all treatments, combined with the management practices such as use of resistant cultivars and the judicial use of insecticides.

Rubia et al. (1996b) used the clipping model to estimate the losses by stem borers and predicted that up to 30% dead hearts at vegetative stage and 10% white heads reduced grain yield non-significantly but at grain filling stage it caused an almost proportionate yield reduction.
Chaudhary *et al.* (1998) conducted field trials with high yielding variety of rice BR-11 to find out a suitable and environmentally safer approach for the control of pest insects of rice based on application threshold level (ATL) and found that ATL based spray offered effective control of pest insects without affecting the natural enemies and gave a yield increase of more than 30%. It was suggested that ATL based/need based sprays were better for the management of pest insects of rice compared with fixed time or calendar-based spraying.

Sherawat *et al.* (2007) determined ETL for chemical control of rice stem borers, *Scirpophaga incertulus* and *S. innotata*. The tillers were artificially clipped off 55 DAT to produce different infestation levels i.e. 0.0, 2.5, 5.0, 7.5, 10.0, 12.5 and 15.0 percent. The economic analysis showed that at 7.5 percent infestation level, cost of chemical control was equal or less than yield reduction and below this infestation level cost of control was more as compared to the value of yield reduction due to borers’ infestation. Consequently, 7.5 percent infestation level was recommended as ETL for stem borers.

Similarly a number of researchers had purposed different ETLs for the chemical control of rice stem borers. For example, a single egg mass of YSB m$^{-2}$ (Israel and Padmanabhan, 1976; Viajante and Heinrich, 1987), 5-10% dead hearts or white heads (Catling, 1978; Rao and Rao, 1982; David *et al*., 1988; Mathur *et al*., 1999), 5, 10 and 15% dead hearts at early transplanting stage, 30 DAT and 50 DAT respectively (Dyck *et al*., 1981; Hashmi *et al*., 1983; Inayatullah *et al*., 1986), 20% or more infestation level (Rehman and Ghouri, 1981; Catling *et al*., 1987b), 4% white heads (Andow and Kiritani, 1983), one dead heart per 2 hills at early stage and 1 dead heart hill$^{-1}$ at late stages or 1 egg mass or 1 adult moth m$^{-2}$ at panicle initiation and later stages (Chattarjee and Maiti, 1985), 10% infestation at 60 DAT (Maher *et al*., 1985), 10% white heads (Tu *et al*., 1985), 5-10 moths per night capture in light traps (Inayatullah *et al*., 1986), 0.5-1 live larva hill$^{-1}$, 3.8% dead hearts and 0.5-1 egg masses m$^{-2}$ (Bandong and Litsinger, 1988; Wang *et al*., 1994).
2.2.2 Leaffolder

Chiang (1977) reported the threshold level of rice leaffolder as 10 eggs per 100 plants, 70% of larvae in second instar or 20 damaged leaves per 100 plants.

Dyck et al. (1981) carried out greenhouse and field studies to determine ETL for *C. medinalis* on rice and suggested 1-2 larvae per hill as ETL for this pest insect.

Bautista et al. (1984) showed that yield loss due to rice leaffolder was positively correlated with the percentage leaves damage and reported 16.5% and 21.3% yield losses due to 17.5% and 26.6% damaged leaves respectively. From this data the economic injury level of 5% damaged leaves was estimated.

Shen and Lu (1984) carried out studies on the yield losses caused by *C. medinalis* to rice and the economic threshold for its control. Yield losses were highest at the early earing stage, medium at the tillering stage and lightest at the milky stage. Percentage foliage injury, area of foliage lost and yield losses were correlated with the population size of the pest at all the three vegetative growth stages. The ETL was determined 0.75-1.4 third instar larvae hill$^{-1}$ at the tillering stage and 0.5-0.7 third instar larvae hill$^{-1}$ at the early earing stage.

Tu et al. (1985) described a system of integrated control for pest insects of rice and reported that in case of RLF the insects should be controlled at 3 larvae hill$^{-1}$.

Chen and Wu (1986) determined the economic thresholds for the control of *C. medinalis* on rice on the basis of relation of yield loss due to insect populations and infestations and proposed, 15000-20000 larvae mu$^{-1}$ (1mu = 0.067 ha) at tillering, 12000-15000 larvae mu$^{-1}$ at booting stage and/or 3-5% leaf-fold.

Wu et al. (1990) studied the relationship between larval density of rice leaffolder, injury of rice plant and rice yield loss. The results showed that losses in rice yield were 0.188, 0.180 and 0.235 gm caused by third, fourth and fifth larval instars, respectively. Based on the effects of series of natural and social factors, data analysis of the natural population, life table of this insect, the synthetic consideration of economic principle that the benefits must not be less than cost of control, determined the action threshold of rice leaf roller as 13370 eggs mu$^{-1}$ or 6574 1$^{st}$-2$^{nd}$ instar larvae mu$^{-1}$.
Bhatti (1995) conducted a greenhouse study and suggested the economic threshold level of 5-10 % damaged leaves hill\(^{-1}\) at flowering period for rice leaffolder.

Dodia \textit{et al.} (1997) determined the ETL for \textit{C. medinalis}. The different infestation levels were 0, 2, 5, 10, 20, 30, 40 and 50% of damaged leaves. Mean grain yield was highest when there was no leaf damage. This was not significantly different from yield obtained with 2% leaf damage. Yield generally decreased with increasing leaf damage. Incremental cost benefit ratio was highest (1:10.14) where the 20% leaf damage infestation was applied.

Prable and Saikia (1999) carried out field studies on assessment of yield losses due to rice leaffolder at different growth stages of two rice varieties IR-50 and CO-45. In plots with no protection at the reproductive stage there was higher leaffolder damage and lower grain yield, with minimum yield losses of 4.2 and 5.5% for the two rice varieties respectively. Leaffolder damage was reduced and higher grain yields were observed in rice plots which were protected at all growth stages or at a particular growth stage compared with untreated plants. The protection of crops at 10% leaf damage at vegetative or 5% at flowering stage was found most economical.

Anonymous (2002; 2003c) determined the ETL for the chemical control of rice leaffolder and suggested that the control measures were more economical at infestation of 3 and 5% folded leaves respectively.

Subhash and Singh (2001) conducted experiments to study the spatial distribution of leaffolder on rice in terms of its damage to determine its economic threshold level. Based on gain threshold of 0.39 tons ha\(^{-1}\) and regression coefficient of yield-infestation model, economic threshold level was determined as 4% folded leaves during panicle-emergence stage of the crop.

Litsinger \textit{et al.} (2006b) reported that the most effective action thresholds (ATs) level against rice leaffolders \textit{C. medinalis} and \textit{M. patnalis} (Lepidoptera: Pyralidae), in each of the three growth stages i.e., vegetative, reproductive and the ripening, was 15% damaged leaves.
Satish *et al.* (2007) conducted a three-year study and found that leaffolder incidence on rice was 1.2-20.5% folded leaves with highest infestation between 45-55 DAT. A generic crop growth model ‘InfoCrop’ was used to calibrate and validate leaffolder damage. This validated model was used for simulating economic threshold level of the pest. Simulated ETL was found to be 9, 11 and 12% folded leaves at 50 DAT and 12, 15 and 14% at 70 DAT during 2003, 2004, 2005, respectively. These models however could account for changes in inputs used, weather and interaction between crop and pest. They suggested that these models could be potential tools for formulating site specific ETLs for the pests.
2.3 MATERIALS AND METHODS

The experiments were conducted at farmer’s fields in traditional rice area i.e., the Kallar tract to determine ETLs of rice stem borers (*Scirpophaga incertulas*, *S. Innotata*) and rice leaffolder (*Cnaphalocrosis medinalis*) during the years 2005 & 2006. The experiments were laid out in randomized complete block design (RCBD) with six treatments for rice stem borers (0, 1, 3, 5, 7 and 9% infestation) and leaffolder (0, 2, 4, 6, 8 and 10% infestation) with three replications. Nursery of rice (*Oryza sativa* L. cv. Super basmati) was sown and transplanted with row to row and plant to plant distance of 22 cm in well prepared soil according to the traditional land puddling practices of the area as recommended. The plot size was 1m² for each treatment in each replication. All the agronomic practices and input used were same for all the treatments, except different infestation levels. To mimic the damage behavior of rice stem borers and leaffolder, the simulative injury technique was used (Anonymous, 2002; 2003c). The treatments were applied at 55 DAT.

Due to the attack of stem borers, dead hearts are formed at early crop stages. So, artificial dead hearts were produced with the help of dissecting needle. The number of tillers injured to produce dead hearts, was calculated by using the following formula:

\[
\text{No. of tillers injured} = \frac{\text{Treatment (percent value) \times \text{Total tiller count}}}{100}
\]

Whereas in case of rice leaffolder, a 10 cm area of flag leaf, leaving about 4 cm from the tip, was covered with black adhesive tape very carefully to mimic the symptoms of rice leaffolder’s attack. The number of leaves, treated artificially, was calculated by using the following formula:

\[
\text{No. of leaves treated} = \frac{\text{Treatment (percent value) \times \text{Total leaves count}}}{100}
\]

2.3.1 Data analysis:

After harvesting, data on paddy yield (at 14% moisture) and other yield components i.e., number of panicles m⁻², number of ripened grains per panicle and 1000 grain weight, were recorded and subjected to statistical analysis by using the program
MSTAT-C (1989). The means of significant treatments were compared at 5% level of significance through Duncan’s multiple range test (DMRT) following the procedure outlined by Steel and Torrie (1984). Economic analysis of yield losses was done to determine the ETLs for chemical control of these major pest insects of rice crop.
### 2.4 RESULTS AND DISCUSSION

The rice yield is predicted by number of panicles m$^{-2}$, number of ripened grains per panicle and 1000-grain weight (Srivastava et al., 2004). The analysis of variance shows that treatments (% infestation level) had significant effect on number of productive tillers m$^{-2}$ ($F = 4.303; df =5; P = 0.024$) and yield m$^{-2}$ ($F = 30.3653; df = 5; P = 0.00$), whereas non significant effect on number of grains per panicle ($F = 1.5754; df = 5; P = 0.253$) and 1000-grain weight ($F = 0.041; df = 5; P = 0.344$) in case of RSB (Table 2.1). However, the treatments induced significant variation in number of grains per panicle ($F = 3.382; df = 5; P = 0.044$), 1000-grain weight ($F = 5.268; df = 5; P = 0.013$) and yield m$^{-2}$ ($F = 4.069; df = 5; P = 0.028$), whereas no significant variation in number of productive tillers m$^{-2}$ ($F = 0.335; df = 5; P = 0.864$), in case of RLF (Table 2.2).

#### Table 2.1: Comparison of mean values of different yield components for rice stem borers

<table>
<thead>
<tr>
<th>Infestation level (%)</th>
<th>No. of productive tillers m$^{-2}$</th>
<th>No. of grains panicle$^{-1}$</th>
<th>1000-grain weight (g)</th>
<th>Average yield (g m$^{-2}$)</th>
<th>Average yield kg ha$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (T1)</td>
<td>221a</td>
<td>103.22a</td>
<td>20.96a</td>
<td>478.50a</td>
<td>4727.58a</td>
</tr>
<tr>
<td>1 (T2)</td>
<td>223a</td>
<td>103.11a</td>
<td>20.90a</td>
<td>478.78a</td>
<td>4730.35a</td>
</tr>
<tr>
<td>3 (T3)</td>
<td>219ab</td>
<td>103.11a</td>
<td>21.00a</td>
<td>473.25a</td>
<td>4675.71a</td>
</tr>
<tr>
<td>5 (T4)</td>
<td>217abc</td>
<td>102.00a</td>
<td>20.95a</td>
<td>469.50a</td>
<td>4638.66a</td>
</tr>
<tr>
<td>7 (T5)</td>
<td>210bc</td>
<td>101.22a</td>
<td>20.90a</td>
<td>450.10b</td>
<td>4446.98b</td>
</tr>
<tr>
<td>9 (T6)</td>
<td>208c</td>
<td>100.33a</td>
<td>20.71a</td>
<td>440.00c</td>
<td>4347.20c</td>
</tr>
</tbody>
</table>

LSD = 9.199 LSD = 3.010 LSD = 1.588 LSD = 9.247 LSD=91.36

**Note:** Means were compared at 5% level of significance.

Means sharing the same letter do not differ significantly.

The number of productive tillers m$^{-2}$ in case of RSB decreased significantly with increasing level of infestation, except for 1% infestation level; which indicated the increased number of productive tillers m$^{-2}$. Mean number of productive tillers m$^{-2}$ was maximum (223) for 1% infestation level, followed by 221, 219, 217, 210 and 208 tillers m$^{-2}$ for 0, 3, 5, 7 and 9% infestation levels respectively (Table 2.1).
The number of ripened grains per panicles and 1000-grain weight were not affected significantly by increasing infestation levels (Tables 2.1). This non-significant effect attributed to the fact that rice plant compensates for stem borer injury by translocation of its photosynthetic assimilates from damaged tillers to healthy tillers and increasing photosynthesis rate of leaves, adjacent to stem borer killed-tiller’s leaves (Rubia et al., 1996b). However, their values decreased slightly with increasing the number of damaged tillers per plant (Chen et al., 1982).

The grain yield increased with the decrease in infestation level (Table 2.1 and 2.3). The highest grain yield (4730.35 kg ha\(^{-1}\)) was obtained from 1% infestation followed by 0, 3, 5, 7 and 9% infestations with 4727.58, 4675.71, 4638.66, 4446.98 and 4347.20 kg ha\(^{-1}\) respectively. Higher yield at 1% infestation level than that obtained at 0% infestation level attributed to ability of rice plant to compensate the rice stem borer damage by increasing the production of new tillers (Heong and Escalada, 1999; Rubia et al., 1990, 1996b and Islam and Karim, 1997). These additional tillers contributed to increase the paddy yield. So, enhancing plant compensating mechanism to stem borer injury might be a better strategy for stem borer management than insecticide application (Rubia et al., 1996b). The results also suggested that at low level attack of rice stem borer, control measure should not be adopted at all in any case because it will be mere wastage of resources. This practice will not only save expenditure incurred in the form of insecticide application, but will also favor the conservation potential of insect biodiversity of rice fields.

The paddy yield data were put for economic analysis by considering the reduction in yields in monetary terms for each treatment and the cost of chemical control involved. The ETL was worked out as 5% damaged tillers for carrying out the necessary control measures against rice stem borers (RSB) (Table 2.3). At this level reduction in yield was 88.92 kg ha\(^{-1}\) worth Rs. 2223 (considering paddy@Rs.25 kg\(^{-1}\)) and cost of control was Rs. 2100 ha\(^{-1}\) which was nearly equal to benefit drawn, hence it was more economical. The results confirm to the findings of Inayatullah et al. (1986), Anonymous (2002, 2003c) and Suhail et al. (2008) who also determined 5% damaged tillers as ETL for RSB control.
However, the results are different from those of Sherawat et al. (2007) who recommended 7.5% damaged stems as ETL to control this pest insect.

In case of rice leaffolder the mean values for productive tillers were not affected significantly with increasing infestation by rice leaffolder. However, number of grains per panicle and 1000 grain weight decreased gradually with increasing leaffolder damage which ultimately decreased average yield with a slight significant difference. The highest yield was obtained with full control having 0% infestation followed by 2, 4, 6, 8 and 10% damaged leaves respectively (Table 2.2).

<table>
<thead>
<tr>
<th>Infestation level (%)</th>
<th>No. of productive tillers m⁻²</th>
<th>No. of grains panicle¹</th>
<th>1000 grain weight (g)</th>
<th>Average yield (g m⁻²)</th>
<th>Average yield (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (T1)</td>
<td>218a</td>
<td>104.0a</td>
<td>20.90a</td>
<td>470.1a</td>
<td>4644.588a</td>
</tr>
<tr>
<td>2 (T2)</td>
<td>218a</td>
<td>103.9a</td>
<td>20.50a</td>
<td>465.5a</td>
<td>4599.140a</td>
</tr>
<tr>
<td>4 (T3)</td>
<td>219a</td>
<td>103.1a</td>
<td>20.20ab</td>
<td>458.0ab</td>
<td>4525.040ab</td>
</tr>
<tr>
<td>6 (T4)</td>
<td>218a</td>
<td>102.9a</td>
<td>20.15ab</td>
<td>454.2ab</td>
<td>4487.496ab</td>
</tr>
<tr>
<td>8 (T5)</td>
<td>218a</td>
<td>101.5a</td>
<td>17.90bc</td>
<td>435.3b</td>
<td>4300.764b</td>
</tr>
<tr>
<td>10 (T6)</td>
<td>216a</td>
<td>96.33b</td>
<td>15.85c</td>
<td>431.7b</td>
<td>4265.196b</td>
</tr>
</tbody>
</table>

LSD = 5.356   LSD = 4.963   LSD = 2.703   LSD = 24.60   LSD = 243.1

Note: Means were compared at 5% level of significance. Means sharing the same letter do not differ significantly.

As evident from the table 2.4 low infestation levels of rice leaffolder resulted in small decrease in paddy yield as compared to its control because partial defoliation increased photosynthesis in remaining leaves (Wareing et al., 1968). Rice farmers overestimate the losses caused by rice leaffolder and become much frightened due to visible damage symptoms by rice leaffolder and thus often overuse insecticide from fear of losses (Litsinger et al., 2005). They mostly spray even at low infestation levels because of the easy availability of insecticides at low prices in the Kallar tract of the Punjab. Compared to granular insecticides foliar sprayable insecticides, besides killing rice pest insects harm to natural enemies to a greater extent, which tend to keep these pests at low densities. This practice, however, is not only a cause of environmental pollution but also harmful to both farmers and ecosystem (Fernando, 1970).
The paddy yields data were put to economic analysis by considering the reduction in yields in monetary terms for each treatment and the cost of chemical treatment involved to control rice leaffolder. From table 2.4 it is clear that the cost of control was more at 2%, whereas loss was more at 4% infested leaves. This implied that ETL for rice leaffolder lied in between these two infestation levels. So, the ETL was worked out as 3% damaged leaves for carrying out the necessary control measures against rice leaffolder by using granular insecticide Padan (cartap 4G). At this infestation level cost of control and benefits were almost equal, hence more economical. The results of the present study are in accordance to those of Tu et al. (1985) and Anonymous (2002) but different from those of Bautista et al. (1984), who reported 5% damage leaves as action threshold.

Table 2.3: Economics of chemical control for rice stem borers.

<table>
<thead>
<tr>
<th>Infestation level (%)</th>
<th>Average yield (kg ha⁻¹)</th>
<th>Reduction in yield (kg ha⁻¹)</th>
<th>Decrease in yield in monetary terms (Rs. ha⁻¹)</th>
<th>Cost of control (Rs. ha⁻¹)</th>
<th>Cost/Benefit ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (T1)</td>
<td>4727.58</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1 (T2)</td>
<td>4730.35</td>
<td>+2.77</td>
<td>+69.25</td>
<td>2100</td>
<td>Tota loss of Rs.2100</td>
</tr>
<tr>
<td>2 (T3)</td>
<td>4675.71</td>
<td>51.87</td>
<td>1296.75</td>
<td>2100</td>
<td>1: 0.62</td>
</tr>
<tr>
<td>4 (T4)</td>
<td>4638.66</td>
<td>88.92</td>
<td>2223.0</td>
<td>2100</td>
<td>1: 1.06</td>
</tr>
<tr>
<td>6 (T5)</td>
<td>4446.98</td>
<td>280.60</td>
<td>7015.0</td>
<td>2100</td>
<td>1: 3.34</td>
</tr>
<tr>
<td>9 (T6)</td>
<td>4347.20</td>
<td>380.38</td>
<td>9509.5</td>
<td>2100</td>
<td>1: 4.53</td>
</tr>
</tbody>
</table>

Table 2.4: Economics of chemical control for rice leaffolder.

<table>
<thead>
<tr>
<th>Infestation level (%)</th>
<th>Average yield (kg ha⁻¹)</th>
<th>Reduction in yield (kg ha⁻¹)</th>
<th>Decrease in yield in monetary terms (Rs. ha⁻¹)</th>
<th>Cost of control (Rs. ha⁻¹)</th>
<th>Cost/Benefit ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (T1)</td>
<td>4644.59</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2 (T2)</td>
<td>4599.14</td>
<td>45.45</td>
<td>1136.25</td>
<td>2100</td>
<td>1:0.54</td>
</tr>
<tr>
<td>4 (T3)</td>
<td>4525.04</td>
<td>119.55</td>
<td>2988.75</td>
<td>2100</td>
<td>1:1.42</td>
</tr>
<tr>
<td>6 (T4)</td>
<td>4487.50</td>
<td>157.09</td>
<td>3927.25</td>
<td>2100</td>
<td>1:1.87</td>
</tr>
<tr>
<td>8 (T5)</td>
<td>4300.76</td>
<td>343.83</td>
<td>8595.75</td>
<td>2100</td>
<td>1:4.09</td>
</tr>
<tr>
<td>10 (T6)</td>
<td>4265.20</td>
<td>379.39</td>
<td>9484.75</td>
<td>2100</td>
<td>1:4.51</td>
</tr>
</tbody>
</table>

Note: As cost of production was the same for all treatment and was not considered during economic analysis and only cost of protection through insecticide and reduction in yield in monetary terms were considered. In case of chemical control measures Padan 4G @ 22.50 Kg/ha, costs Rs. 1750/ha (@ Rs.700/bag weighing 9Kg), net transportation charges Rs.100 and application charges @250/ha. The paddy price was taken @ Rs. 25/kg. (The data was analyzed by considering mean of two years).
2.5 SUMMARY AND CONCLUSION

In Pakistan pesticides consumption is increasing alarmingly. Such tremendous use of pesticides does not drain only the exchequer, but also presents a growing threat to the people and environment of the country. For effective and economic suppression of the population of pest insects in rice ecosystem along with conservation of the population of natural enemies, the judicial use of pesticides on the basis of ETLs on ecosystem analysis combined with other management practices is utmost essential and there is still much room for improving the state of IPM in rice.

From the results of our study it was concluded that chemical based control measures should be adopted when infestation reached at 5% dead hearts and 3% damaged leaves for the control of rice stem borers and leaffolder, respectively.

Generally ETLs are developed only on the basis of economic costs and losses. However, if losses to natural enemies, health, environment and difficulties in performing insecticide application are also considered, the higher will be the thresholds.
SECTION 3

Comparison of biodiversity of insects associated with LIP & HIP rice crop agroecosystems
3.1 INTRODUCTION

Biodiversity is the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems (CBD, 1992). Like water, air and soil, biodiversity is the hub of the wheel of life and this technologically sophisticated wheel, however, will no longer run if we destroy the biodiversity (Ignacimuthu, 2005).

For understanding and preservation of biodiversity, the judicial use of insects for scientific study is being encouraged. Insects are one of the most important and diverse group in the natural world, define the complete nature of biodiversity and their condition is indicative of ecosystem health as they play vital role in its functioning (Stroke, 1988; Williamson, 1995; Siemann et al., 1999; You et al., 2005; Jana et al., 2006).

Rice (*Oryza sativa* L.) is a cereal food plant of the family Poaceae. It is an erect grass that can grow upto 1.2 m tall and survive in a wide range of temperature and rainfall. It is cultivated mostly in South and South-East Asian countries and about 120,000 rice varieties are grown across the world in an extensive range of climatic (especially warm climate), soil and water conditions (Alam et al., 2001; Babu et al., 2006).

Rice is the only cereal crop that can live in standing water (Ali, 1995). The water level in rice fields vary according to its availability and crop stage. This is the most important constraint to the type of organisms that may be able to live in rice field environment. The rice field physically and morphologically consists of two types of habitats: the actual field on which there are rice plants and the surrounding bunds, which harbor weeds (Bambaradeniya et al., 2004; Bambaradeniya and Amerasinghe, 2003). The rice plant passes through vegetative (germination-panicle initiation), reproductive (panicle development-flowering) and ripening (milk grain-mature grain) growth stages.
The vegetative and reproductive stages of rice crop are represented by aquatic phase of the rice field while the semi aquatic and terrestrial dry phases correspond to the grain ripening stage. Therefore, a rice field agroecosystem undergoes through three major ecological phases: aquatic, semi-aquatic and terrestrial dry phase during a single crop cycle (Fernando, 1995). Each of these phases supports a particular type of fauna and flora. Resultantly the rice field has the greatest biodiversity as compared to the other tropical rain fed systems (Schoenly et al., 1998).

The biodiversity of fauna and flora of rice fields has characteristic of rapid colonization as well as rapid reproduction and growth of organisms. These organisms colonize rice fields by resting stages in soil, by air and via irrigation water (Fernando, 1995, 1996). The fauna inhabiting the vegetation, water and soil sub-habitat of rice field are dominated by invertebrates. Those that inhabit the vegetation are generally insects and spiders. In relation to the rice crop, the fauna in rice field include pests, their natural enemies (predators and parasitoids) and neutral forms etc. The organisms inhabiting the rice field ecosystem can be considered as opportunistic biota with high resilience stability as they posses the ability to recover rapidly from various disturbances, including chemical inputs (Heckman, 1979; Fernando, 1996; Bambaradeniya et al., 1998).

A rice field is frequently disturbed by farming practices i.e., tillage, irrigation, crop establishment and agrochemical application. Traditional rice systems were sufficiently multifaceted ecosystems and did not involve the use of chemical fertilizers, maintained a moderate but stable yield for thousands of years because a rich array of micro-organisms and other invertebrates enabled them to maintain soil fertility by generation of nutrients through recycling for rice cultivation in contrast to modern rice cultivation (Moorman and Breeman, 1978; Roger et al., 1991; Lawler, 2001; Ignacimuthu, 2005).

One of the key features of modern agriculture is crop specialization (monoculture) in the production system, which has decreased species diversity in rice fields and has lead to the system instability (Roger et al., 1991; Wilby et al., 2006). Ecological sustainability of rice fields and the effect of rice production on biodiversity varied with production and
management of rice ecosystems i.e., whether the fields are managed organically or with agrochemicals. The modern management techniques which fall under the general heading of ‘Green Revolution’ (Naylor, 1996) utilizing greater amounts of agrochemicals have resulted into the reduction of biodiversity in rice fields (Roger et al., 1991; Reid and Heitmeyer, 1995; Lawler, 2001; Tilman et al., 2001; Wilby and Thomas, 2002; Philpott and Armbricht, 2006) that could lead to problem of sustainability in long term due to poor species composition (Tilman and Downing, 1994; Swift and Ingram, 1996; McCann, 2000).

Words like sustainability, biodiversity, integrated systems and low input now buttress the more familiar “organic farming” (Anonymous, 1993). Low input (Organic) farming is a system of crop production which reduces as much as possible the use of external inputs and replaces them with internal inputs such as reduced tillage and retention of crop residues in order to maintain soil productivity, control pest insects beside increasing the biodiversity (Sullivan, 2003). During the past 20 years, farmers have shown increasing interest in low input organic farming because it is economically more attractive. Also in commercial production, the fertilizers and pesticides quantities used often exceed the crop and soil capacities for uptake and purification so causing surface and ground water pollution which affects biodiversity. It is therefore, LIP (organic) agriculture which would increase biodiversity of flora and fauna and contribute to a healthier living environment (Cacek and Linda, 1986; Reganold et al 1987; Itoh, 2000; Tilman et al., 2001; Drinkwater, 1998; Pretty, 1998; Reganold et al 2001; Tilman, 2001; Hayes, 2002; Mader et al., 2002; Hole et al., 2004; Storr, 2004).

The surveys conducted on biodiversity associated with the rice field agroecosystem have clearly shown that this man-made ecosystem contributes to sustain a rich biodiversity and is one of the most sustainable forms of agriculture. But increased human population growth has transformed agroecosystem from domesticated one, which was more natural, to more industrial ecosystem (Shohab, 2006; Roger et al., 1991) that posed a threat to the future sustainability of this unique ecosystem (Kurihara, 1989; Roger et al., 1991; Odum, 1997; Gao, 2003).
However, the current state of knowledge about insect biodiversity associated with rice crop is inadequate and a lot of research is waiting to be done in this field. At present, the alarm bells signaling the loss of biodiversity ring loud and clear throughout the world. Because loss of biodiversity in agriculture is a time bomb that is slowly ticking away towards ecological and alimentary disaster and when it finally explodes it will probably be too late. We are actually on brink of an abyss under current food demands and production (Anonymous, 2000). The rich biodiversity associated with this unique man-made temporary wetland clearly indicates that rice field agroecosystem contributes to sustain and enhance a rich biodiversity of unique as well as threatened species and could be compatible with conservation objectives leading to formulation of the strategies for the sustainable management of this system (Bambaradeniya and Amerasinghe, 2003; Bambaradeniya et al., 2004).

Pakistan is endowed with diverse biomes and habitats colonized by a multitude of precious fauna and flora. The species composition of rice pest and natural enemies throughout the world is relatively well documented but only a few studies have examined the overall insect biodiversity associated with rice crop. In Pakistan, Javed and Ahmad (1974), Ahmad (1985), Hashmi (1994), Khan and Ahmad (1987), Karim and Riazuddin (1999) have done work on different aspects of insect biodiversity related to rice crop. But a comprehensive work on the insect biodiversity of this unique man made ecosystem is still scanty, scattered and in unsatisfactory condition. Due to these reasons the substantial data on different aspects of biodiversity and ecosystems necessary for quantitative analysis is currently not available. This dilemma along with accelerated species and ecosystems extinction has raised the need for biodiversity studies, its documentation and to develop the methods by which diversity can be maintained. Therefore, documentation of biodiversity is necessary and primary requisite for its conservation and sustainable use (Ehrlich and Wilson, 1990; Anonymous, 2003d).

As this study represents first time the most comprehensive insects’ faunal inventory and analysis related to rice crop in Pakistan, therefore, changes to the insect biodiversity associated with rice crop would be evaluated with greater precision and
confidence in coming decades. Moreover this study aims not only to establish a baseline data on species richness and distributions to which future surveys and conservation activities could be related but also to assess differences from place to place, under different management systems, or from present to future. In nutshell there was an ample scope of research about this subject with special reference to the positive and negative impacts of agrochemicals on insect biodiversity of rice crop. Therefore, the present project was taken with the following objectives:

1. To explore & compare the insect fauna associated with low input (LIP) and high input (HIP) rice crops.
2. To test the hypothesis that HIP rice farming has impaired the biodiversity associated with this crop.
3. To compare the cost benefit ratio of the LIP and HIP rice production systems.
3.2 REVIEW OF LITERATURE

Heckman (1974) studied the community of organisms present in the rice paddy and the pattern of their seasonal succession. The relative abundance of 205 species was observed and it was found that a few species were consistently common but most were abundant and actively propagated in well defined seasonal periods. After a certain time the dominant species were replaced by other species. After flooding the fields for rice crop, four distinct aggregations of species were found succeeding each other. During a single season of rice paddy two primary phases, dry and wet, were easily noticeable and within the wet phase four periods were defined by the successive aggregations of species.

Javed and Ahmad (1974) reported 60 species of rice pest insects and studied in detail about the pattern of infestation caused by stem borers and their control strategies on rice crop in southern part of Sindh (Pakistan).

Zalom et al. (1980) observed the population of the hydrophilids viz. Berosus styliferus (Horn), Hydrophilus triangularis (Say) and Tropisternus lateralis (Fabricius) in rice paddies. Aquatic light traps adjacent to water margins at 5 m and 30 m distances from levees were used to determine relative abundance of adults and larvae. All the stages of B. styliferus and H. triangularis were more abundant near the levees. Whereas adults of T. lateralis were also commonly found on the levees during the first 10 weeks of post flood period, however its eggs and larvae were numerous at the 30 m distance. They found that colonization of hydrophilids in paddies occurred through water connections, flight and over wintering adults.

Madsen and Madsen (1982) conducted a study to assess the population of beneficial arthropods, in an organic (essentially pesticide free) orchard and one which followed a complete pesticide program. Beneficial arthropods species were found in excess in organic orchards. They also noted that the pest species were below treatment threshold in both orchards.
Ahmad (1985) made an inventory of 128 species of rice pest insects of Pakistan and Azad Kashmir. The systematics, bioecology and control strategies of some insect species were also described.

Khan and Ahmad (1985) described 59 insect species of rice crop from Punjab, Pakistan in which 17, 13 and 29 species were of parasitoids, predators and pest insects, respectively. They also studied various aspects of biology, phenology, varietal resistance, chemical control, effect of various combinations of temperature and relative humidity on population dynamics of potential rice pest insects and their natural enemies. They suggested that extensive studies were needed on economic threshold levels and formulation of population forecasting models of these pests.

Kurihara (1989) explained the role of tubificids and mud snails in rice field ecosystem and found that the tubificid oligochaetes occurred in high densities, where irrigation water was polluted with sewage, having high organic matter contents in the soil and free from highly toxic pesticides. The abundance of tubificids reduced not only weeds but also the need for herbicides and high levels of inorganic fertilizers. The mud snails consumed a sludge-reed compost mixture used as fertilizer in rice fields. The high concentration of heavy metal in the sludge were accumulated in the snails, which made them, unfit for human consumption. Based on these results and the known ecology of tubificids and snails, a possible recycling system was thus proposed comprising sewage sludge, reeds, fish, insects and egrets using these two kinds of benthic organisms.

Heong et al. (1991) analyzed the arthropod community associated with irrigated rice grown in five sites in Luzon Island, Philippines, using guild categories. Phytophages and predators were dominant in all sites. The phytophagous species were mainly from Homoptera and dominated by *Nephotettix viresense* (Distant) and *Sogatella furcifera* (Harvoth). Predators were mainly from Heteroptera with *Microvelia douglasi atrolieata* Bergoth (Veliidae), *Mesovelia vittigera* (Horvath) (Mesoveliidae) and *Cyrtorhinus lividipennis* Reuter (Miridae) as the most abundant species.
Hesler et al. (1993) showed that the difference in abundance of pest between organic and conventional rice fields was non significant. However, pest damage in seedling stage appeared slightly higher in organic systems but this did not affect the final plant densities in the fields. Also population of non pest species was generally higher in organic fields notably of three predatory taxa: a giant water bug (*Belostoma flumineum*), back swimmer (*Notonecta* spp.) and an adult predacious diving beetle (*Thermonectus basillaris*). But the variety of taxa did not differ significantly between conventional and organic rice fields. The quotient of similarity between the treatments was 0.923 indicating that a number of similar species were present in both organic and conventional systems.

Hashmi (1994) categorized 72 insect species associated with rice crop as major and minor pests and described their identification, biology, damage symptoms and control measures in Pakistan.

Jenkinson et al. (1994) reported about one of the longest running trials for about more than 150 years old, the Broadbalk experiment at the Rothamsted Experimental Station in UK. The trial compared the wheat farming by organic and synthetic chemical fertilizers. Wheat yields were shown to be an average slightly higher in organically fertilized plots (3.45 tones ha\(^{-1}\)) than the plots received chemical fertilizers (3.40 tons ha\(^{-1}\)). The most important was that soil fertility (measured as soil organic matter and nitrogen levels) increased by 120% over 150 years in organic plots compared with only 20% increase in chemically fertilized plots.

Simpson et al. (1994b) monitored the effects of various nitrogen fertilizers and pesticide management on algal, zooplankton and mollusk population in a wetland rice field. Dominant groups developed in succession were mosquito, chironomid larvae, ostracods, copepods and cladocerans. Population of ostracods, mosquito and chironomid larvae increased rapidly after nitrogen application. However, at crop cycle level, aquatic invertebrates’ populations were not significantly affected by the application of carbofuran and butachlor.

Way and Heong (1994) discussed the biodiversity relevant to pest management of tropical irrigated rice pests, in terms of variation within rice plant, rice fields, groups of
rice fields and rice associated ecosystems. It was concluded that with the stable water supply in the unique cropping conditions and by the manipulation of relatively few manageable components of diversity, stability could be conferred such that pests were kept at levels, which did not justify the use of insecticides. The justification for supplementary use of insecticides needed to be completely reassessed. Because the insecticide-based approach was not only costly and demanded impracticable decisions by the farmers (even on need based use) but also was harmful to natural controls.

Drinkwater et al. (1995) compared differences between conventional and organic tomato agroecosystems in integrated and multidisciplinary ways. They compared ecological characteristics and productivity of commercial farms and categorized as either organic (ORG) or conventional (CNV) based on their use of organic soil amendments and biological control or reliance on synthetic fertilizers and pesticides respectively. CNV and ORG production systems could not be distinguished based on agronomic criteria. However, differences were demonstrated on the basis of diversity indicators suggesting that ecological processes determining the yields and pest levels in these two management systems were distinct. In particular nitrogen mineralization potential, microbial and parasitoid abundance and diversity were higher in ORG farms. Results of similar type were also obtained by Letourneau and Goldstein (2001).

Kajimura et al. (1995) investigated the reproduction of *Sogatella furcifera* in chemically fertilized rice field and an organically farmed field. In organic field the density of immigrants was significantly higher, while the settling rate of female adults and the survival rate of immature stages of following generations were lower. As a result the density of nymphs and adults in the ensuing generations decreased in organically farmed field. For a comparison, in an experiment, potted rice plants were grown using seedling and soil from organically and chemically farmed fields. When *Sogatella furcifera* were reared on these plants their reproductive rates and appearance of brachypterous female adults were lower on plant in pots where soil was used from organic fields. They suggested that specific nutritional condition in rice plants suppressed the population of *S. furcifera* in the organically farmed fields.
Berry et al. (1996) compared the species richness and evenness of the selected groups of the beneficial arthropods between organic and conventional carrot (*Daucus carota* L.) fields in New Zealand. Organic fields had significantly higher numbers of Hymenoptera (parasitoids), Coleoptera (Staphylinidae) and Neuroptera (Hemerobiidae) compared with conventional fields. Organic fields were found to have significant more diverse predatory and parasitic communities than in conventional fields. They stressed the use of these beneficial arthropods for biological control of pests in conventional and organic crops.

Anonymous (1998) conducted a study to analyze arthropod community patterns in small rice fields managed by different cultural methods i.e. conventional and by low input sustainable agricultural (LISA) method in Suwon. In LISA fields half of the nitrogen fertilizers and quarter of the pesticides were applied as compared to conventional fields. A total of 15 orders and 43 families of arthropods were collected. No difference was found in species richness (composition) and species evenness (abundance) between two differently practiced fields. The arthropod community was analyzed using guild categories. The arthropods were found in order of pest (phytophagous)>natural enemy>non-pest in their densities. The pest species were mainly Homoptera and dominated by Delphacidae (*Nilaparvata lugens* Stal and *Sogatella furcifera* Horvath) constituted more than 80% of pest abundance. The spider was the most dominant group in the natural enemy and constituted >90% of natural enemy abundance dominated by *Pirata subpiraticus*.

Inthavong et al. (1998) identified a total of 435 species of insects belonging to 266 genera and 121 families in 13 orders and categorized into 4 guilds. In which predators (31.26%), parasites (29.66%), phytophages (28.28%) and scavengers (10.80%) were reported. Populations of all taxa except that of scavenger increased with crop age. The number of species encountered per guild was generally high at 49 DAT but additional species were collected at 63 DAT in some locations. Pest to natural enemy ratio values increased from 1:1.2 at 21 DAT to 1:1.6 at 63 DAT. Hemiptera was the most abundant order of the phytophagous guild while most of the predators were from
Coleoptera. The diversity of arthropods in rice fields was encouraged due to absence of application of chemicals and richness of the irrigated rice ecosystem in forest patches.

Schoenly et al. (1998) proposed guidelines linking biodiversity concepts (rank-abundance curves, guilds and community metrics) and assessment methods (surrogate taxa) to agroecology in order to enhance the understanding of tropical rice ecosystems for research and training programs. Canopy and floodwater invertebrates were collected by vacuum sampler and strainer, respectively. The samples were taken at weekly intervals after rice seedling transplantation to harvest. The samples included 202 taxa with 9,570 individuals for the plant canopy and 180 taxa with 84,905 individuals for the flood water. Rank-abundance curves revealed that many taxa remain abundant over all crop stages. In floodwater due to numerical dominance (75%) by 2 crustaceans, evenness of invertebrate in the floodwater was lower than that for plant canopy. The natural enemies constituted the largest guild, in both the canopy and floodwater, followed by herbivores, detritivores and tourists (taxa with unknown interaction with rice field biota). The herbivores and detritivores dominated faunas in early crop periods in the canopy and flood water respectively. The predatory fauna was dominated in both habitats at mid and late crop stages.

Karim and Riazuddin (1999) presented a list of 52 pest insects of rice crop in Pakistan. They also reviewed briefly about identification, biology, control methods and future control strategies of major pests of rice in the country.

Victor and Reuben (1999) studied the breeding pattern of mosquito immatures and successional changes in the abundance of aquatic insects in rice fields in Madurai, South India. The population of different species of Culicidae reached their peak ranging from 7-28 DAT. A total of 14 families (consisting of 17 subfamilies) of aquatic insects belonging to six insect orders i.e. Coleoptera, Diptera, Ephemeroptera, Hemiptera, Anisoptera and Zygoptera were collected. The notonectids, coenagrionids, libellulids and velliids acted as important predators of mosquito immatures in rice fields. The diversity of different groups of aquatic insects showed a clear pattern in diversity of surface predators and non-predators (mosquito immatures).
Hu (2001) analyzed empirically the profitability and determinants of low-inputs sustainable rice farming (LISRF), by using survey data in Japan. The conventional farming methods were compared to LISRF and it was found that LISRF farms generated 5-6 time higher net profit due to less yield loss and labor expenditures as well as due to higher product prices.

Esbjerg and Petersen (2002) conducted a study in order to determine the effect of reduce doses of pesticides on fauna and flora in barley, wheat and sugar beet fields. The herbicides and insecticides were applied at normal, half and quarter doses whereas fungicides doses were not reduced. At the end of experiment, it was found that species richness tended to increase with decreasing doses whereas rare and scarce species occurred frequently at reduced doses. Finally, it was concluded that the reduction of herbicides and insecticides improved the “nature element” of the fields.

Shah et al. (2003) conducted studies to determine the effect of organic and conventional farming practices on coleopterous fauna. A total of 27,749 individual belonging to 140 species were identified. Overall abundance of Coleoptera was highest on organically managed farms. Carabid and staphylinid beetles formed 79.7% and 16.7%, respectively of the total catch. *Pterostichus melanarius* was the dominant species among the carabids and found highest on organic farms. On the other hand *Tachinus signatus* was the most abundant species among staphylinids on conventional farms indicated that farming practices influenced the overall abundance and dominance of a particular species.

Midori (2003) examined the effects of low chemical application on: ecological conservation, farm management and low input sustainable rice farming (LISRF). Data were collected by interviewing farmers who practiced limited application of agrochemicals and/or no till farming practices. The number of aquatic animals in paddy fields was greater in the fields that received less application of pesticides and herbicides, which also contributed to reduce the stress in environment.

Zahir et al. (2003) reported 355 species of insects associated with rice crop in Bangladesh. The collected insects were identified and grouped as plant feeders, non-rice
plant feeders, predators and parasitoids. They described that presence of non-rice plant feeders played an important role in supporting natural enemies soon after crop establishment. They concluded that as the system hosted a very rich and diverse complex of plant feeders and their natural enemies, so, a stable relationship existed between them.

Bambaradeniya et al. (2004) carried out a survey in Sri Lanka to document the overall biodiversity associated with rice agroecosystem. The total fauna recorded and identified from the rice fields consisted of 494 species of invertebrates in which 255 species were of insects. Among the insects 55 species were rice pest insects and 200 species were of natural enemies of pest insects, non-rice pests/visitors and scavengers/decomposers. The fauna recorded were observed to follow a uniform pattern of succession and seasonal colonization. They suggested that strategies could be formulated, based on biodiversity as an organizing principle, for the sustainable management of the rice field agroecosystem.

Lee and Park (2004) conducted studies to understand arthropod community structure and effect of conventional rice farming practices on arthropod community in order to enhance IPM in rice fields. Guild categories were used to analyze arthropod community. In unsprayed site the arthropod populations were found in order of non-pest>natural enemies>pest. This order, however, was dependant upon immigration rates of pests, regional characteristics, cultural practices and sampling methods. The pests were mainly Homoptera and dominated by Delphacidae (Nilaparvata lugens Stal, Sogatella furcifera Horvath and Lodelphax striatellus Fallen) and Cicadellidae (Nephotettix cincticeps Uhler) which constituted >81% of pest abundance. Spiders were among the natural enemies and constituted >90% of the natural enemy abundance. Chironomids, which mainly formed non-pest guild, occurred abundantly in early growing season and gradually decreased with rice crop age. In mid and late growing season of the rice crop pest and natural enemies occurred in more abundance. Irrigation water quality had a strong influence on predator’s densities. Different planting methods viz. transplanting, water seeding and drill seeding were found having no difference in pest abundance or arthropod community pattern. Lastly different cultural methods i.e.
conventional and low input sustainable agriculture (LISA) showed no significant difference in arthropod abundance and species composition in rice paddy fields.

Kimura (2005) reviewed aquatic organisms in floodwater, from protozoan to insects and fishes in rice field and observed their populations, seasonal variations, antagonistic relations and the effect of field management. It was concluded that field management such as use of fertilizers and pesticides, water management and ploughing played a major role in determining the populations of aquatic organisms.

Koss et al. (2005) intensively sampled arthropods from potato fields under three pest management regimes: conventional fields treated with broad spectrum insecticides (Hard), conventional fields treated with selective insecticides (Soft) and organic fields (Organic) treated with insecticides certified for organic. The bugs (*Geocoris* spp. and *Nabis* spp. (Hemiptera) and spiders (Araneae) were the most abundant >90% of the predators. Total predators densities were highest in Organic and Soft fields while lowest in Hard fields. On the ground, beetles (carabid and staphylinid) and spiders make up to >90% of ground active predators. Total predator densities (carabid and staphylinid beetles and linyphiid spiders) were highest in Organic and Soft fields while lowest in Hard fields. At the same time the organic fields also had highest densities of two important pests: the green peach aphid (*Myzus persicae* Sulzer) and the Colorado potato beetle (*Leptinotarsa decemlineata* Say). However, selective insecticides allowed conventional growers to achieve densities of predators similar to those in organic fields while retaining low pest densities equal to the fields treated with broad spectrum insecticides.

Jana et al. (2006) studied the diversity of five insect orders viz. Hemiptera, Orthoptera, Hymenoptera, Lepidoptera and Coleoptera in the industrial and non industrial areas of the district Midnapur, India. The impact of industrialization on the biodiversity of these insect orders and the possibility of existence of bioindicator species were evaluated. A total of 120 species under 98 genera and 37 families of insects were collected. The data of five orders revealed that the species richness of Hemiptera, Orthoptera and Lepidoptera was higher in non-industrial zone than industrial zone.
Hymenoptera showed no particular trend whereas Coleoptera showed higher species richness in industrial areas. It was concluded that even in an apparent, homogeneous ecological condition species richness drastically changed with the influence of industries. A decline in total insect fauna by at least 23.33% was noticed in industrial areas. Some species of lepidopteran, hemipteran and orthopteran insects were susceptible to industrial pollution and some of the members of these orders were considered as a bioindicator.

Wilby et al. (2006) reported that land use and management controlled biodiversity associated with rice crop. A relationship was established between land use variables and arthropod community attributes (species diversity, abundance and guild structure) across a diversified gradient in rice dominated landscape in Vietnam. It was shown that rice habitats as compared to other land contained most diverse arthropod communities. Overall reduction in biodiversity was associated with reduction in heterogeneity and amount of uncultivated cover across the landscape. Crop and vegetation richness was found to have positive effects on arthropod species density in tillering and flowering stages of rice crop, respectively. With the increased area under rice crop differential effects on feeding guilds in rice associated communities were also observed with increased predators and decreased detritivores. Thus the impact of rice cover and landscape heterogeneity on arthropod community structure was identified and concluded that land use change associated with expansion of rice monoculture impact diversity and functioning of arthropod community.

Rani et al. (2007) studied the diversity of rice leaffolders and their natural enemies in district Madurai, India. Among the three species of rice leaffolders viz. Canaphalocrosis medinalis Guenee, Marsmai pantalis Bradley and Marasmai ruralis (Walker) the former was dominant. M. ruralis was found throughout the year but in small number. Among the natural enemies like egg parasitoid, Trichogramma spp. was recorded with minimum incidence. Among the larval parasitoids like Apanteles sp. Goniozus sp. and Trichomma cnaphalocrosis (Uchida) the latter was found abundant. While the pupal parasitoid, Xinthopimpla flavolaneata (Cameron) and larval pupal parasitoid, Brachymeria sp. was common in rice ecosystem on rice leaffolders.
Roger et al. (2007) summarized the information about behavior of pesticides and their impact on microorganisms and on non-target invertebrates in wetland rice fields. From the information, it was concluded that the pesticide application at recommended levels rarely had a bad effect on microbial population or their activities, however, had more effect on invertebrate population. Certain concerns regarding long term effects of pesticides on microorganisms, primary producers and invertebrates of importance to soil fertility, predators of rice pests and microbial metabolism of pesticides were also raised.

The accumulated evidences are now strong enough to encourage organic farmers and organizations to ensure that biodiversity is of significantly important for organic system. The reason for higher arthropod diversity and abundance in organic systems is mainly related to plant protection management, low input organic fertilization, more diversified crop rotations and more structured landscape with semi-natural habitats and undisturbed field margins. Conversion to organic farming thus could be seen as a first step towards a modern system of agriculture that not only produces commodities but its widespread expansion would be a cost-efficient policy option to increase biodiversity (Pfiffner, 2000; Stolton, 2002; Nadia, 2003).
3.3 MATERIALS AND METHODS

3.3.1: Selection of research sites

The study was conducted in the months of May to October for two cropping seasons in the years 2006 and 2007, in three traditional rice growing districts i.e., Sialkot, Gujranwala and Sheikhupura located in the Kallar tract. Again in each of these districts two sites (paired) one with low inputs (LIP) and other with high inputs (HIP) of agrochemicals were selected (Fig. 1.1). The size of farm on all localities (especially within a pair) were kept as similar as possible (each consisting of 15 acres of Super basmati rice) (Wickramasinghe et al., 2004; Feber et al., 1997). The distance between the paired sites was not more than 5 Km, thereby controlling for geographic variation (Hesler et al., 1993; Wickramasinghe et al., 2004). All the study sites were at least at a distance of 250 m from roadside to avoid the pollution caused by automobile exhaust. In case of low input farming the use of chemicals fertilizers was reduced to at least to 50% as compared to HIP fields along with ETL based application of insecticides in LIP (Sullivan, 2003; Lee and Park, 2004). Data was taken on weekly basis from rice nurseries and on fortnightly basis from rice crop during the whole crop season. Sampling was made essentially from the innermost fields on three consecutive days and sampling from the two sites of one district was essentially made on the same day.

3.3.2: Insect Collection

Rice fields in the same growing season, passes through different physical states i.e., aquatic, semi aquatic and dry or terrestrial phase. Besides this all insect capture methods are biased towards catching insects of certain size, mass or flight behavior (Muirhead-Thomson, 1991; Sutherland, 1998). It is therefore, a single insect collecting technique may be biased as some insect species may be over represented while other might be underestimated or even missing. Therefore, multiple sampling techniques were adopted by applying same sampling methods in all sites and a large number of specimens
were collected by using various sampling methods i.e., sweep nets, light traps, pitfall traps and aquatic nets of standard sizes. As the experiment was performed in three different districts having paired sites, the temporal difference among pairs was controlled by sampling these three pairs on consecutive days (Wickramasinghe et al., 2004). The detail of sampling methods used during this study is given by:

3.3.2.1: Sweep net

A standard sweep net of 32 cm diameter was used for this purpose. After entering in the field from the corner and moving diagonally in the central field (in cross wise way), the net was swept once at each step in figure of eight. Ten such sweeps constituted one sample. In total twenty samples were made from each locality. The collected insects were killed in a potassium cyanide killing bottle and stored in 70% ethanol for later sorting and identification. The moths were, however, pinned and stored in wooden boxes (Cameron et al., 1981; Wickramasinghe et al., 2004; Leitao et al., 2007).

3.3.2.2: Light trap

For nocturnal flying insects bucket type light traps having potassium cyanide bottle at the bottom as killing agent, equipped with 60 watts electric bulb were operated in proper location among the selected rice fields, from dusk to dawn and insect specimens were collected at weekly and fortnightly intervals from nurseries and crop fields in each locality, respectively. The height of the tarp was adjusted according to height of the crop (Bowden, 1982; Yahiro and Yano, 1997).

3.3.2.3: Pitfall trap

For terrestrial insect fauna pitfall traps were used. Wide mouth plastic jars (11 cm deep and 7.5 cm in diameter) were introduced into other plastic jars which were permanently buried in the field bunds (at end of cropping season when water dried from the fields the traps were shifted into the rice field). Twenty traps were installed at each site at 10 feet interval in an alternating pattern along the length of field bunds in the selected field (Fig. 3.1). The traps were filled (2-3 cm) at the bottom with 95% ethylene glycol with few drops of detergent to kill and preserve the insects and were emptied through out the growing season on each collection day and contents were filtered in the
standard sieve No. 40. The samples were labeled according to date and locality and stored properly. The insects were sorted in the laboratory under a stereoscopic binocular microscope and then transferred into 70% alcohol until further identification (Oraze et al., 1988; Paoletti et al., 1999; Woin et al., 2005).

![Diagram of pitfall traps installation](image.png)

**Fig. 3.1: Diagrammatic representation of pattern of pitfall traps installation.**

3.4.2.4: *Aquatic net*

The aquatic insects were collected by using aquatic net of 1 mm mesh, with a mouth of 20 cm diameter, at the end a handle of medium length, enabling sampling between rice plants. The net was dragged in a standard net sweep (SNS) manner consisting of two drags (back and forth) along one meter path. Ten drags of such type were made to make one sample and twenty samples were taken from each locality throughout the growing season. However, the sampling was stopped near crop maturity because it was not possible as water level was very low or had dried in the fields at that time (Lawton, 1970; CheSalmah et al., 1998).

3.3.3: *Insect preservation and identification*

The collected specimens were sorted, pinned, labeled and mounted in collection boxes and minute specimens were preserved in glass vials in 70% ethyl alcohol in the “Insect Biodiversity and Biosystematics Lab” (IBBL) Department of Agri. Entomology, University of Agriculture, Faisalabad. Naphthalene balls mounted on steel pins were kept in collection boxes for the safety of collected specimens.
Materials and Methods

The collected specimens were manually sorted into recognizable taxonomic units, counted and identified under stereo-zoom microscope (Meiji- Japan) with the help of available taxonomic literature and reference museum collection (in Insect Biodiversity and Biosystematics Laboratory and Insect Museum, Department of Agri. Entomology, University of Agriculture, Faisalabad; Per Mehr Ali Shah University of Arid Agriculture, Rawalpindi; Bahudin Zakria University, Multan; Insect Museum, National Agriculture Research Council, Islamabad; Insectarium, Pakistan Museum of Natural History, Islamabad; Department of Zoology, University of Karachi; G.C. University Lahore and University of the Punjab, Lahore) possibly up to species level or otherwise to morpho-species within known genera or families (Choe, 1997; Siemann et al., 1999; Wilby et al., 2006) and those, not identified even to family level, or their identification was not possible because of their damaged parts were left out of the analysis of diversity (Wickramasinghe et al., 2004). The insects were then also sorted according to their trophic groups to make guild structure on various crop growth stages. Field observations and literature review were used to assign each species to one of five trophic categories used (CSIRO, 1991; Siemann et al., 1999; Moursi et al., 2001; Bambaradeniya and Amerasinghe, 2003; Bambaradeniya et al., 2004; Edirisinghe and Bambaradeniya, 2006). Voucher specimens were deposited in a reference collection housed with IBBL, University of Agriculture, Faisalabad (UAF).

3.3.4: Metrological data

Metrological data of mean temperature, relative humidity and rainfall was collected from the observatory of each district and the affect of these factors on insect diversity and abundance was calculated.

3.3.5: Data analysis

The insect biodiversity was calculated using the Shannon-Weaver and Simpson's diversity indices and Hill’s diversity numbers (Shannon and Weaver, 1949; Simpson, 1949; Hill, 1973) along with various multivariate analysis which are described as:

3.3.5.1: Shannon-Weaver diversity index \( (H) \): was used to determine which sample has more abundant species. A species diversity study takes into account the number of
species (species richness) and the importance of individuals in species (evenness) (Vandermeer, 1981). Shannon's index accounts for both abundance and evenness of the species present. The proportion of species $i$ relative to the total number of species ($p_i$) was calculated, and then multiplied by the natural logarithm of this proportion ($\ln p_i$). The resulting product was summed across species, and multiplied by -1.

$$H = -\sum_{i=1}^{S} p_i \ln p_i$$

$H$ is a more reliable measure as sampling size increases.

The addition of the calculation of evenness ($J$) or equitability ($E_H$) was also applied. Shannon's equitability ($E_H$) was calculated by dividing $H$ by $H_{\text{max}}$ (here $H_{\text{max}} = \ln S$).

$$J = E_H = H/ H_{\text{max}} = H/ \ln S$$

The evenness index measures how evenly species are distributed in a sample. When all species in a sample are equally abundant an evenness index will be at its maximum, decreasing towards zero as the relative abundance of the species diverges away from evenness (Sebastian et al., 2005). It means evenness assumes a value between 0 and 1 with 1 being complete evenness i.e., a situation in which all species are equally abundant.

**3.3.5.2: Simpson's diversity index ($\lambda$ or $D$):** was used to determine which sample has more rare species. It is a simple mathematical measure that characterizes species diversity (rarity) in a community as

$$D = \lambda = \sum_{i=1}^{S} p_i^2$$

where $p_i$ is the proportional abundance of the $i$th species and is given by

$$p_i = n_i/N, i= 1,2,3,\ldots S$$

where $n_i$ is the number of individuals of $i^{th}$ species and $N$ is the known total number of individuals for all $S$ species in the population. Simpson’s index varies from 0 to 1 and
gives the probability that two individuals drawn at random from an infinitely large population belong to the different species. For a given species richness (S), evenness (J) increases as D decreases, and for a given evenness, D decreases as richness increases.

3.3.5.3: Hill’s diversity numbers: In order to represent number of abundant species in samples and also to represent species maximum in abundance Hill’s diversity numbers were used. In equation form, Hill’s diversity numbers are

\[ N_A = \sum_{i=1}^{s} (p_i)^{1/(1-A)} \]

where \( p_i \) is the proportion of individuals belonging to \( i^{th} \) species. Hill shows that the 0\(^{th}\), 1\(^{st}\) and 2\(^{nd}\) order of these diversity numbers (i.e., \( A=0, 1 \) and \( 2 \)) coincide with three of the most important measures of diversity. Hills diversity numbers are

Number 0: \( N_0 = S \)

where \( S \) is the total number of species, so, \( N_0 \) is the number of all species in the sample regardless of their abundance

Number 1: \( N_1 = e^H \)

where \( H \) is the Shannon’s index and \( N_1 \) is the measure of number of abundant species in the sample. \( N_1 \) will always be intermediate between \( N_0 \) and \( N_2 \) and

Number 2: \( N_2 = 1/\lambda \)

where \( \lambda \) is Simpson’s index and \( N_2 \) is the number of species maximum in abundance in a sample.

3.3.5.4: Estimation of species richness: The estimated species richness was calculated to determine whether the sampling sites had been sufficiently sampled or not. To calculate the estimated number of species the procedure laid out by Chao was followed. The Chao 1 quantitative estimator (Chao, 1984; Colwell and Coddington, 1994) was calculated as:

\[ S_{Chao1} = S_{obs} + (a^2/2b) \]

where \( S_{obs} \) is the number of species observed and \( (a) \) and \( (b) \) are the number of singletons and doubletons respectively.
3.3.5.5 Cluster analysis: Cluster analysis was used to investigate the degree of association or resemblance of sampling sites. It is a useful data reduction technique that is helpful in identifying patterns and groupings of objects. The Minitab version 13.1 and STATISTICA-6 programs were used for cluster analysis using flexible strategy and chord distance, a measure of dissimilarity by following Ward’s method (Ward, 1963; Lance and William, 1967; Faith, 1991; Sebastian et al., 2005).

3.3.5.6 Principal Component Analysis (PCA): Principal component analysis was used to identify the direction of change of species richness by using Minitab version 13.1.

3.3.5.7 Sorensen similarity index: The Sorensen index (Sorensen, 1948) also known as Sorensen’s similarity coefficient, was used for comparing the similarity of two samples (sites) (Janson and Vegelius, 1981). The short hand version of the formula, as applied to qualitative data, is

\[ C_S = \frac{2C}{A+B} \]

where \( C_S \) is similarity coefficient, A and B are the species numbers in sample A and B, respectively and C is the number of species shared by the two samples. The value for this index always ranges between 0 to 1. Where 0 means completely different and 1 means completely similar samples.

3.3.6 Cost/benefit ratios:

A cost/benefit ratio of LIP and HIP systems was calculated on the basis of total costs of production and total gains from the yield of both rice production systems.
3.4 RESULTS AND DISCUSSION

3.4.1: Insect fauna associated with rice crop agroecosystem in the Kallar tract

During the present study a total of 535812 insects belonging to 520 insect species under 143 insect families and 16 insect orders were collected (Table 3.1).

Table 3.1: Number of insect species under different families and insect orders.

<table>
<thead>
<tr>
<th>Insect orders</th>
<th>No. of species</th>
<th>No. of families</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coleoptera</td>
<td>145</td>
<td>28</td>
</tr>
<tr>
<td>Lepidoptera</td>
<td>75</td>
<td>21</td>
</tr>
<tr>
<td>Hymenoptera</td>
<td>74</td>
<td>17</td>
</tr>
<tr>
<td>Diptera</td>
<td>64</td>
<td>27</td>
</tr>
<tr>
<td>Hemiptera</td>
<td>58</td>
<td>17</td>
</tr>
<tr>
<td>Homoptera</td>
<td>36</td>
<td>5</td>
</tr>
<tr>
<td>Orthoptera</td>
<td>19</td>
<td>6</td>
</tr>
<tr>
<td>Odonata</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>Dermaptera</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Dictyoptera</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Collembola</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Neuroptera</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Thysanura</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Ephemeroptera</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Isoptera</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Plecoptera</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Distribution patterns of all the sixteen insect orders are tabulated in table 3.1 and in appendix-III. Coleoptera was the most diverse order with 145 species under 28 families followed by Lepidoptera (76, 21), Hymenoptera (74, 17), Diptera (60, 27), Hemiptera (58, 17), Homoptera (37, 5), Orthoptera (20, 6), Odonata (16, 2), Dermaptera (9, 5), Dictyoptera (9, 3), Collembola (4, 3), Neuroptera (4, 3), Ephemeroptera (2, 2), Thysanura (2, 2), Isoptera (2, 1) and Plecoptera with 1 species under 1 family (Fig. 3.2).
Results and Discussion

3.4.2: Diversity of insect orders

3.4.2.1: Diversity of insect orders in rice crop

From appendix-III it is clear that in most of cases species which were abundant at one site were also in abundance or present in fairly good number in other sites with little effects of inputs applied and there was not even a single species recorded abundantly from one site only. It means that abundant species have wider distribution range as compared to rare species (Hanski, 1982; Brown, 1984; Paivinen et al., 2005). This phenomenon is called density-distribution relationships and is a universal pattern in ecology and also had been explained as ecological specialization (Hanski, et al., 1993; Hanski and Gyllenberg, 1997; Gaston and Blackburn, 2000). A deeper look at species composition suggested that the fluctuations in species richness and abundance were more or less correlated with feeding habitat of the species, competition with their congeneric peers or their preferences for a particular type of...
of environment (polluted or unpolluted). Resultantly absolutely absent, rarely present or present in abundance in that particular type of habitat only. The values of various diversity components for various insect orders are given in table 3.2. A brief description of these insect orders with respect to various diversity indices along with the fluctuations on the species richness and abundance is given by:

From table 3.2 it is clear that in case of Coleoptera the values of S, N, H, D & J were 145, 260694, 3.0824, 0.0962 & 0.6194 respectively. The (H) value indicated that Coleoptera had less number of abundant species (N1=21) in which 10 were maximum in abundance (N2). The lower value of J indicated that species in Coleoptera were distributed with a low (62%) evenness with dominance of few species among which Psammobius sp. and Berosus sp.1 occurred maximum in abundance. Due to a lower evenness the rarity (D) was high (Appendix-III, Table, 3.2, Fig. 3.3).

In Lepidoptera there exist a large number of highly destructive crop pests against which maximum insecticides are used (Razaq et al., 2005). It was the second most abundant insect order in the present study. The values of S, N, H, D & J were 75, 8600, 3.5936, 0.0432 & 0.8323 respectively. The high value of (H) in comparison with that of Coleoptera showed that in this order there was a high number of abundant species (N1=36) in which 23 species were maximum in abundance (N2). The lower value of (D) indicated that it possessed less number of rare species and due to this low rarity the species were distributed with high evenness (83%) and with only 17% dominance of Cnaphalocrocis medinalis and Scirpophaga innotata (Appendix-III, Table, 3.2, Fig. 3.3).

Hymanoptera is the most important insect order due to a number of insect species which are potential pollinators and parasitoids. Its ecological specialist species are also being used widely for habitat quality assessment (Trevis, 1996). The values of S, N, H, D & J were 74, 20611, 3.2720, 0.0619 & 0.7602 respectively. Here, the value of (H) was less than that of Lepidoptera. This showed that in this order in comparison with Lepidoptera the number of abundant species (N1=26) was less in which 16 species were maximum in abundance (N2). But value of (D) indicated that
number of rare species was more than that for Lepidoptera. Due to this higher rarity the value of (J) also decreased and was less than that for Lepidoptera, which indicated that 76% species were evenly distributed with 24% dominance of *Temelucha* sp. and *Cotesia* sp.2 (Appendix-III, Table, 3.2, Fig. 3.3).

**Table 3.2: Diversity of insect orders.**

<table>
<thead>
<tr>
<th>Insect Order</th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
<th>J</th>
<th>N1</th>
<th>N2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coleoptera</td>
<td>145</td>
<td>260694</td>
<td>3.0824</td>
<td>0.0962</td>
<td>0.6194</td>
<td>21</td>
<td>10</td>
</tr>
<tr>
<td>Lepidoptera</td>
<td>75</td>
<td>8600</td>
<td>3.5936</td>
<td>0.0432</td>
<td>0.8323</td>
<td>36</td>
<td>23</td>
</tr>
<tr>
<td>Hymanoptera</td>
<td>74</td>
<td>20611</td>
<td>3.2720</td>
<td>0.0619</td>
<td>0.7602</td>
<td>26</td>
<td>16</td>
</tr>
<tr>
<td>Diptera</td>
<td>64</td>
<td>65334</td>
<td>3.3576</td>
<td>0.0561</td>
<td>0.8073</td>
<td>28</td>
<td>17</td>
</tr>
<tr>
<td>Hemiptera</td>
<td>58</td>
<td>41125</td>
<td>2.4647</td>
<td>0.1484</td>
<td>0.6070</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Homoptera</td>
<td>36</td>
<td>23117</td>
<td>2.8855</td>
<td>0.1049</td>
<td>0.8052</td>
<td>18</td>
<td>9</td>
</tr>
<tr>
<td>Orthoptera</td>
<td>19</td>
<td>3142</td>
<td>2.4235</td>
<td>0.1227</td>
<td>0.8231</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>Odonata</td>
<td>16</td>
<td>3448</td>
<td>1.9649</td>
<td>0.2428</td>
<td>0.7087</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Dermaptera</td>
<td>9</td>
<td>5110</td>
<td>1.7910</td>
<td>0.2104</td>
<td>0.8151</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Dictyoptera</td>
<td>9</td>
<td>624</td>
<td>1.8015</td>
<td>0.2012</td>
<td>0.8199</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Collembola</td>
<td>4</td>
<td>90714</td>
<td>1.2823</td>
<td>0.2930</td>
<td>0.9250</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Neuroptera</td>
<td>4</td>
<td>358</td>
<td>0.9237</td>
<td>0.5217</td>
<td>0.6663</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Thysanoptera</td>
<td>2</td>
<td>256</td>
<td>0.3843</td>
<td>0.7754</td>
<td>0.5544</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ephemeroptera</td>
<td>2</td>
<td>194</td>
<td>0.4797</td>
<td>0.6977</td>
<td>0.6921</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Isoptera</td>
<td>2</td>
<td>12438</td>
<td>0.6063</td>
<td>0.5843</td>
<td>0.8748</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Plecoptera</td>
<td>1</td>
<td>47</td>
<td>0</td>
<td>1</td>
<td>#</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

S=Species richness, N=Species abundance, H=Shannon’s index, D=Simson’s index, J=Evenness, N1 & N2=Hill’s numbers of diversity (N1=Number of abundant species & N2=Number of species maximum in abundance. Their values were rounded off to nearest whole numbers).

**Note:** Insect orders having approximately equal values of (S) were compared with each other.

For Diptera the values of S, N, H, D & J were 64, 65334, 3.3576, 0.0561 & 0.0.8073 respectively. In this case the value of (H) was more than that for Hymanoptera. This showed that in Diptera, number of abundant species (N1=28) was high than for Hymanoptera. Among these species 17 species were maximum in abundance (N2). But a lower value of (D) indicated that number of rare species was less than that of Hymanoptera. Due to this low rarity the species were distributed with high evenness of about 81% with 19% dominance of *Anopheles subpictis* and *Chironomid* sp.2 (Appendix-III, Table, 3.2, Fig. 3.3).
Results and Discussion

Fig. 3.3: Comparison of (a) insect species richness and (b) abundance of various insect orders

Cole(Coleoptera), Lep(Lepidoptera), Hym(Hymenoptera), Dip(Diptera), Hem(Hemiptera), Hom(Homoptera), Orth(Orthoptera), Odo(Odonata), Derm(Dermoptera), Dict(Dictyoptera), Coll(Collembola), Neu(Neuroptera), Thy(Thysanoptera), Eph(Ephemeroptera), Iso(Isopoda), Ple(Plecoptera).

Hemiptera is also one of the most important insect orders because its member species include not only rice pest but predators of rice pest insects as well. The values of N, S, H, D & J were 58, 41125, 2.4647, 0.1484 & 0.6070 respectively. The low value of (H) as compared to Diptera indicated that there were less number of abundant species (N1=11). Among these abundant species 6 species (N2) were maximum in abundance. A high value of (D) explained presence of rare species in enormous quantity in comparison with Diptera. Due to presence of more number of rare species value of (J) also reduced which illustrated that species were distributed with low evenness of about 61% evenness and with the dominance of *Callicorixa* sp.,
Results and Discussion  

Section 3

*Micronecta* sp. and *Corixa* sp. (all predatory species). (Appendix-III, Table 3.2, Fig. 3.3).

All the members of Homoptera are sap feeding phytophagous species. Some species like *Sogatella furcifera*, *Nilaparvata lugens* and some *Nephotettix* spp., are either serious pest of rice crop or vectors of viral diseases throughout the rice growing areas of the world (Siwi and Roechan, 1983; Dahal, 1997; Hibino *et al*., 1978; Bottenberg *et al*., 1990; Suzuki, *et al*., 1992). The values of S, N, H, D & J were 36, 23117, 2.8855, 0.1049 & 0.8052 respectively. Here, the high value of (H) as compared to Hemiptera, suggested that there were more number of abundant species (N1=18) in which 9 were maximum in abundance (N2). But a low value of (D) explained presence of rare species in less number as compared to Hemiptera, due to which it had high value of (J) which illustrated that about 81% species were evenly distributed with about 19% dominance of only one species namely *Laodelphax* sp. The other abundant species were *Nilaparwata lugens* and *Nephotettix nigropiclus*, *Cicadulina bipunctella* and *Sogatella furcifera* (Appendix-III, Table 3.2, Fig. 3.3).

Just like Coleoptera, Diptera and Hemiptera the members of Orthoptera include herbivores and carnivores (predatory) insect species. Among its members rice grasshoppers constitute an important pest insects group of rice crop. In nursery stage of rice crop, especially, they cause havoc damages. The values of S, N, H, D & J for Orthoptera were 19, 3142, 2.4235, 0.1227 & 0.8231 respectively. The value of (H) advocated that there were more abundant species (N1=11) in which 8 species were maximum in abundance. But value of (D) explained that rare species were present in low number. This was the reason that value of (J) was high illustrating that about 82% species were evenly distributed with 18% dominance of *Oxya chinensis*. The other abundant species were *Acheta domestica*, *Cconocephalus maculates*, *Oxya nitidula*, *Oxya velox* and *Oxya fuscovittata* respectively (Appendix-III, Table 3.2, Fig. 3.3).

Before this study *Oxya velox* was considered as abundant species in rice crop (Brohi *et al*., 2000) but according to results of present study *Oxya chinensis* was most abundant species. This was an interesting and important finding of this study.

Odonata is the insect orders whose all members are well known predators in both of naiads and adult stages of their life cycles (Benke, 1976). The values of S, N, H, D & J were 16, 3448, 1.9649, 0.2428 & 0.7087 respectively. Here, the low value of
(H) in comparison with Orthoptera indicated that it had less number of abundant species (N1=7) in which only 4 species were maximum in abundance (N2). On the other hand high value of (D) showed that there was high number of rare species. This high rarity lowered the value of (J) which indicated that the species were distributed with a comparatively low evenness of about 71% (as compared to Orthoptera) with dominance of *Agriocnemis* sp. along with *Agriocnemis pygmaea* and *Agriocnemis femina femina* (Appendix-III, Table 3.2, Fig. 3.3).

In case of Dermaptera the values of S, N, H, D & J were 9, 5110, 1.7910, 0.2104 & 0.8151 respectively. The values of (H), (D) and (J) showed that number of abundant species (N1=6) was high and rare species (D) was low. Due to low rarity the species occurred with high evenness of about 82%, with dominance of *Forficula auricularia* and *Anisolabis annulipes* (Appendix-III, Table 3.2, Fig. 3.3). Out of 6 abundant species 4 were maximum in abundance (N2).

In case of Dictyoptera the values of S, N, H, D & J were 9, 624, 1.8015, 0.2012 & 0.8199 respectively. Here, the values of (H) and (D) were almost similar to those for Dermaptera. Consequently number of abundant species (N1=6) & species maximum in abundance (N=2), values of rarity and evenness were almost similar with those of Dermaptera. However, the value of (J) illustrated that about 82% species were evenly distributed with dominance of *Blatella* sp.1, *Blatella* sp.2, *Blatella germanica* (Appendix-III, Table 3.2, Fig. 3.3).

The values of S, N, H, D & J for Collembola were 4, 90714, 1.2823, 0.2930 & 0.9250 respectively. From the values of (H), (D), (J), (N1) and (N2) it was evident that almost all species viz., *Sminthurus viridus*, *Entomobrya* sp., *Desoria* sp. and *Isotomurus* sp. were in abundance in decreasing order having 93% even distribution (Appendix-III, Table, 3.2, Fig. 3.3).

Some of the members of the order Neuroptera are well known predators. For neuropteran the values of S, N, H, D & J were 4, 358, 0.9237, 0.5217 & 0.6663 respectively. In comparison with Collembola a low value of (H) indicated less number of abundant species (N1=2) but a high value of (D) indicated more number of rare species which affected even distribution of species and reducing evenness to about 67%. These values showed that distribution of individuals among species was not uniform i.e., dominated by two species i.e., *Chrysoperla carnea* and *Dendroleon* sp.
The same 2 abundant species were also maximum in abundance (N2=2) (Appendix-III, Table 3.2, Fig. 3.3).

In case of Thysanoptera the values of S, N, H, D & J were 2, 256, 0.3843, 0.7754 & 0.5544 respectively. But for Ephemeroptera these values were 2, 194, 0.4797, 0.6977 & 0.6921 respectively. From these values it was concluded that in both insect orders about 50% i.e. one species was dominant out of two species. In case of Thysanoptera, *Thrips oryzae* and in case of Ephemeroptera *Baetis* sp. was dominant (Appendix-III, Table 3.2, Fig. 3.3). The value for N1 and N2 for both of insect orders was 1. This indicated that the same single abundant species was also occurring maximum in abundance.

Isoptera is of least economic importance for rice crop. The values of S, N, H, D & J for Isoptera were 2, 12438, 0.6063, 0.5843 & 0.8748 respectively. These values showed that both of the species viz., *Odontotermes obesus* and *Microtermes obesi* were abundantly present with high evenness of 87% (Appendix-III, Table 3.2, Fig. 3.3).

Plecoptera consisted of only one species namely *Perla* sp. and hence the diversity analysis was not possible (Appendix-III, Table 3.2, Fig. 3.3).

### 3.4.2.2 Effect of HIP and LIP rice farming systems on diversity of insect orders

For Coleoptera the values of S, N, H, D & J in case of LIP were 144, 165630, 3.126, 0.089 & 0.629 and for HIP were 131, 95064, 2.968, 0.113 & 0.609 respectively (Table 3.3, Fig. 3.4). These results indicated that LIP had more number of abundant species (N1=22) and less number of rare species. Due to less number of rare species in LIP the species were about 63% evenly distributed as compared to HIP rice where species were about 61% evenly distributed because of high rarity. Ultimately the difference in values of (H) between HIP and LIP rice crops was significant (P<0.05) (Table 3.3). The LIP systems had higher values of (S) and (N) as compared to HIP systems. The high value of (H) and low value of (D) for LIP indicated that most of coleopteran species preferred less polluted environment and present in abundance in fields receiving lower quantities of agrochemicals (Berry *et al.*, 1996; Epstein *et al.*, 2000). Due to preference of coleoptrans for LIP some of its species were completely absent in HIP (Appendix-III & IV) including some others which were present in low
number. This effect might be due to application of agrochemicals for rice crop production and protection (Rainio and Niemela, 2003).

Table 3.3: Comparison of order wise insect diversity in LIP and HIP rice farms.

<table>
<thead>
<tr>
<th>Insect Order</th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
<th>J</th>
<th>N1</th>
<th>N2</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coleoptera</td>
<td>HIP</td>
<td>LIP</td>
<td>HIP</td>
<td>LIP</td>
<td>HIP</td>
<td>LIP</td>
<td>HIP</td>
<td>P-Value</td>
</tr>
<tr>
<td>Lepidoptera</td>
<td>HIP</td>
<td>LIP</td>
<td>HIP</td>
<td>LIP</td>
<td>HIP</td>
<td>LIP</td>
<td>HIP</td>
<td>P-Value</td>
</tr>
<tr>
<td>Hymanoptera</td>
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<td>LIP</td>
<td>HIP</td>
<td>LIP</td>
<td>HIP</td>
<td>LIP</td>
<td>HIP</td>
<td>P-Value</td>
</tr>
<tr>
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<td>HIP</td>
<td>LIP</td>
<td>HIP</td>
<td>LIP</td>
<td>HIP</td>
<td>P-Value</td>
</tr>
<tr>
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<td>HIP</td>
<td>LIP</td>
<td>HIP</td>
<td>LIP</td>
<td>HIP</td>
<td>P-Value</td>
</tr>
<tr>
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<td>HIP</td>
<td>LIP</td>
<td>HIP</td>
<td>LIP</td>
<td>HIP</td>
<td>P-Value</td>
</tr>
<tr>
<td>Orthoptera</td>
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<td>HIP</td>
<td>LIP</td>
<td>HIP</td>
<td>LIP</td>
<td>HIP</td>
<td>P-Value</td>
</tr>
<tr>
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<td>LIP</td>
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<td>LIP</td>
<td>HIP</td>
<td>P-Value</td>
</tr>
<tr>
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<td>LIP</td>
<td>HIP</td>
<td>LIP</td>
<td>HIP</td>
<td>P-Value</td>
</tr>
<tr>
<td>Dictyoptera</td>
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<td>P-Value</td>
</tr>
<tr>
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<td>HIP</td>
<td>P-Value</td>
</tr>
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<td>HIP</td>
<td>P-Value</td>
</tr>
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</tr>
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</tr>
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<td>HIP</td>
<td>LIP</td>
<td>HIP</td>
<td>P-Value</td>
</tr>
</tbody>
</table>

S=Species richness, N=Species abundance, H=Shannon’s index, D=Simson’s index, J=Evenness, N1 & N2=Hill’s numbers of diversity (N1=Number of abundant species & N2=Number of species maximum in abundance. Their values were rounded off to nearest whole numbers), Level of significance=5%

In case of Lepidoptera the values of S, N, H, D & J for LIP were 74, 4832, 3,644, 0.039 & 0.847 but for HIP were 67, 3768, 3,473, 0.050 & 0.826 respectively (Table 3.3, Fig. 3.4.) indicating that LIP had more number of abundant species (N1=38) and less number of rare species. Due to less number of rare species in LIP the species were 84% evenly distributed as compared to HIP rice crop where species were distributed with 82% evenness. The difference in values of (H) between HIP and LIP was significant (P<0.05) along with high values of (S) and (N) in LIP as compared to HIP. This also means that most of lepidopterous insect species were also sensitive to agrochemicals and preferred LIP rice fields. A total of eight species were completely absent in HIP fields (Appendix-III & IV). The eight species absent in HIP all were visitor/tourists/neutral. Seven of these species were of butterflies which could be used as bioindicator to reflect the health of rice agroeosystem (Howard et al., 1998; Collinge et al., 2003; Fitzherbert et al., 2006; Anoop, 2008). As these species were present only in LIP rice fields and this trend indicated that LIP fields were healthier and thus friendlier to lepidopterous insects as compared to HIP rice fields.
**Results and Discussion**

Fig. 3.4: Comparison of (a) insect species richness and (b) abundance of various insect orders in HIP and LIP rice fields.

Cole(Coleoptera), Lep(Lepidoptera), Hym(Hymenoptera), Dip(Diptera), Hem(Hemiptera), Hom(Homoptera), Orth(Orthoptera), Odo(Odonata), Derm(Dermaptera), Dict(Dictyoptera), Coll(Collembola), Neu(Neuroptera), Thy(Thysanoptera), Eph(Ephemeroptera), Iso(Isoptera), Ple(Plecoptera).

The values of S, N, H, D & J in case of Hymenoptera for LIP were 73, 11904, 3.367, 0.052 & 0.785 while for HIP were 66, 8707, 3.055, 0.083 & 0.0729 respectively (Table 3.3, Fig. 3.4) indicating that LIP had more number of abundant species (N1=29) and less number of rare species. Due to less number of rare species in LIP these were evenly distributed up to 79% as compared to HIP rice crop where species were distributed with 73% evenness. This also indicated that most of hymanopterous insect species were sensitive to environmental pollution caused by agrochemicals in HIP farms. The difference in values of (H) between HIP and LIP
was significant (P<0.05) along with high values of (S) and (N) in LIP as compared to HIP. These results are in conformity with those of (Berry et al., 1996).

In case of Diptera the values of S, N, H, D & J for LIP were 64, 33715, 3.465, 0.046 and 0.833 while for HIP were 56, 31619, 3.094, 0.085 & 0.769 respectively (Table 3.3, Fig. 3.4). The results indicated that LIP had more number of abundant species (N1=32) and less number of rare species as compared to HIP rice fields. Due to less number of rare species in LIP the species were distributed with 83% evenness. But, in case of HIP due to high rarity the species were 77% evenly distributed. This distribution of species in case of Diptera in LIP and HIP rice fields indicated that the dipterans respond negatively to change of inputs from low to high. Due to this reason the difference in values of (H) between HIP and LIP was significant (P<0.05) along with high (S) and (N) in LIP as compared to HIP fields. Diptera is not only medically most important insect order but it also contains a number of insect species which are predators and parasitoids. Besides this some species of Diptera act as alternative prey (in the absence of rice pest insects in early days of crop establishment) for generalist predators’ population against pest species. The important species which act as alternative prey belonged to insect families viz., Ephydridae and the Chironomidae (Wu et al., 1994; Settle et al., 1996; Park and Lee, 2006) which remained abundant throughout all crop stages (Appendix-V).

For Hemiptera the values of S, N, H, D & J for LIP were 57, 23012, 2.509, 0.142 & 0.621 and for HIP were 54, 18113, 2.365, 0.161 & 0.593 respectively (Table 3.3, Fig. 3.4). The results demonstrated that LIP had more number of abundant species (N1=12) and less number of rare species as compared to HIP rice fields. Due to less number of rare species in LIP the species were distributed with 62% evenness. But, in case of HIP due to high rarity the species were 59% evenly distributed. This distribution of species in Hemiptera among LIP and HIP rice fields indicated that the hemipteran respond negatively to change of inputs from low to high. This was the reason that the difference in values of (H) between HIP and LIP was significant (P<0.05) with greater value of (S) and (N) in LIP as compared to HIP rice fields. These results are in conformity with those of Moreby (1996).

In case of Homoptera the values of S, N, H, D & J for LIP were 35, 13210, 2.904, 0.114 & 0.800 but for HIP the values were 35, 9907, 2.843, 0.095 & 0.817
respectively (Table 3.3, Fig. 3.4). The results indicate that LIP systems had not only more number of abundant species (N1=18) but also a slight high number of rare species as compared to HIP rice fields. Due to this reason in LIP the species were distributed with slight low evenness of 80% as compared to HIP where species were 81% evenly distributed. The distribution of insect abundance between LIP and HIP rice fields indicated that the homopteran respond negatively to increasing amounts of inputs. Due to this reason the difference in values of (H) between HIP and LIP was significant (P<0.05) with same value of (S) but with high value of (N) in LIP as compared to those for HIP rice fields.

For Orthoptera the values of S, N, H, D & J for LIP were 19, 1457, 2.475, 0.117 and 0.840 and for HIP were 15, 1685, 2.296, 0.135 & 0.848 respectively (Table 3.3, Fig. 3.4). The results indicate that LIP had more number of abundant species (N1=12) and a slight less number of rare species as compared to HIP rice fields. Consequently, species occurred with almost equal evenness of about 84% in both of LIP and HIP rice fields. This distribution of species of Orthoptera among LIP and HIP rice fields indicated that the orthopterans were not affected by change of inputs from low to high. However, the difference in values of (H) between HIP and LIP was significant (P<0.05) in favour of LIP fields.

In case of Odonata the values of S, N, H, D & J for LIP were 16, 2290, 1.954, 0.251 & 0.708 but for HIP were 12, 1158, 1.909, 0.229 & 0.768 respectively (Table 3.3, Fig. 3.4) indicating that in case of Odonata LIP had not only more number of abundant species (N1=7) but also more number of rare species as compared to HIP rice fields. Due to higher value of rarity in LIP, the species were distributed with 71% evenness while in case of HIP due to a low number of rare species the distribution of species was with some high evenness of about 77% (Table 3.3). As there was high species richness and evenness in case of LIP farms as compared to HIP farms, the difference in values of diversity between HIP and LIP was significant (P<0.05). This means that the odonates were affected negatively to extensive use of agrochemicals and had specific habitat preferences (Corbet, 1999). This was the reason that in most of ecological studies they have been used to evaluate the changes in the habitats and water quality caused by biotic or abiotic factors (Schmidt, 1985; Lenz, 1991, Bulankova, 1997). Therefore, being rapid and sensitive indicators they are being used
to evaluate environmental quality producing comparable results to disturbances both at small and large spatial scales. On the basis of these features they are considered as very useful group of animals for habitat assessment and biodiversity monitoring (Stewart and Samways, 1998; Andreas and Johann, 2001; Jakab et al., 2002; Bried and Ervin, 2005; Catling, 2005; Foote and Hornung, 2005; Jenny, 2007; Sato and Riddiford, 2008). They are also considered as keystone taxa because of their controlling influence on the trophic interactions (Bambaradeniya et al., 2004).

For Dermaptera the values of S, N, H, D & J for LIP were 8, 2266, 1.726, 0.241 and 0.785 but for HIP were 9, 2844, 1.769, 0.201 & 0.851 respectively (Table 3.3, Fig. 3.4). The results indicate that LIP had less number of abundant species (N1=5) and more of rare species as compared to HIP rice fields which had more abundant species (N1=6). Due to more number of rare species in LIP the species were distributed with low evenness of about 79% as compared to HIP where due to low rarity the species were distributed with high evenness of 85%. The difference in values of (H) between HIP and LIP was significant (P<0.05) with high (S) and (N) for HIP. This means that the HIP method of rice farming had less effect on Dermaptera. These findings are against those of Epstein et al. (2000) and Peusens and Gobin (2007).

In case of Dictyoptera the values of S, N, H, D & J for LIP were 9, 175, 1.743, 0.212 & 0.793 but for HIP were 9, 499, 1.724, 0.227 and 0.785 respectively (Table 3.3, Fig. 3.4). The results indicate that LIP had more number of abundant (N1=6) and less number of rare species as compared to HIP rice fields. In this case species were distributed with almost equal evenness (79%) among LIP and HIP rice crop agroecosystems. The difference in values of (H) between HIP and LIP was statistically non significant (P>0.05). It was the only insect order with high preference for HIP farming as far as species abundance was concerned which was about three times higher in case of HIP. So, from these values it is clear that species of Dictyoptera preferred polluted type of environment. They were not affected by disturbances through extensive use of agrochemical or had adjusted themselves to these drastic practices and consequently exhibited a strong density increase in HIP fields (Alstad et al., 1982). The results are thus in accordance with Jeffries (1997) observation that disturbance acted at many scales and took many forms.
In case of Collembola the values for S, N, H, D and J for LIP were 4, 52999, 1.296, 0.289 & 0.935 but for HIP were 4, 37715, 1.256, 0.300 & 0.906 respectively (Table 3.3, Fig. 3.4). The results indicate that values for all diversity components except for (N) were almost similar for both types of rice fields. The species were present in abundance in LIP than in HIP indicating that collembolan were sensitive to pollution and hence could be considered as bi indictors which respond well to human induced disturbances (Sousa et al., 2004). As a result of their sensitivity to polluted environment the difference between LIP and HIP farms was significant (P<0.05). The results are in conformity with those of El-Titi and Ipach, (1989) and Rickerl et al. (1989).

For neuropteran the values for S, N, H, D & J for LIP were 4, 261, 0.795, 0.598 & 0.573 and for HIP were 4, 97, 1.179, 0.365 & 0.851 respectively (Table 3.3, Fig. 3.4). The species richness between LIP and HIP was same but abundance was high in LIP rice farms. There were more abundant species (N1=3) and low number of rare species in HIP as compared to LIP fields which ultimately affected distribution of species. The species in HIP were distributed with high evenness of 85% (due to low rarity) but with 57% evenness in case of LIP (due to more number of rare species). The reason for low evenness value in case of LIP was the fact that in this case the species were numerically dominated by only one species i.e. *Chrysoperla cornea* which ultimately affected the number of individuals allotted to each species. The difference between the values of (H) of LIP and HIP was statistically significant (P<0.05) with greater value for HIP (Appendix-III, Table 3.3). From the species abundance value it could be suggested that Neuroptera also responded negatively to change of inputs value from low to high being sensitive to HIP (Berry et al., 1996).

In case of Thysanoptera the values of S, N, H, D & J for LIP were 2, 91, 0.180, 0.916 & 0.260 and for HIP were 2, 165, 0.465, 0.710 & 0.671 respectively (Table 3.3, Fig. 3.4). These values suggested that in case of HIP due to high value of (N), the evenness value was also high i.e. 91% whereas it was 67% in case of LIP because of low value of (N). The HIP systems were significantly (P<0.05) different from LIP with higher value of (H) for HIP (Table 3.3). From these results it could be inferred that the thrips preferred HIP (McNeil and Southwood, 1978; Mattson, 1980; Scriber, 1984; Rustamani et al., 1999; Malik et al., 2003).
For Ephemeropera the values for S, N, H & D for LIP were 2, 172, 0.463 & 0.712 while for HIP these values were 2, 22, 0.586 & 0.603 respectively (Table 3.3, Fig. 3.4). The results indicate that the species were distributed with 66 and 84% evenness in LIP and HIP rice fields, respectively. The number of abundant and maximum abundant species was same (1) for both types of cultivation systems. The difference in the values of (H) between LIP and HIP systems was non significant (P>0.05). The results showed that LIP system had more rare species, besides having greater species abundance as compared to HIP. So, it was concluded that Ephemeropera preferred LIP system in which their population increased many folds as compared to HIP (Lenat, 1988; Sandin and Johnson, 2000)

In case of Isoptera the values for N, S, H, D & J for LIP were 2, 4877, 0.537, 0.648 & 0.775 and for HIP were 2, 7561, 0.640, 0.553 & 0.923 respectively (Table 3.3, Fig. 3.4.). These results showed that both of the species in HIP were present in abundance leading to more number of abundant species (N1=2) but in case of LIP abundant species was only 1 leading to high rarity. As a result, species in HIP were distributed with 92% evenness compared to LIP where distribution was 77%. All these results suggested that species of termite preferred polluted type of habitats.

Plecoptera consisted of only one species namely Perla sp. The diversity analysis and comparison between LIP and HIP systems was not possible owing to very minimal species richness that was only one species (Table 3.3, Fig. 3.4). However, from appendix-III it is clear that LIP had more number of individuals (36) as compared to HIP with only 11 individuals. This also suggested that plecopteran were sensitive to pollution as they respond negatively to increase in input concentration. This is the reason that in most of ecological studies they have also been used in biomonitoring to estimate the ecologically suitability of habitats (Lenat, 1988; Sandin and Johnson, 2000).

3.4.3: Spatial distribution of insect fauna

The distribution and change in insect biodiversity with respect to change in space or location is called spatial distribution (Drechsler and Settele, 2001; Bambaradeniya and Amerasinghe, 2003). During the present studies the changes in
insect diversity among the three districts were also observed. These changes could be due to local landscape & land fragmentation (comprised the splitting of habitats in smaller and more isolated units) by roads, railway lines, buildings and industrial emission which also had profound effects on biodiversity (Fahring, 2003; Hanski, 2005; Andreas and Lennart, 2006; Bianchi et al., 2006). The spatial variation in insect biodiversity among the three districts is described below:

**3.4.3.1: Comparison of insect diversity of rice crop agroecosystems among three districts of the Kallar tract**

The values of S, N, H, D & J were 479, 166734, 4.3334, 0.0319 & 0.7021 for Sialkot and 494, 174512, 4.2321, 0.0333 & 0.6823 for Gujranwala, while these values were 501, 194566, 4.1898, 0.0402, 0.6740 for Sheikhupura, respectively (Table 3.4 & Fig. 3.5a,b).

**Table 3.4: Comparison of insect diversity among three districts.**

<table>
<thead>
<tr>
<th>District</th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
<th>J</th>
<th>N1</th>
<th>N2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sialkot</td>
<td>479</td>
<td>166734</td>
<td>4.3334a</td>
<td>0.0319</td>
<td>0.7021</td>
<td>76</td>
<td>31</td>
</tr>
<tr>
<td>Gujranwala</td>
<td>494</td>
<td>174512</td>
<td>4.2321ab</td>
<td>0.0333</td>
<td>0.6823</td>
<td>68</td>
<td>30</td>
</tr>
<tr>
<td>Sheikhupura</td>
<td>501</td>
<td>194566</td>
<td>4.1898b</td>
<td>0.0402</td>
<td>0.6740</td>
<td>66</td>
<td>24</td>
</tr>
</tbody>
</table>

*S=Species richness, N=Species abundance, H=Shannon’s index, D=Simson’s index, J=Evenness, N1 & N2=Hill’s numbers of diversity (N1=Number of abundant species & N2=Number of species maximum in abundance. Their values were rounded off to nearest whole numbers), Level of significance=5%.

**Note:** The districts bearing same letter are statistically non-significantly different from each other

In the District Sialkot a higher value of (H) showed that it had more abundant species (N1=76) as compared to other districts. Among these abundant species 31 species were maximum in abundance (N=2). But on the other hand a lower value of (D) depicted that it had less number of rare species as compared to other districts. Due to this low rarity the species were distributed with high (70%) evenness (Table 3.4).

For the District Gujranwala the value of (H) showed that in this district abundant species (N1=68) were less than that for Sialkot. Among these abundant species 30 species were maximum in abundance (N2). On the other hand in case of rare species the situation was vice versa i.e. it had more number of rare species than Sialkot. Due to this high rarity the species were distributed with low (68%) evenness as compared to Sialkot (Table 3.4).
For the District Sheikhupura the value of (H) was less but of (D) was high as compared to other districts indicating that it had less number of abundant species but high number of rare species. It is also clear from the values of N1 (66) and N2 (24). Because of high number of rare species, the evenness value, as compared to other districts, was also low which showed that insect species were 67% evenly distributed (Table 3.4).

As biodiversity in an area is based on both the number of individuals (abundance) and the number of species present (Allen et al., 1999; Hubbell, 2001; Magurran, 2004; Beck et al., 2006; Jana et al., 2006). The results show that among three districts, Sheikhupura had greater values for species richness and abundance as compared to other districts leading to propagate a diverse insect fauna besides supporting a high number of rare species as compared to Gujranwala and Sialkot (Table 3.4). The differences of the diversity between the districts of Sialkot and Gujranwala and of Gujranwala and Sheikhupura were statistically non significant. It means that Sialkot and Gujranwala were similar whereas Gujranwala and Sheikhupura were similar but Sialkot and Sheikhupura were different from each other (as they possessed different letters) in case of species composition. Overall species richness and abundance in Sialkot was less and in Sheikhupura was high whereas Gujranwala lied in between the two districts as far as its role in supporting insect diversity (species richness and abundance) was concerned. The reason for high diversity in Sheikhupura is due to the facts that it was less developed (fewer industries having less industrial emissions and less land fragmentation due to housing societies and other infrastructure) as compared to Sialkot and Gujranwala. Also it is located in south, at less height from sea level whereas Sialkot is situated in the north at comparatively high altitude as compared to Sheikhupura and Gujranwala. As a general rule, species diversity and abundance decreases in terrestrial environment as we move towards north and towards higher elevation and altitude (Terborgh, 1973; Begon et al., 1986; Stevens, 1989; Rosenzweig, 1992; Cushman et al., 1993; Farrell and Mitter, 1993; Vaisanen and Heliovaara, 1994; Schoenly et al., 1996; Choe, 1997; Eeley and Foley, 1999; Schafer and Lundstrom, 2001; Sebastian et al., 2005; Amori et al., 2009). All these factors could be among the other reasons that had contributed to support a rich insect fauna in Sheikhupura as compared to other districts.
3.4.3.2: Comparison of effects of LIP & HIP rice crop agroecosystems on the insect diversity among three districts of the Kallar tract

The values of S, N, H, D & J in District Sialkot for LIP were 464, 98877, 4.3025, 0.0313 & 0.7004 but for HIP were 385, 67857, 4.2423, 0.0351 & 0.7126 respectively (Table 3.5, Fig. 3.5c,d). The results indicate that LIP had more number of abundant species (N1=73) and less number of rare species in comparison with HIP. In LIP among 73 abundant species 31 were maximum in abundance (N2). The species in LIP and HIP rice crops were distributed with 70 and 71% evenness respectively. The difference in values of (H) between HIP and LIP in Sialkot was significant (P<0.05) with higher species richness and abundance in LIP fields.

The values of S, N, H, D & J for LIP and HIP fields were almost equal in the District Gujranwala (Table 3.5 & Fig. 3.5c,d). In case of LIP among 65 abundant species (N1) 31 were maximum in abundance (N2) whereas, in HIP fields among 64 abundant species 26 were maximum in abundance. The difference in the values of (H) between LIP and HIP fields was non significant (P>0.05).

### Table 3.5: Effect of LIP & HIP rice crop agroecosystems on insect diversity among three districts.

<table>
<thead>
<tr>
<th>District</th>
<th>Inputs</th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
<th>J</th>
<th>N1</th>
<th>N2</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sialkot</td>
<td>High</td>
<td>385</td>
<td>67857</td>
<td>4.2423</td>
<td>0.0351</td>
<td>0.7126</td>
<td>69</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>464</td>
<td>98877</td>
<td>4.3025</td>
<td>0.0313</td>
<td>0.7004</td>
<td>73</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Gujranwala</td>
<td>High</td>
<td>397</td>
<td>72103</td>
<td>4.1723</td>
<td>0.0381</td>
<td>0.6763</td>
<td>64</td>
<td>26</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>478</td>
<td>102409</td>
<td>4.1756</td>
<td>0.0318</td>
<td>0.6978</td>
<td>65</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Sheikhupura</td>
<td>High</td>
<td>409</td>
<td>78347</td>
<td>4.1168</td>
<td>0.0463</td>
<td>0.6846</td>
<td>61</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>492</td>
<td>116219</td>
<td>4.1790</td>
<td>0.0382</td>
<td>0.6742</td>
<td>65</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

S=Species richness, N=Species abundance, H=Shannon’s index, D=Simson’s index, J=Evenness, N1 & N2=Hill’s numbers of diversity (N1=Number of abundant species & N2=Number of species maximum in abundance. Their values were rounded off to nearest whole numbers), Level of significance=5%.

In case of the District Sheikhupura the values of S, N, H, D & J for LIP were 492, 116219, 4.1790, 0.0382 & 0.6742 but for HIP were 409, 78347, 4.117, 0.046 & 0.685 respectively (Table 3.5 & Fig. 3.5c,d). These results indicate that LIP had more number of abundant species (N1=65) but less number of rare species in comparison with HIP fields. The species in LIP were 67% evenly distributed as compared to HIP rice crop where distribution was with 69% evenness. The difference in values of (H)
between HIP and LIP was significant (P<0.05) along with higher species richness and abundance in LIP fields (Table 3.5).

The higher number of insect species in the organic system (LIP) was possibly due to the availability of suitable substrates for them to breed on, in the absence of polluted and harmful environment due to agrochemicals (Benton et al., 2002a, b).

![Fig. 3.5: Comparison of (a & b) species richness & abundance and comparison of (c, d) species richness and abundance between LIP & HIP rice fields among three districts of the Kallar tract.](image)

### 3.4.4: Spatio-temporal variation

The change in diversity with respect to passage of time or along a time scale is called temporal diversity (da Fonseca and Sarkar, 1998; Drechsler and Settele, 2001; Bambaradeniya and Amerasinghe, 2003). Rice crop during a single cropping season passes through different crop/ecological stages (generally corresponding to a particular month of the growing season) supporting a special type of insect fauna associated with that particular type of crop stage or habitat (Fernando, 1995; Bambaradeniya et al., 1998; Bambaradeniya and Amerasinghe, 2003). During the rice cropping seasons the following changes in the insect fauna of rice crop in each of the three districts of the Kallar tract were noted:
3.4.4.1: Temporal variation in insect faunal diversity in the District Sialkot

The values for S, N, H, D, J were 250, 20529, 3.0610, 0.1358, 0.5544 at pre-nursery; 344, 36890, 3.8140, 0.0551, 0.6530 at nursery; 390, 59158, 4.0882, 0.0432, 0.6852 at tillering-booting; 387, 29216, 4.2696, 0.0333, 0.7166 at flowering-milking; 368, 20909, 4.2342, 0.0395, 0.7167 at grain ripening stage of rice crop (Table 3.6).

Table 3.6: Temporal variation in insect faunal diversity associated with rice crop agroecosystem in the District Sialkot.

<table>
<thead>
<tr>
<th>Crop Stage</th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
<th>J</th>
<th>N1</th>
<th>N2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-nursery (May)</td>
<td>250</td>
<td>20529</td>
<td>3.0610</td>
<td>0.1358</td>
<td>0.5544</td>
<td>21</td>
<td>7</td>
</tr>
<tr>
<td>Nursery (June)</td>
<td>344</td>
<td>36890</td>
<td>3.8140</td>
<td>0.0551</td>
<td>0.6530</td>
<td>45</td>
<td>18</td>
</tr>
<tr>
<td>Tillering-Booting (July-August)</td>
<td>390</td>
<td>59158</td>
<td>4.0882</td>
<td>0.0432</td>
<td>0.6852</td>
<td>59</td>
<td>23</td>
</tr>
<tr>
<td>Flowering-Milking (September)</td>
<td>387</td>
<td>29216</td>
<td>4.2696</td>
<td>0.0333</td>
<td>0.7166</td>
<td>71</td>
<td>30</td>
</tr>
<tr>
<td>Grain Ripening (October)</td>
<td>368</td>
<td>20909</td>
<td>4.2342</td>
<td>0.0395</td>
<td>0.7167</td>
<td>69</td>
<td>25</td>
</tr>
</tbody>
</table>

S=Species richness, N=Species abundance, H=Shannon’s index, D=Simson’s index, J=Evenness, N1 & N2=Hill’s numbers of diversity (N1=Number of abundant species & N2=Number of species maximum in abundance. Their values were rounded off to nearest whole numbers).

In the District Sialkot, insect species richness and abundance increased with crop age and reached maximum at tillering-booting stage in the months of July-August and then declined gradually towards crop maturity. The value of (H) increased from pre-nursery stage and reached at its maximum at flowering-milking stage in the month of September and then decreased slightly at grain ripening stage. It means highest number of abundant species N1 (i.e. 71 species in which 30 species were maximum in abundance) was in the month of September (Table 3.6). The number of rare species (D) was maximum at pre-nursery stage and indicated that most of the species in the month of May (pre-nursery stage) were present in very low number because they had just started to invade the fields where puddling operations had been started. This result was also supported by the fact that at pre-nursery stage abundant species (N1) were least (21) as compared to other crop stages. The rarity decreased as the crop age increased with minimum at flowering-milking stage. This might be due to the drastic effects by application of agrochemicals (in the end of August or in the
start of September) on some sensitive species causing their mortality. As a consequence only abundant species left behind and thus resulted into lower value of rare species. There was, then, a slight increase in the rarity at grain ripening stage in the month of October. The fact was that as the rice crop reached at its maturity, many species including a number of tourist species, visited rice fields to utilize this special type of man made aquatic habitat for many purposes and contributed to increase in rarity.

Besides this at grain ripening stage, the species left for rice crop because of drastic changes in plant and soil which made rice crop less favorable for many species ultimately there was an increase in the rarity of species as compared to flowering-milking stage. The values of (J) also depicted that evenness increased gradually from pre-nursery to grain ripening stages of rice crop gradually with its maximum value (72%) at flowering milking and grain ripening stages.

### 3.4.4.2: Spatio-temporal variation in insect faunal diversity associated with LIP & HIP rice crop agroecosystems in the District Sialkot

For LIP system the values for S, N, H, D, J were 209, 11701, 3.1034, 0.1109, 0.5809 at pre-nursery; 305, 19195, 3.8701, 0.0519, 0.6766 at nursery; 350, 36191, 3.8963 0.0497, 0.6651 at tillering-booting; 340, 19603, 4.1048, 0.0343, 0.7042 flowering-milking; 324, 11532, 4.1937, 0.0373, 0.7255 at grain ripening stage, respectively. But in case of HIP the values for S, N, H, D, J were 157, 8828, 2.7062, 0.19570.5352 at pre-nursery; 299, 17695, 3.5091, 0.0667, 0.6458 at nursery; 281, 22967, 4.1204, 0.0389, 0.7308 at tillering-booting; 281, 9613, 4.1392, 0.0435, 0.7341 at flowering-milking; 259, 9377, 3.9557, 0.0500, 0.7119 at grain ripening stage, respectively (Table 3.7).

The results indicate that species richness and abundance was high for LIP system at all crop stages as compared to HIP system and these were maximum at tillering-booting stage in both of the systems. The values of (H) for LIP indicated that number of abundant species were high for this system, except for tillering-booting and flowering-milking stage where HIP had high values for these stages indicating more number of abundant species, which was also evident from N1 values (61 and 62) for these crop stages for HIP. The values of (D) were also high for HIP for all stages of
crop (except for tillering-booting stage) indicating that HIP system did not allow all the species to attain higher abundance so most of the species remained in scarcity and hence resulted into more number of rare species. At tillering-booting stage rarity was high for LIP as compared to that for HIP. This could be due to HIP practices, especially due to the use of insecticides in the end of August, which did not allow all species to behave in the same manner and affected deleteriously to most of sensitive species resulting into disappearance of these low populated species and consequently number of abundant species at tillering-booting stage in HIP system increased. Due to harms (unfavourable conditions) of intensive farming system sensitive species avoided from HIP system and their population did not increase in abundance and remained below a certain level and contributed to more number of rare species.

**Table 3.7: Spatio-temporal variation in insect faunal diversity associated with LIP & HIP rice crop agroecosystems in the District Sialkot.**

<table>
<thead>
<tr>
<th>Crop Stage</th>
<th>Inputs</th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
<th>J</th>
<th>N1</th>
<th>N2</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-nursery (May)</td>
<td>High</td>
<td>157</td>
<td>8828</td>
<td>2.7062</td>
<td>0.1957</td>
<td>0.5352</td>
<td>14</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>209</td>
<td>11701</td>
<td>3.1034</td>
<td>0.1109</td>
<td>0.5809</td>
<td>22</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Nursery (June)</td>
<td>High</td>
<td>299</td>
<td>17695</td>
<td>3.5091</td>
<td>0.0667</td>
<td>0.6458</td>
<td>33</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>305</td>
<td>19195</td>
<td>3.8701</td>
<td>0.0519</td>
<td>0.6766</td>
<td>47</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Tillering-Booting (July-August)</td>
<td>High</td>
<td>281</td>
<td>22967</td>
<td>4.1204</td>
<td>0.0389</td>
<td>0.7308</td>
<td>61</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>350</td>
<td>36191</td>
<td>3.8963</td>
<td>0.0497</td>
<td>0.6651</td>
<td>49</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Flowering-Milking (September)</td>
<td>High</td>
<td>281</td>
<td>9613</td>
<td>4.1392</td>
<td>0.0435</td>
<td>0.7341</td>
<td>62</td>
<td>23</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>340</td>
<td>19603</td>
<td>4.1048</td>
<td>0.0343</td>
<td>0.7042</td>
<td>60</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Grain Ripening (October)</td>
<td>High</td>
<td>259</td>
<td>9377</td>
<td>3.9557</td>
<td>0.0500</td>
<td>0.7119</td>
<td>52</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>324</td>
<td>11532</td>
<td>4.1937</td>
<td>0.0373</td>
<td>0.7255</td>
<td>66</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

S=Species richness, N=Species abundance, H=Shannon’s index, D=Simson’s index, J=Evenness, N1 & N2=Hill’s numbers of diversity (N1=Number of abundant species & N2=Number of species maximum in abundance. Their values were rounded off to nearest whole numbers), Level of significance=5%.

The species at pre-nursery, nursery and grain ripening stages were distributed with high evenness in LIP indicating that all species had fairly good population than in HIP but with greater evenness at tillering-booting and flowering-milking stages in case of HIP. This could be due to the reduction of sensitive and rare species due to application of agrochemicals resulting in high evenness values for HIP at these crop stages. The difference between the values of (H) for LIP and HIP rice fields was significant (P<0.05) in favour of LIP for all crop stages, except for flowering-milking stage where the difference was non significant (P = 0.05). However, the overall
difference between the values of diversity of LIP and HIP systems with respect to different crop stages was significant along with higher values of species richness and abundance for LIP (P<0.05) (Table 3.7).

3.4.4.3 Temporal variation in insect faunal diversity in the District Gujranwala

The values for S, N, H, D, J were 240, 14828, 3.5542, 0.0685, 0.6485 at pre-nursery; 345, 32728, 3.6341, 0.0639, 0.6219 at nursery; 407, 71946, 3.9862, 0.0373, 0.6634 at tillering-booting; 416, 27206, 4.3388, 0.0291, 0.7195 at flowering-milking; 377, 27613, 4.0300, 0.0510, 0.6793 at grain ripening stage of rice crop, respectively (Table 3.8).

Table 3.8: Temporal variation in insect faunal diversity associated with rice crop agroecosystem in the District Gujranwala.

<table>
<thead>
<tr>
<th>Crop Stage</th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
<th>J</th>
<th>N1</th>
<th>N2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-nursery (May)</td>
<td>240</td>
<td>14828</td>
<td>3.5541</td>
<td>0.0685</td>
<td>0.6485</td>
<td>34</td>
<td>14</td>
</tr>
<tr>
<td>Nursery (June)</td>
<td>345</td>
<td>32728</td>
<td>3.6341</td>
<td>0.0639</td>
<td>0.6219</td>
<td>37</td>
<td>15</td>
</tr>
<tr>
<td>Tillering-Booting (July-August)</td>
<td>407</td>
<td>71946</td>
<td>3.9862</td>
<td>0.0373</td>
<td>0.6634</td>
<td>53</td>
<td>26</td>
</tr>
<tr>
<td>Flowering-Milking (September)</td>
<td>416</td>
<td>27206</td>
<td>4.3388</td>
<td>0.0291</td>
<td>0.7195</td>
<td>76</td>
<td>34</td>
</tr>
<tr>
<td>Grain Ripening (October)</td>
<td>377</td>
<td>27613</td>
<td>4.0300</td>
<td>0.0510</td>
<td>0.6793</td>
<td>56</td>
<td>19</td>
</tr>
</tbody>
</table>

S=Species richness, N=Species abundance, H=Shannon’s index, D=Simson’s index, J=Evenness, N1 & N2=Hill’s numbers of diversity (N1=Number of abundant species & N2=Number of species maximum in abundance. Their values were rounded off to nearest whole numbers).

In the District Gujranwala the values of S, N, H, D, N1 and N2, changed almost in the same manner as for the District Sialkot. The insect fauna of rice crop behaved almost in the same manner for both of the districts. However, the values of (J) responded in a different way in comparison with Sialkot. These fluctuated throughout the crop stages. However, the species at all crop stages were distributed with almost equal evenness with highest (71%) at flowering-milking stage.
3.4.4.4: Spatio-temporal variation in insect faunal diversity associated with LIP & HIP rice crop agroecosystems in District Gujranwala

The values for S, N, H, D, J in case of LIP system were 199, 10729, 3.3637, 0.0823, 0.6355 at pre-nursery; 293, 18591, 3.4976, 0.0823, 0.6158 at nursery; 364, 38449, 3.9631, 0.0408, 0.6720 at tillering-boothing; 369, 1732, 4.2338, 0.0328, 0.7163 at flowering-milking; 318, 16233, 3.8711, 0.0550, 0.6718 at grain ripening stage, respectively. However, in case of HIP the values for S, N, H, D, J were 153, 4099, 3.4912, 0.0803,0.6940 at pre-nursery; 248, 14137, 3.4989, 0.0707, 0.6346 at nursery; 299, 33497, 3.8047, 0.0467, 0.6674 at tillering-booting; 298, 9885, 4.2377, 0.0323, 0.7438 at flowering-milking; 271, 11380, 4.0050, 0.0512, 0.7149 at grain ripening stage, respectively (Table 3.9).

Table 3.9: Spatio-temporal variation in insect faunal diversity associated with LIP & HIP rice crop agroecosystems in the District Gujranwala.

<table>
<thead>
<tr>
<th>Crop Stage</th>
<th>Inputs</th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
<th>J</th>
<th>N1</th>
<th>N2</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-nursery (May)</td>
<td>High</td>
<td>153</td>
<td>4099</td>
<td>3.4912</td>
<td>0.0803</td>
<td>0.6940</td>
<td>32</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>199</td>
<td>10729</td>
<td>3.3637</td>
<td>0.0823</td>
<td>0.6355</td>
<td>28</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Nursery (June)</td>
<td>High</td>
<td>248</td>
<td>14137</td>
<td>3.4989</td>
<td>0.0707</td>
<td>0.6346</td>
<td>33</td>
<td>14</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>293</td>
<td>18591</td>
<td>3.4976</td>
<td>0.0722</td>
<td>0.6158</td>
<td>33</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Tillering-Booting (July-August)</td>
<td>High</td>
<td>299</td>
<td>33497</td>
<td>3.8047</td>
<td>0.0467</td>
<td>0.6674</td>
<td>44</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>364</td>
<td>38449</td>
<td>3.9631</td>
<td>0.0408</td>
<td>0.6720</td>
<td>52</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Flowering-Milking (September)</td>
<td>High</td>
<td>298</td>
<td>9885</td>
<td>4.2377</td>
<td>0.0323</td>
<td>0.7438</td>
<td>69</td>
<td>30</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>369</td>
<td>1732</td>
<td>4.2338</td>
<td>0.0328</td>
<td>0.7163</td>
<td>68</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Grain Ripening (October)</td>
<td>High</td>
<td>271</td>
<td>11380</td>
<td>4.0050</td>
<td>0.0512</td>
<td>0.7149</td>
<td>54</td>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>318</td>
<td>16233</td>
<td>3.8711</td>
<td>0.0550</td>
<td>0.6718</td>
<td>47</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

S=Species richness, N=Species abundance, H=Shannon’s index, D=Simson’s index, J=Evenness, N1 & N2=Hill’s numbers of diversity (N1=Number of abundant species & N2=Number of species maximum in abundance. Their values were rounded off to nearest whole numbers), Level of significance=5%.

In case of Gujranwala mixed type of results with complicated pattern between HIP and LIP were obtained. At some crop stages some diversity values for HIP were higher than for LIP and vice versa. The values of species richness progressively increased from pre-nursery stage and reached at their maximum values at flowering-milking stage and then declined at grain ripening stage. Similarly, species abundance increased from pre-nursery and reached highest in tillering-booting stage and then sharply declined. It was observed that at all crop stages species richness and abundance were higher for LIP rice fields but almost at all crop stages the species...
were distributed with slight high evenness for HIP (Table 3.9).

The differences in values of (H) between LIP and HIP systems were significant (P<0.05) at pre-nursery & grain ripening stage for HIP and at tillering-booting stage for LIP. However, these differences were non significant (P>0.05) at nursery and flowering milking stages. The value of (D) was high at almost all crop stages (except at tillering-booting) for LIP system with highest at pre-nursery and lowest at flowering-milking stage. This indicated that LIP had more number of rare species. The species in LIP system, as a result, were distributed with comparatively low evenness with lowest value of 61% at nursery stage. Similarly, the number of abundant species and species maximum in abundance were also high at almost all crop stages (except at tillering-booting stage) for HIP system with highest value of 69 species among which 30 were maximum in abundance at flowering-milking stage. Overall the difference between diversity of LIP and HIP systems was non significant (P>0.05) (Table 3.5 & 3.9).

3.4.4.5: Temporal variation in insect faunal diversity in the District Sheikhupura

The values for S, N, H, D, J were 236, 18559, 3.0635, 0.1146, 0.5607 at pre-nursery stage; 344, 33470, 3.4911, 0.0938, 0.5977 at nursery; 402, 90914, 4.0140, 0.0424,0.6694 at tillering-booting; 419, 30618, 4.1957, 0.0377, 0.6949 at flowering-milking; 408, 21013, 4.4253, 0.0286, 0.7362 at grain ripening stage, respectively (Table 3.10).

The results indicate that in the District Sheikhupura the insect species richness increased with crop age and reached maximum at flowering-milking in the month of September and then declined at grain ripening stage. The insect abundance also increased with crop age and reached at its maximum at tillering-booting stage in the months of July-August and then decreased drastically towards crop maturity. The value of (H) increased continuously from pre-nursery stage (May) to grain ripening stage (October). The results indicate that grain ripening stage hosted highest number (83) of abundant species in which 34 were maximum in abundance (Table 3.10).

The value of (D) was highest at pre-nursery stage which decreased gradually with crop age. This indicated that rarity decreased with crop age with lowest at grain
### Results and Discussion

#### Table 3.10: Temporal variation in insect faunal diversity associated with rice crop agroecosystem in the District Sheikhupura.

<table>
<thead>
<tr>
<th>Crop Stage</th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
<th>J</th>
<th>N1</th>
<th>N2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-nursery (May)</td>
<td>236</td>
<td>18559</td>
<td>3.0635</td>
<td>0.1146</td>
<td>0.5607</td>
<td>21</td>
<td>8</td>
</tr>
<tr>
<td>Nursery (June)</td>
<td>344</td>
<td>33470</td>
<td>3.4911</td>
<td>0.0938</td>
<td>0.5977</td>
<td>32</td>
<td>10</td>
</tr>
<tr>
<td>Tillering-Booting (July-August)</td>
<td>402</td>
<td>90914</td>
<td>4.0140</td>
<td>0.0424</td>
<td>0.6694</td>
<td>55</td>
<td>23</td>
</tr>
<tr>
<td>Flowering-Milking (September)</td>
<td>419</td>
<td>30618</td>
<td>4.1957</td>
<td>0.0377</td>
<td>0.6949</td>
<td>66</td>
<td>26</td>
</tr>
<tr>
<td>Grain Ripening (October)</td>
<td>408</td>
<td>21013</td>
<td>4.4253</td>
<td>0.0286</td>
<td>0.7362</td>
<td>83</td>
<td>34</td>
</tr>
</tbody>
</table>


ripening stage indicating that at this stage most of the species were present in fairly good number. The value of (J) also increased continuously from pre-nursery to grain ripening stage reflecting that even distribution of species increased as the crop progressed and at grain ripening stage eveness reached at its maximum with 73% even distribution of species. From these results it is evident that District Sheikhupura was different from the other two districts (Sialkot & Gujranwala) because in Sheikhupura diversity followed a uniform and smooth pattern.

### 3.4.4.6: Spatio-temporal variation in insect faunal diversity associated with LIP & HIP rice crop agroecosystems in the District Sheikhupura

In the District Sheikhupura the values for S, N, H, D, J in case of LIP system were 177, 12570, 2.7549, 0.1456, 0.5322 at pre-nursery; 302, 20497, 3.2087, 0.1226, 0.5619 at nursery; 369, 50447, 4.0926, 0.0334, 0.6924 at tillering-booting; 389, 18825, 4.0288, 0.0488, 0.6756 at flowering-milking; 366, 13845, 4.1631, 0.0365, 0.7053 at grain ripening stage, respectively. In case of HIP the values for S, N, H, D, J were 175, 5989, 3.3769, 0.0769, 0.6538 at pre-nursery; 250, 12973, 3.6944, 0.0633, 0.6691 at nursery; 308, 40467, 3.7136, 0.0732, 0.6481 at tillering-booting; 303, 11793, 4.1307, 0.0365, 0.7229 at flowering-milking; 294, 7168, 4.5753, 0.0208, 0.8050 at grain ripening stage, respectively (Table 3.11).
The number of species increased gradually and reached at its maximum at flowering-milking stage in case of LIP while it was maximum at tillering-booting stage in case of HIP field and then there was gradual decline in number of species in both of the systems. But species abundance was highest at tillering-booting stages for both of LIP and HIP fields. The value of (H) for LIP and HIP systems increased continuously from pre-nursery to grain ripening stage with a slight decrease at flowering-milking stage for LIP. The rarity (D) on the other hand for both of the systems was maximum at pre-nursery stage indicating that before the start of crop most of the species present were with lower populations. The rarity of species decreased gradually with crop age but with slight increase in number of rare species at tillering-booting and flowering-milking stage in case of HIP and LIP rice fields, respectively.

Table 3.11: Spatio-temporal variation in insect faunal diversity associated with LIP & HIP rice crop agroecosystems in the District Sheikhupura.

<table>
<thead>
<tr>
<th>Crop Stage</th>
<th>Inputs</th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
<th>J</th>
<th>N1</th>
<th>N2</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-nursery (May)</td>
<td>High</td>
<td>175</td>
<td>5989</td>
<td>3.3769</td>
<td>0.0769</td>
<td>0.6538</td>
<td>29</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>177</td>
<td>12570</td>
<td>2.7549</td>
<td>0.1456</td>
<td>0.5322</td>
<td>15</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Nursery (June)</td>
<td>High</td>
<td>250</td>
<td>12973</td>
<td>3.6944</td>
<td>0.0633</td>
<td>0.6691</td>
<td>40</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>302</td>
<td>20497</td>
<td>3.2087</td>
<td>0.1226</td>
<td>0.5619</td>
<td>24</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Tillering-Booting (July-August)</td>
<td>High</td>
<td>308</td>
<td>40467</td>
<td>3.7136</td>
<td>0.0732</td>
<td>0.6481</td>
<td>41</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>369</td>
<td>50447</td>
<td>4.0926</td>
<td>0.0334</td>
<td>0.6924</td>
<td>59</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Flowering-Milking (September)</td>
<td>High</td>
<td>303</td>
<td>11793</td>
<td>4.1307</td>
<td>0.0365</td>
<td>0.7229</td>
<td>62</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>389</td>
<td>18825</td>
<td>4.0288</td>
<td>0.0488</td>
<td>0.6756</td>
<td>56</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Grain Ripening (October)</td>
<td>High</td>
<td>294</td>
<td>7168</td>
<td>4.5753</td>
<td>0.0208</td>
<td>0.8050</td>
<td>97</td>
<td>48</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>366</td>
<td>13845</td>
<td>4.1631</td>
<td>0.0384</td>
<td>0.7053</td>
<td>64</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

S=Species richness, N=Species abundance, H=Shannon’s index, D=Simson’s index, J=Evenness, N1 & N2=Hill’s numbers of diversity (N1=Number of abundant species & N2=Number of species maximum in abundance. Their values were rounded off to nearest whole numbers), Level of significance=5%

The eveness values also increased as the crop matured with slight decrease at tillering-booting and flowering-milking stages for HIP and LIP systems, respectively. At almost all crop stages (except for tillering-booting stage) the species were distributed with high eveness for HIP. The values of (N1) and (N2) showed that number of abundant species and number of species maximum in abundance was high in case of HIP for various crop stages except for at tillering-booting stage (Table 3.11). The differences in the values of (H) between LIP and HIP rice crop overall and for all crop stages were significant (P<0.05) (Table 3.5 & 3.11).
3.4.4.7: Overall temporal variation in insect faunal diversity in the Kallar tract

In the Kallar tract the overall values for S, N, H, D, J were 361, 53916, 3.3459, 0.0995, 0.5682 at pre-nursery; 450, 103088, 3.7887, 0.0615, 0.6202 at nursery; 482, 222018, 4.1628, 0.0344, 0.6738 at tillering-booting; 488, 87040, 4.4641, 0.0259, 0.7212 at flowering-milking; 484, 69535, 4.3943, 0.0339, 0.7108 at grain ripening stage, respectively (Table 3.12, Fig. 3.6).

Table 3.12: Overall temporal variation in insect faunal diversity associated with rice crop agroecosystem in the Kallar tract.

<table>
<thead>
<tr>
<th>Crop Stage</th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
<th>J</th>
<th>N1</th>
<th>N2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-nursery (May)</td>
<td>361</td>
<td>53916</td>
<td>3.3459</td>
<td>0.0995</td>
<td>0.5682</td>
<td>28</td>
<td>10</td>
</tr>
<tr>
<td>Nursery (June)</td>
<td>450</td>
<td>103088</td>
<td>3.7887</td>
<td>0.0615</td>
<td>0.6202</td>
<td>44</td>
<td>16</td>
</tr>
<tr>
<td>Tillering-Booting (July-August)</td>
<td>482</td>
<td>222018</td>
<td>4.1628</td>
<td>0.0344</td>
<td>0.6738</td>
<td>64</td>
<td>29</td>
</tr>
<tr>
<td>Flowering-Milking (September)</td>
<td>488</td>
<td>87040</td>
<td>4.4641</td>
<td>0.0259</td>
<td>0.7212</td>
<td>86</td>
<td>38</td>
</tr>
<tr>
<td>Grain Ripening (October)</td>
<td>484</td>
<td>69535</td>
<td>4.3943</td>
<td>0.0339</td>
<td>0.7108</td>
<td>80</td>
<td>29</td>
</tr>
</tbody>
</table>

S=Species richness, N=Species abundance, H=Shannon’s index, D=Simson’s index, J=Evenness, N1 & N2=Hill’s numbers of diversity (N1=Number of abundant species & N2=Number of species maximum in abundance. Their values were rounded off to nearest whole numbers), Level of significance=5%.

It is clear from table 3.12 and fig. 3.6 that species richness increased as the rice grew towards maturity with the maximum at flowering-milking stage and then there was a slight decline at grain ripening stage. Similarly, species abundance also increased from pre-nursery to maximum at tillering-booting stage and then declined continuously. The results indicate that species richness was maximum in the month of September but species abundance was maximum in months of July & August which corresponded to flowering-milking and tillering-booting stages of rice crop respectively. The (H) increased continuously from pre-nursery stage towards crop maturity with maximum at flowering-milking stage and with a slight decrease at grain ripening stage. The number of rare species (D) was maximum at pre-nursery stage which gradually decreased with age of crop and attained lowest value at flowering-milking and then increases slightly at grain ripening stage. These changes in values of (D) indicated that number of rare species decreased as crop matured because with the
passage of time all the invading species started to increase their population in rice crop habitat and hence the $(J)$ increased with crop age. The evenness values reflected that number of individuals of all species increased as the crop progressed. The values of $N_1$ and $N_2$ also followed the same pattern with some decline at grain ripening stage (Table 3.12). The results are in accordance with those of Heong et al. (1991), Suhling et al. (2000) and Wilby et al. (2006).

![Comparison of insect species richness and abundance at various stages of rice crop](image)

Fig. 3.6: Comparison of insect species (a) richness and (b) at various stages of rice crop in the Kallar tract.

### 3.4.4.8: Overall spatio-temporal variation in insect faunal diversity associated with LIP & HIP rice crop agroecosystems in the Kallar tract

In the Kallar tract the overall values for $S$, $N$, $H$, $D$, $J$ in case of LIP system were 310, 35000, 3.2429, 0.1047, 0.5653 at pre-nursery; 419, 58283, 3.6961, 0.0691, 0.6121 at nursery; 459, 125087, 4.1617, 0.0351, 0.6790 at tillering-booting; 472, 55749, 4.3829, 0.0284, 0.7119 at flowering-milking; 458, 41610, 4.2959, 0.0362, 0.7012 at grain ripening stage, respectively. In case of HIP the values for $S$, $N$, $H$, $D$, $J$ were 266, 18916, 3.3684, 0.0941, 0.6033 at pre-nursery; 350, 44805, 3.7604, 0.0580, 0.6419 at nursery; 404, 96931, 4.0327, 0.0406, 0.6720 at tillering-booting; 404,
Results and Discussion

31291, 4.4390, 0.0257, 0.7397 at flowering-milking; 389, 27925, 4.4015, 0.0324, 0.7381 at grain ripening stage, respectively (Table 3.13 & Fig. 3.7).

**Table 3.13: Overall spatio-temporal variation in insect faunal diversity associated with LIP & HIP rice crop agroecosystems in the Kallar tract.**

<table>
<thead>
<tr>
<th>Crop Stage</th>
<th>Inputs</th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
<th>J</th>
<th>N1</th>
<th>N2</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-nursery (May)</td>
<td>High</td>
<td>266</td>
<td>18916</td>
<td>3.3684</td>
<td>0.0941</td>
<td>0.6033</td>
<td>29</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>310</td>
<td>35000</td>
<td>3.2429</td>
<td>0.1047</td>
<td>0.5653</td>
<td>25</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Nursery (June)</td>
<td>High</td>
<td>350</td>
<td>44805</td>
<td>3.7604</td>
<td>0.0580</td>
<td>0.6419</td>
<td>42</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>419</td>
<td>58283</td>
<td>3.6961</td>
<td>0.0691</td>
<td>0.6121</td>
<td>40</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Tillering-Booting (July-August)</td>
<td>High</td>
<td>404</td>
<td>96931</td>
<td>4.0327</td>
<td>0.0406</td>
<td>0.6720</td>
<td>56</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>459</td>
<td>125087</td>
<td>4.1617</td>
<td>0.0351</td>
<td>0.6790</td>
<td>64</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Flowering-Milking (September)</td>
<td>High</td>
<td>404</td>
<td>31291</td>
<td>4.4390</td>
<td>0.0257</td>
<td>0.7397</td>
<td>84</td>
<td>38</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>472</td>
<td>55749</td>
<td>4.3829</td>
<td>0.0284</td>
<td>0.7119</td>
<td>80</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Grain Ripening (October)</td>
<td>High</td>
<td>389</td>
<td>27925</td>
<td>4.4015</td>
<td>0.0324</td>
<td>0.7381</td>
<td>81</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>458</td>
<td>41610</td>
<td>4.2959</td>
<td>0.0362</td>
<td>0.7012</td>
<td>73</td>
<td>27</td>
<td></td>
</tr>
</tbody>
</table>

S=Species richness, N=Species abundance, H=Shannon's index, D=Simson's index, J=Evenness, N1 & N2=Hill’s numbers of diversity (N1=Number of abundant species & N2=Number of species maximum in abundance. Their values were rounded off to nearest whole numbers), Level of significance=5%.

It is evident from table 3.13 & fig. 3.7 that the values of S, H, J, N1 and N2 increased with crop age and reached at their maximum at flowering-milking stage of the rice crop in September for both HIP and LIP systems and then declined at grain ripening stage in October. The species abundance also increased with crop age and was maximum at tillering-booting stage in July-August for both of the systems and then declined towards crop maturity. The number of rare species (D) decreased with crop age and was minimum at flowering-milking stage, it then increased slightly at grain ripening stage. These results suggested that maximum number of insect species utilized rice crop agroecosystem as a habitat at flowering-milking stage. The values of (H) indicating abundant species in sampled population for both of the systems were also maximum at flowering-milking stage. It is clear that at flowering-milking stage due to high number of abundant species the number of rare species was less. Almost at all crop stages (except at tillering-booting stage) the species were distributed with high evenness for HIP. Similarly, N1 and N2 were also higher at flowering-milking stage. The differences among the values of (H) at all crop stages were significant (P<0.05) in favour of HIP system except for tillering-booting stage (Table 3.13).
3.4.5: Diversity of trophic guilds

3.4.5.1: Diversity of various trophic guilds of insects

Among the arthropods the insects constitute a major group of rice field fauna. The collected insects were categorized into functional guilds based on their role in rice crop agroecosystem. The five major insect trophic categories identified were:

1. Rice herbivores (both major and minor pests)
2. Non rice plant feeders (NRP); included the insects: which were pest of crops other than rice, weed feeders, the visitors/tourists or the neutral insect i.e., with no known role in rice crop and visit this ecosystem for variety of purposes
3. Predators
4. Parasitoids (the natural enemies) and lastly
5. The scavengers/detritivors/decomposers.
The percentage of recorded species of rice plant herbivores, NRP/neutral, parasitoids, predators and scavengers/detritivors was 26.5, 22.9, 9.2, 32.5 and 8.8% respectively (Fig. 3.8). Results of similar pattern are also obtained by Bambaradeniya et al., 2004. The results indicate that natural enemies (predators and parasitoids) the important biological control agents, constituted a big portion (41.7%) of sampled population. Predators mainly included carabid beetles, dragonflies and aquatic & terrestrial predatory bugs, while parasitoids include many species of hymenopteran wasps and a few species of dipteran flies. The complex trophic linkages among the various trophic guilds operating in rice crop ecosystem ensure the proper functioning of its processes. According to Ooi and Shepard (1994) long histories of rice cultivation have allowed stable relationship to evolve between rice pest insects and their natural enemies and in turn the stability of rice crop ecosystem depends upon the efficient trophic interactions among these functional types.

The values for S, N, H, D, J were 138, 53946, 3.9735, 0.0358, 0.8064 for herbivores; 119, 63133, 3.2577, 0.0702, 0.6817 for NRP; 48, 18953, 3.1049, 0.0713, 0.8021 for parasitoids; 169, 230386, 3.4626, 0.0611 0.6750 for predators; 46, 169394, 1.9616, 0.2082, 0.5124 for scavengers, respectively (Table 3.14; Fig. 3.9).

The rice herbivores ranked 2nd for (S) and 3rd for (N). A high value of (H) and low (D) indicate these consisted of more number of abundant and less number of rare

Fig. 3.8: Percent contribution of various trophic guilds in sampled population in the Kallar tract.
species. Resultantly the herbivores were 80% evenly distributed with 53 abundant species among which 26 species were maximum in abundance.

Table 3.14: Diversity of various trophic guilds of insects associated with rice crop agroecosystem in the Kallar tract.

<table>
<thead>
<tr>
<th>Status</th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
<th>J</th>
<th>N1</th>
<th>N2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbivores</td>
<td>138</td>
<td>53946</td>
<td>3.9735</td>
<td>0.0358</td>
<td>0.8064</td>
<td>53</td>
<td>28</td>
</tr>
<tr>
<td>NRP</td>
<td>119</td>
<td>63133</td>
<td>3.2577</td>
<td>0.0702</td>
<td>0.6817</td>
<td>26</td>
<td>14</td>
</tr>
<tr>
<td>Parasitoids</td>
<td>48</td>
<td>18953</td>
<td>3.1049</td>
<td>0.0713</td>
<td>0.8021</td>
<td>22</td>
<td>14</td>
</tr>
<tr>
<td>Predators</td>
<td>169</td>
<td>230386</td>
<td>3.4626</td>
<td>0.0611</td>
<td>0.6750</td>
<td>32</td>
<td>16</td>
</tr>
<tr>
<td>Scavengers</td>
<td>46</td>
<td>169394</td>
<td>1.9616</td>
<td>0.2082</td>
<td>0.5124</td>
<td>7</td>
<td>4</td>
</tr>
</tbody>
</table>

S=Species richness, N=Species abundance, H=Shannon’s index, D=Simson’s index, J=Evenness, N1 & N2=Hill’s numbers of diversity (N1=Number of abundant species & N2=Number of species maximum in abundance. Their values were rounded off to nearest whole numbers).

The NRP/visitors ranked 3rd for (S) and 2nd for (N). In comparison with rice herbivores, they possessed low (H) and a high (D) indicated less number of abundant and more of rare species. This could be due to the reason that tourist insects only visited rice fields and did not adopt this habitat permanently and consequently most of species of this trophic guild remained with lower population i.e. in rarity. In this case out of 119 species 26 were abundant and among these 14 were maximum in abundance.

The parasitoids ranked 4th for (S) and 5th for (N). From the values of H, D and J it is clear that species of parasitoids were 80% evenly distributed. This indicated that it had more number of abundant species but less of rare species. It is also clear from the values of Hill’s numbers which showed that out of 48 species 22 were abundant and among these 14 were those maximum in abundance.
The predators had highest species richness ($S$) and abundance ($N$) but a low value of ($J$) indicated that species of predators were distributed with low evenness. This also indicated that it had more number of rare species and less of abundant species. In comparison with herbivores a low value of ($H$) and high of ($D$) indicated that although predators had more species richness and abundance but number of abundant species was less and number of rare species was more as compared to rice herbivores. The predators were 67% evenly distributed with 32 abundant species in which 16 were maximum in abundance. Anyhow, from the results it is clear that species richness and abundance of predators was high as compared to rice herbivores. These results are in accordance with those of Way and Heong (1994).

In case of scavengers ($S$) was lowest but ($N$) ranked 2$^{nd}$ after predators. From the values of ($H$), ($D$) and ($J$) it is evident that about 51% species were evenly distributed. This low evenness was due to high number of rare species and low number of abundant species. These results were further strengthened by the Hill’s numbers which showed that out of 46 species of parasitoids only 7 were in abundance and among these there were only 4 species present maximum in abundance. It is clear from table 3.14 and fig. 3.9 that rice fields sustained abundant population of scavengers/detritivores which was distributed among 48 species. The presence of detritivores played an important role in supporting natural enemies’ population at a critical time of season soon after crop establishment by providing alternative prey. The species constituting alternate prey also called linking species (Settle, 2001). These species provide predator’s population a head start on later developing pest population, so are of crucial importance for effective natural control of pest species (Ban and kiritani, 1980; Settle et al., 1996; Islam et al., 2003; Wilby et al., 2006).

It is also clear from 3.14 and fig. 3.9 that rice crop supported a rich fauna of natural enemies consisting of 217 species which had high species richness and abundance than rice herbivores (consisting of only 138 species in which six species were major and 132 minor pest of rice). These results are in agreement with those of Ahmad, (1985), Heong et al. (1991), Ooi and Shepard, (1994), Way and Heong, (1994), Settle et al. (1996), Islam et al. (2003), Bambaradeniya et al. (2004), Lavelle et al. (2004) and Ignacimuthu, (2005). The present study thus strengthens the claims that rice crop supports high species richness and abundance of various trophic guilds.
leading to stable interactions. In most of cases species richness and abundance of natural enemies remained greater than those of the pest population and intervention by pesticides usually not required (Ooi and Shepard, 1994; Way and Heong, 1994). Such rich and diverse insect fauna could be the cornerstone of modern IPM program which resonates with the concepts of sustainable development in agriculture (Heong et al., 1991; Settle et al., 1996; Bambaradeniya and Amerasinghe, 2003 and Islam et al., 2003).

3.4.5.2: Diversity of trophic guilds of insects associated LIP & HIP rice crops

For LIP rice fields the values for S, N, H, D, J were 136, 30252, 3.9432, 0.0377, 0.8027 for herbivores; 118, 29064, 3.4242, 0.0558, 0.7178 for NRP; 48, 11297, 3.2307, 0.0570, 0.8346 for parasitoids; 167, 147686, 3.4440, 0.0630, 0.6729 for predators; 46, 99206, 2.0174, 0.1997, 0.5269 for scavengers, respectively. In case of HIP the values for S, N, H, D, J were 123, 23694, 3.9619, 0.0353, 0.8102 for herbivores; 98, 34069, 3.0132, 0.0932, 0.6572 for NRP; 44, 7656, 2.7942, 0.1034, 0.7384 for parasitoids; 151, 82700, 3.4529, 0.0597, 0.6882 for predators; 42, 70188, 1.8542, 0.2214, 0.4961 for scavengers, respectively (Table 3.15).

It is clear from table 3.15 and fig. 3.10 that LIP systems were more species rich with high species abundance as compared to HIP. These results are in conformity with those of Bengtsson et al. (2005).

A slight high value of (H) for HIP in case of herbivores indicated that the systems receiving greater amounts of inputs had more number of abundant species (52) as compared to LIP. On the other hand HIP systems had less number of rare species as compared to LIP. This suggested that in HIP systems agrochemicals used in high quantities had deleterious effects on species leading to low species richness and abundance. However, LIP had higher values for species richness and abundance (Table 3.15, Fig. 3.10). The difference in values of (H) between HIP and LIP systems statistically was non significant (P=0.05).

In case of NRP the value of (H) for HIP was low but was high for LIP indicating that HIP systems supported less number of abundant species and more of rare species as indicated by high value of (D) for HIP. These results indicate that a
number of species of NRP visited LIP fields frequently as compared to their visits of HIP rice fields. Although, HIP systems had high species abundance (Table 3.15, Fig. 3.10) but at the same time a high value of (D) indicated that this abundance was only due to a few species and rest of the species were in rarity. Since, most of the species in HIP were less in abundance (rare) which ultimately affected the even distribution of species. Consequently, the species in LIP systems were distributed with more (71%) evenness as compared to HIP systems. The difference in values of (H) between HIP and LIP was statistically significant (P>0.05).

Table 3.15: Diversity of trophic guilds of insects associated LIP & HIP rice crop agroecosystems in the Kallar tract.

<table>
<thead>
<tr>
<th>Status</th>
<th>Inputs</th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
<th>J</th>
<th>N1</th>
<th>N2</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbivores</td>
<td>High</td>
<td>123</td>
<td>23694</td>
<td>3.9619</td>
<td>0.0353</td>
<td>0.8102</td>
<td>52</td>
<td>28</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>136</td>
<td>30252</td>
<td>3.9432</td>
<td>0.0377</td>
<td>0.8027</td>
<td>51</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>NRP</td>
<td>High</td>
<td>98</td>
<td>34069</td>
<td>3.0132</td>
<td>0.0932</td>
<td>0.6572</td>
<td>20</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>118</td>
<td>29064</td>
<td>3.4242</td>
<td>0.0558</td>
<td>0.7178</td>
<td>30</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Parasitoids</td>
<td>High</td>
<td>44</td>
<td>7656</td>
<td>2.7942</td>
<td>0.1034</td>
<td>0.7384</td>
<td>16</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>48</td>
<td>11297</td>
<td>3.2307</td>
<td>0.0570</td>
<td>0.8346</td>
<td>25</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Predators</td>
<td>High</td>
<td>151</td>
<td>82700</td>
<td>3.4529</td>
<td>0.0597</td>
<td>0.6882</td>
<td>31</td>
<td>16</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>167</td>
<td>147686</td>
<td>3.4440</td>
<td>0.0630</td>
<td>0.6729</td>
<td>31</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Scavengers</td>
<td>High</td>
<td>42</td>
<td>70188</td>
<td>1.8542</td>
<td>0.2214</td>
<td>0.4961</td>
<td>6</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>46</td>
<td>99206</td>
<td>2.0174</td>
<td>0.1997</td>
<td>0.5269</td>
<td>7</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

S=Species richness, N=Species abundance, H=Shannon’s index, D=Simson’s index, J=Evenness, N1 & N2=Hill’s numbers of diversity (N1=Number of abundant species & N2=Number of species maximum in abundance. Their values were rounded off to nearest whole numbers), Level of significance=5%.

For parasitoids in case of HIP the values for (H) and (J) were lower while (D) was high as compared these for LIP. This depicted that parasitoids in HIP were with less number of abundant species (N1=16) and with more number of rare species. The higher values of (H) & (J) and lower (D) in case of LIP showed that this system had
more number of abundant species (N1=25) and the species were distributed evenly with a high evenness (83%). These results suggested that majority of the species of parasitoids preferred LIP system and also that natural enemies were affected negatively by conventional agricultural practices (Table 3.15, Fig. 3.10). The difference in values of (H) between HIP and LIP was statistically significant (P>0.05). The results are in accordance with the findings of Bengtsson et al. (2005).

In case of predators the values for all diversity indices were almost similar. Hence the difference between HIP and LIP was statistically non significant (P>0.05). However, LIP systems had more species richness and abundance as compared to HIP systems (Table 3.15, Fig. 3.10). These results are in accordance with those of Winston, (1997), Paoletti et al. (1999) and Wilson et al. (2008).

From table 3.15 it is also clear that LIP system had high diversity of herbivores which in turn supported a high diversity of predators and parasitoids in this system (Siemann, 1998). There are many factors that influence the abundance of natural enemy’s groups in the agricultural landscape. Many of these factors (e.g., agrochemicals) are under the control of the individual farmers, who can manage their land and resources to increase the abundance of beneficial organism groups (Bengtsson et al., 2005). From the results it is clear that rice ecosystem hosts a very rich and diverse complex fauna of herbivores and their natural enemies, often leading a fairly stable system unless disturbed by agrochemicals (Islam et al., 2003).

In case of scavengers the values for (H) and (J) were lower for HIP as compared to LIP systems. This indicated that in LIP systems most of species were present in abundance distributed with high evenness (52%) as compared to HIP systems (Table 3.15, Fig. 3.10). The value of (D) in case of HIP was high as compared to LIP indicating that in case of HIP there was more number of rare species because higher amounts of agricultural inputs did not allow all the species to flourish and attain high abundance. Due to this high rarity the species were distributed with low evenness. Consequently, HIP and LIP systems were statistically significantly (P<0.05) different from each other.
3.4.5.3: Temporal variation in diversity of trophic guilds

Rice plant passes through different morphological stages during a single cropping season and each of these stages harbored a particular insect fauna (Bambaradeniya et al., 2004). So, diversity of all trophic guilds continuously changed with growth of rice crop. As this diversity changed with passage of time so, could be called as temporal diversity.

**Diversity of rice herbivores**

For herbivores the values of \( S, N, H, D, J \) were 84, 2854, 3.3275, 0.0671, 0.7555 at pre-nursery; 114, 7477, 3.6878, 0.0454, 0.7786 at nursery; 132, 13525, 3.7911, 0.0420, 0.7764 at tillering-booting; 134, 19437, 3.4875, 0.0818, 0.7121 at flowering-milking; 132, 10653, 3.8466, 0.0456, 0.7878 at grain ripening stage, respectively (Table 3.16).

It is clear from table 3.16 and fig. 3.11 that species richness (\( S \)) and abundance (\( N \)) of rice insect herbivores increased with rice crop age. These reached at their maximum values at flowering-milking stage of the crop and then declined at grain ripening stage. The value of (\( H \)) increased with crop age and was maximum at grain ripening stage indicating that at this stage number of abundant species (\( N_1 \)) was high (47) among which 24 were maximum (\( N_2 \)) in abundance as compared to other crop stages. The value of (\( D \)) was maximum at flowering-milking stage indicating that at this stage the number of rare species was high. This value was lowest at tillering-booting stage indicating that at this stage rarity was less and almost all species were present in fairly good number. The eveness at all crop stages was almost the same indicating that all the species of rice crop herbivores were present with equal distribution. The results are in conformity with those of Wilby et al. (2006).

**Diversity of NRP**

For NRP the values of \( S, N, H, D, J \) were 75, 5129, 3.2620, 0.0546, 0.7536 at pre-nursery; 91, 10666, 3.2471, 0.0607, 0.7198 at nursery; 94, 31382, 2.6943, 0.1242, 0.5930 at tillering-booting; 111, 11660, 3.3646, 0.0656, 0.7144 at flowering-milking; 102, 4296, 3.5968, 0.0456, 0.7777 at grain ripening stage, respectively (Table 3.16).

In case of NRP the values of species richness and abundance also increased with crop age and reached at their maximum at flowering milking and tillering
Table 3.16: Temporal variation in diversity of trophic guilds of insects associated with rice crop agroecosystem in the Kallar tract.

<table>
<thead>
<tr>
<th>Status</th>
<th>Crop Stage</th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
<th>J</th>
<th>N1</th>
<th>N2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbivores</td>
<td>Pre-nursery</td>
<td>84</td>
<td>2854</td>
<td>3.3275</td>
<td>0.0671</td>
<td>0.7555</td>
<td>26</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Nursery</td>
<td>114</td>
<td>7477</td>
<td>3.6878</td>
<td>0.0454</td>
<td>0.7786</td>
<td>40</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Tillering-Booting</td>
<td>132</td>
<td>13525</td>
<td>3.7911</td>
<td>0.0420</td>
<td>0.7786</td>
<td>44</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Flowering-Milking</td>
<td>134</td>
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<td>1.9240</td>
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<td>1.7984</td>
<td>0.2709</td>
<td>0.4697</td>
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S=Species richness, N=Species abundance, H=Shannon’s index, D=Simson’s index, J=Evenness, N1 & N2=Hill’s numbers of diversity (N1=Number of abundant species & N2=Number of species maximum in abundance. Their values were rounded off to nearest whole numbers).

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booting stages of rice crop respectively and then decreased gradually (Table 3.16, Fig. 3.11).

The (H) fluctuated throughout the crop stages and was maximum at grain ripening stage. This showed that at this crop stage number of abundant species (N1) was the maximum (36). Out of these abundant species 22 were maximum in abundance (N2). The other crop stages, on contrary, possessed lower values for (H) indicating that number of abundant species at those crop stages was also low with lowest at tillering-booting stage. At this stage the number of abundant species was
only 14 in which 8 were present maximum in abundance. The number of rare species first increased with crop age and reached to maximum at tillering-booting stage and then decreased gradually with crop age with lowest at grain ripening stage. These results suggested that most of the species of NRP did not prefer rice crop at tillering-booting stage (for breeding or other purposes) as compared to other crop stages. Resultantly rarity was less before and after this stage. The species at all crop stages were almost evenly distributed (>70%) except for tillering-booting stage where the species were distributed with low (59%) evenness because of large number of rare species at this stage (Table 3.16).
Diversity of parasitoids

In case of parasitoids the values of S, N, H, D, J were 36, 378, 3.0339, 0.0630, 0.8466 at pre-nursery; 44, 1614, 3.1530, 0.0568, 0.8332 at nursery; 46, 9056, 2.7684, 0.1195, 0.7231 at tillering-booting; 45, 2353, 3.3404, 0.0463, 0.8775 at flowering-milking; 48, 5552, 3.1699, 0.0622, 0.8188 at grain ripening stage, respectively (Table 3.16).

The species richness in case of parasitoids gradually increased with crop age and with a slight decrease at flowering-milking stage, became maximum at grain ripening stage. In case of species abundance it first increased with increase in crop age with the highest at tillering-booting stage and then after a drastic decline at flowering-milking stage, increased again at grain ripening stage (Table 3.16, Fig. 3.11). The value of (H) was maximum at flowering-milking stage which indicated that number of abundant species was high (28) in which 21 species were maximum in abundance, while at other crop stages (H) was low with the lowest value at tillering-booting stage of rice crop with only 16 abundant species in which 8 were maximum in abundance. On the other hand rarity (D) fluctuated throughout the crop stages. It first decreased with crop age and then with sudden increase reached at highest at tillering-booting stage and after that declined to its lowest value at flowering-milking stage and then again increased slightly at grain ripening stage. This indicated that number of rare species of parasitoids was maximum at tillering-booting stage and was minimum at flowering-milking stage. The species at all rice crop stages were distributed almost with equal (78%) evenness with a lowest value of about 72% at tillering-booting stage because of highest number of rare species. The results are different from those of Wilby et al. (2006).

Diversity of predators

For predators the values of S, N, H, D, J were 122, 12056, 3.2970, 0.0730, 0.6863 at pre-nursery; 155, 27215, 3.4612, 0.0555, 0.6863 at nursery; 166, 124806, 3.2797, 0.0696, 0.6416 at tillering-booting; 153, 39106, 3.1693, 0.0827, 0.8775 at flowering-milking; 156, 30203, 3.3738, 0.0660, 0.6681 at grain ripening stage, respectively (Table 3.16).
The predators’ species richness increased with crop age and reached at its maximum value at tillering-booting stage, which after a decline at flowering-milking stage again increased at grain ripening stage. The species abundance increased with crop age with maximum at tillering-booting stage which then decreased abruptly at flowering-milking stage and became lowest at grain ripening stage (Table 3.16, Fig. 3.11). It means at tillering-booting stage species richness and abundance was highest. The (H) fluctuated throughout rice crop stages with the highest value at nursery and lowest at flowering-milking stage. This indicated that nursery stage hosted highest (32) number of abundant species (N1) among which 18 species were maximum in abundance (N2). At flowering-milking stage number of abundant species was lowest and of rare species (D) was highest which decreased from pre-nursery to nursery stage and then increased with crop age and reached at its maximum value at flowering-milking stage and then decreased slightly at grain ripening stage. The species of predator at all rice crop stages were distributed with almost equal eveness (>63%). The results are similar to the findings of Suhling et al. (2000), Lavelle (2004) and Wilby et al. (2006).

**Diversity of scavengers**

In case of scavengers the values of S, N, H, D, J were 44, 33499, 1.6998, 0.2465, 0.4492 at pre-nursery; 46, 56116, 1.9277, 0.1915, 0.5035 at nursery; 44, 43464, 1.9240, 0.2515, 0.5084 at tillering-booting; 45, 17484, 2.1929, 0.1574, 0.5761 at flowering-milking; 46, 18831, 1.7984, 0.2709, 0.4697 at grain ripening stage, respectively (Table 3.16).

In the diversity composition of scavengers notable changes were observed throughout the rice growing. The species richness remained almost the same at all crop stages with slight fluctuations (Wilby et al., 2006). However, the species abundance was maximum at nursery stage followed by tillering-booting, pre-nursery, grain ripening and flowering-milking stage, respectively (Table 3.16, Fig. 3.11). The results are in agreement with those of Suhling et al. (2000) and Wilby et al. (2006). The highest value of species abundance at nursery stage could be due to the reason that during nursery stage all the rice fields in the area were in flooded conditions and were under process of preparation for rice nurseries transplantation and the process of decomposition of dead organic matter (OM) was high but during grain ripening stage...
lowest value of scavengers could be due to the fact that at this stage as fields remain dried and process of decomposition of dead OM, thus slows down. The \((H)\) value after some fluctuations reached to its maximum at flowering-milking stage and then declined at grain ripening stage. At this stage rarity \((D)\) was also lowest. It means that at flowering-milking stage highest number of abundant species \((N1=9)\) was present. Among these 9 species 6 were those present maximum in abundance. The value of \((D)\) was highest at grain ripening stage indicating that at this stage number of rare species was maximum because most of the species of this guild had left the rice field. This was also because many of the species inhabiting rice fields belonged to opportunistic biota which utilized rice field for a certain time period. The species in this case were distributed with less evenness that was maximum \((57\%)\) at flowering-milking stage and least \((44\%)\) at pre-nursery stage (Table 3.16).

A relationship among insect herbivores, predators and scavengers was established on the basis of above described results. In the beginning of rice crop predators were less in abundance, which fed on scavengers (present in fairly good abundance). At this stage the rice herbivores were in scarcity and scavengers acted as alternative prey for the predators of rice herbivores. At tillering-booting stage population of predators became highest which caused severe reduction in population of scavengers by feeding on them. As a result population of scavengers drastically declined at tillering-booting and flowering-milking-stage. The population reduction of scavengers at tillering-booting stage caused decline in population of predators which continued decreasing towards crop maturity and was stressed further by application of insecticides at tillering-booting/flowering-milking stage. Therefore, the insecticides should be used very carefully i.e., only on need basis. Due to reduction in predators’ population at flowering-milking stage population of herbivores at this stage became highest and then decreased at grain ripening stage because of crop maturity.

3.4.5.4 Spatio-temporal variation in the diversity of trophic guilds

Insect diversity of various trophic guilds with respect to different localities (receiving different amounts of inputs) and at different stages of rice crop could be referred as spatio-temporal diversity. Both of the rice production systems (LIP and
HIPC) and different stages of rice crop had strongly influenced the diversity of trophic
guilds as described in the following:

**Spatio-temporal variation in the diversity of herbivores associated LIP & HIP rice crops**

For herbivores in LIP rice fields the values for S, N, H, D, J were 62, 1719, 3.0843, 0.0873, 0.7473 at pre-nursery; 105, 4523, 3.5095, 0.0576, 0.7540 at nursery; 126, 7129, 3.7826, 0.0428, 0.7821 at tillering-booting; 131, 11117, 3.5203, 0.0742, 0.7221 at flowering-milking; 128, 5764, 3.7750, 0.0485, 0.7780 at grain ripening stage, respectively. However, in case of HIP the values for S, N, H, D, J were 66, 1135, 3.4529, 0.0482, 0.8241 at pre-nursery; 93, 2954, 3.7230, 0.0394, 0.8214 at nursery; 118, 6396, 3.7137, 0.0437, 0.7784 at tillering-booting; 127, 8320, 3.3327, 0.1004, 0.6880 at flowering-milking; 113, 4889, 3.7627, 0.0399, 0.7959 at grain ripening stage, respectively (Table 3.17).

For rice herbivores the species richness (S) and abundance (N) was high at all
crop stages in case of LIP except for species richness at pre-nursery stage where
number of species was high in case of HIP (Table 3.17, Fig. 3.12). Similarly (H) was
high at pre-nursery and at nursery stages for HIP whereas at all other crop stages it
was high for LIP. This indicated that at all crop stages LIP systems maintained more
number of abundant species. The (D) in most of crop stages was high in case of LIP
indicating that LIP systems besides maintaining abundant species also supported
many of the rare species. The eveness values for herbivores in case of HIP were high
as compared to those for LIP which could be due to the fact that LIP systems also
supported many rare species due to which eveness values decreased in comparison
with HIP systems. The values of (H) between HIP and LIP systems at all crop stages
were statistically significantly different (P<0.05) from each other except for grain
ripening stage where the difference was statistically non-significantly (P>0.05).

**Spatio-temporal variation in the diversity of NRP associated LIP & HIP rice crops**

For NRP in LIP rice fields the values for S, N, H, D, J were 69, 3237, 3.0452, 0.0737, 0.7192 at pre-nursery; 84, 4530, 3.1866, 0.0769, 0.7192 at nursery; 83, 11724, 2.9638, 0.0927, 0.6721 at tillering-booting; 106, 6971, 3.2221, 0.0835, 0.6909 at flowering-milking; 90, 2602, 3.3224, 0.0728, 0.7383 at grain ripening stage, respectively. However, in case of HIP the values for S, N, H, D, J were 56, 1892, 3.1417, 0.0682, 0.7805 at pre-nursery; 69, 6136, 3.0620, 0.0696, 0.7232 at nursery;
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77, 19658, 2.4433, 0.1565, 0.5625 at tillering-booting; 83, 4689, 3.2905, 0.0688, 0.7447 at flowering-milking; 70, 1694, 3.5757, 0.0382, 0.8417 at grain ripening stage, respectively (Table 3.17).

In case of NRP species richness at all crop stages was high for LIP indicating that for NRP the preferred habitats were with LIP. Similarly, species abundance was also high for LIP except for nursery and tillering-booting stage (Table 3.17, Fig. 3.12). The (H) values for LIP at nursery and tillering-booting stages were high whereas at pre-nursery, flowering-milking and grain ripening stages these were high for HIP. This indicated that in case of HIP abundant species were more which eventually affected rarity of species which in all cases was high for LIP except for tillering-booting stage where (D) was high in case of HIP in comparison with LIP. This could be due to application of biocides at this stage which adversely affected some of the species. This resulted into their low population which increased number of rare species. Species were with greater eveness (>74%) in case of HIP as compared to (<73%) for LIP at pre-nursery, flowering-milking and grain-ripening stages. However, eveness was almost equal at nursery stage for both HIP & LIP whereas was high only at tillering-booting stage for LIP. The differences in values of (H) between HIP and LIP systems were statistically significant (P<0.05) for all crop stages.

Spatio-temporal variation in the diversity of parasitoids associated LIP & HIP rice crops

For parasitoids in LIP rice fields the values for S, N, H, D, J were 26, 196, 2.6561, 0.0996, 0.8152 at pre-nursery; 43, 852, 3.2421, 0.0494, 0.8620 at nursery; 46, 5311, 2.9438, 0.0938, 0.7689 at tillering-booting; 44, 1595, 3.3029, 0.0469, 0.8728 at flowering-milking; 47, 3343, 3.1551, 0.0634, 0.8195 at grain ripening stage, respectively. However, in case of HIP the values for S, N, H, D, J were 21, 182, 2.6182, 0.0867, 0.8600 at pre-nursery; 28, 762, 2.6389, 0.1087, 0.7919 at nursery; 39, 3745, 2.4029, 0.1690, 0.6559 at tillering-booting; 35, 758, 3.0206, 0.0676, 0.8496 at flowering-milking; 42, 2209, 2.8989, 0.0856, 0.7756 at grain ripening stage, respectively (Table 3.17).

The species richness and abundance for parasitoids at all crop stages were high in case of LIP as compared to HIP (Table 3.17 & Fig. 3.12). This showed that
### Table 3.17: Spatio-temporal variation in diversity of trophic guilds of insect associated with LIP & HIP rice crop agroecosystems in the Kallar tract.

<table>
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<th>Status</th>
<th>Crop Stage</th>
<th>Inputs</th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
<th>J</th>
<th>N1</th>
<th>N2</th>
<th>P-value</th>
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<td>0.7447</td>
<td>26</td>
<td>15</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>106</td>
<td>6971</td>
<td>3.2221</td>
<td>0.0835</td>
<td>0.6909</td>
<td>25</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Grain ripening</strong></td>
<td>High</td>
<td>70</td>
<td>1694</td>
<td>3.5737</td>
<td>0.0382</td>
<td>0.8417</td>
<td>35</td>
<td>26</td>
<td>0.00</td>
<td></td>
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<tr>
<td>Low</td>
<td>90</td>
<td>2602</td>
<td>3.3224</td>
<td>0.0728</td>
<td>0.7383</td>
<td>27</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Predators</strong></td>
<td>Pre-nursery</td>
<td>High</td>
<td>21</td>
<td>182</td>
<td>2.6182</td>
<td>0.0867</td>
<td>0.8600</td>
<td>13</td>
<td>11</td>
<td>0.32</td>
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<tr>
<td>Low</td>
<td>26</td>
<td>196</td>
<td>2.6561</td>
<td>0.0996</td>
<td>0.8152</td>
<td>14</td>
<td>10</td>
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<tr>
<td><strong>Nursery</strong></td>
<td>High</td>
<td>28</td>
<td>762</td>
<td>2.6389</td>
<td>0.1087</td>
<td>0.7919</td>
<td>14</td>
<td>9</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>43</td>
<td>852</td>
<td>3.2421</td>
<td>0.0494</td>
<td>0.8620</td>
<td>25</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tillering-Booting</strong></td>
<td>High</td>
<td>39</td>
<td>3745</td>
<td>2.4029</td>
<td>0.1690</td>
<td>0.659</td>
<td>4</td>
<td>11</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>46</td>
<td>5311</td>
<td>2.9438</td>
<td>0.0938</td>
<td>0.7689</td>
<td>19</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Flowering-Milking</strong></td>
<td>High</td>
<td>35</td>
<td>758</td>
<td>3.0206</td>
<td>0.0676</td>
<td>0.8496</td>
<td>20</td>
<td>14</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>44</td>
<td>1595</td>
<td>3.3029</td>
<td>0.0469</td>
<td>0.8728</td>
<td>27</td>
<td>21</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Grain ripening</strong></td>
<td>High</td>
<td>42</td>
<td>2209</td>
<td>2.8989</td>
<td>0.0856</td>
<td>0.7756</td>
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<td>Low</td>
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<td>23</td>
<td>15</td>
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<td><strong>Scavengers</strong></td>
<td>Pre-nursery</td>
<td>High</td>
<td>92</td>
<td>4485</td>
<td>3.1829</td>
<td>0.0795</td>
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<td>24</td>
<td>12</td>
<td>0.31</td>
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<tr>
<td>Low</td>
<td>110</td>
<td>7571</td>
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<td>24</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nursery</strong></td>
<td>High</td>
<td>121</td>
<td>12912</td>
<td>3.2475</td>
<td>0.0687</td>
<td>0.6772</td>
<td>25</td>
<td>14</td>
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<tr>
<td>Low</td>
<td>143</td>
<td>14303</td>
<td>3.5046</td>
<td>0.0535</td>
<td>0.7062</td>
<td>33</td>
<td>18</td>
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<td></td>
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<tr>
<td><strong>Tillering-Booting</strong></td>
<td>High</td>
<td>134</td>
<td>43434</td>
<td>3.2423</td>
<td>0.0745</td>
<td>0.6620</td>
<td>25</td>
<td>13</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>161</td>
<td>81372</td>
<td>3.2625</td>
<td>0.0692</td>
<td>0.6420</td>
<td>26</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Flowering-Milking</strong></td>
<td>High</td>
<td>123</td>
<td>12021</td>
<td>3.1506</td>
<td>0.0817</td>
<td>0.6547</td>
<td>23</td>
<td>12</td>
<td>0.01</td>
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<tr>
<td>Low</td>
<td>149</td>
<td>24085</td>
<td>3.1081</td>
<td>0.0890</td>
<td>0.6211</td>
<td>22</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Grain ripening</strong></td>
<td>High</td>
<td>124</td>
<td>11409</td>
<td>3.4764</td>
<td>0.0545</td>
<td>0.7212</td>
<td>32</td>
<td>18</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>152</td>
<td>18794</td>
<td>3.2487</td>
<td>0.0766</td>
<td>0.6467</td>
<td>25</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>S</strong>=Species richness, N=Species abundance, H=Shannon’s index, D=Simson’s index, J=Evenness, N1=Number of abundant species &amp; N2=species maximum in abundance. Their values were rounded off to nearest whole numbers, NRP=non rice pests, Level of significance=5%.</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>
Fig. 3.12: Comparison of species richness (S) and abundance (N) of trophic guilds of insects at various growth stages of rice crop between LIP and HIP rice fields.

Herb (Herbivor), NRP (Non rice pest), Para (Parasitoid), Pred (Predator), Scav (Scavenger).
parasitoids species preferred LIP over HIP systems being friendlier and safer to them. The number of rare species (D) was high for HIP at all crop stages except for pre-nursery stage where in case of LIP rare species were more. It also means that HIP system had bad effects on population of parasitoids and due to this reason their population became less contributing to higher values of rare species. The species in LIP systems were distributed with greater evenness at all crop stages except for pre-nursery stage. It is worth to mention that N1 and N2 values were almost higher for LIP throughout the cropping season. The difference in (H) values between HIP and LIP systems were statistically significant (P<0.05) at all crop stages except for pre-nursery where P>0.05 (Table 3.17).

**Spatio-temporal variation in the diversity of predators associated LIP & HIP rice crops**

For predators in LIP rice fields the values for S, N, H, D, J were 110, 7571, 3.1965, 0.0967, 0.6800 at pre-nursery; 143, 14303, 3.5046, 0.0535, 0.7062 at nursery; 161, 81372, 3.2625, 0.0692, 0.6420 at tillering-booting; 149, 24085, 3.1081, 0.0890, 0.6211 at flowering-milking; 152, 18794, 3.2487, 0.0766, 0.6467 at grain ripening stage, respectively. However, in case of HIP the values for S, N, H, D, J were 92, 4485, 3.1829, 0.0795, 0.7039 at pre-nursery; 121, 12912, 3.2475, 0.0687, 0.6772 at nursery; 134, 43434, 3.2423, 0.0745, 0.6620 at tillering-booting; 123, 12021, 3.1506, 0.0817, 0.6547 at flowering-milking; 124, 11409, 3.4764, 0.0545, 0.7212 at grain ripening stage, respectively (Table 3.17).

For predators the species richness and abundance at all crop growth stages were higher for LIP, indicating that just like parasitoids the predators also preferred a less polluted habitat (Table 3.17 & Fig. 3.12). In case of LIP (H) was higher for pre-nursery, nursery and tillering-booting stages as compared to HIP for the same crop growth stages, respectively. But at flowering-milking and grain ripening stages (H) was higher for HIP. This showed that at flowering-milking and grain ripening stages number of abundant species became more in case of HIP systems. The reason could be the species sensitive to agricultural pollution left these habitats or toxicity of agrochemicals caused their mortality. As a result number of rare species for HIP declined and ultimately number of abundant species increased in comparison with LIP systems. Similarly, rarity (D) was greater for LIP except for nursery and tillering-
booting stages, which could be due to the side effects of insecticides application at these stages. This indicated that besides supporting a big number of abundant species LIP systems also provided shelter to large number of rare species. The species in case of HIP at most of crop stages were distributed with greater eveness because of less number of rare species. It is also clear from table (3.17) that (H) values in HIP and LIP systems were statistically significantly different (P<0.05) from each other at all crop stages except for pre-nursery stage where both of the systems were not different from each other statistically (P>0.05).

**Spatio-temporal variation in the diversity of scavengers associated LIP & HIP rice crops**

For scavengers in LIP rice fields the values for S, N, H, D, J were 43, 22277, 1.7087, 0.2454, 0.4543 at pre-nursery; 44, 34075, 1.9693, 0.1902, 0.5204 at nursery; 43, 19766, 2.1173, 0.1949, 0.5629 at tillering-booting; 42, 11981, 2.1615, 0.1625, 0.5783 at flowering-milking; 41, 11107, 1.8097, 0.2660, 0.4873 at grain ripening stage, respectively. However, in case of HIP the values for S, N, H, D, J were 31, 11222, 1.6390, 0.2522, 0.4773 at pre-nursery; 39, 22041, 1.8021, 0.2098, 0.4919 at nursery; 36, 23698, 1.6921, 0.3135, 0.4722 at tillering-booting; 36, 5503, 2.1393, 0.1617, 0.5970 at flowering-milking; 40, 7724, 1.7327, 0.2794, 0.4697 at grain ripening stage, respectively (Table 3.17).

As for as diversity of scavengers was concerned the values for (S), (N) and (H) were higher for LIP as compared to HIP except at tillering-booting stage where species abundance was high in case of HIP (Table 3.17, Fig. 3.12). This could be due to the effects of fertilizers and pesticides because after their application the population of mosquitoes and chironomid larvae bloom up due to the reduction in their predators population (Takamura and Yasuno, 1986; Roger et al., 1994; Simpson et al., 1994a,b). The greater species richness and abundance of scavengers/detritivores in early growth stages of crop provided basis for natural biological control of rice pest insects (Ban and kiritani, 1980; Settle et al., 1996). The number of rare species almost at all crop stages was high in case of HIP because of the harms of agrochemicals the pollution sensitive species might disappear. The scavenger species at all rice growth stages, with slight variations, were distributed with almost equal eveness. The values of (H) between HIP and LIP systems were statistically different from each other.
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(P<0.05) except for flowering-milking stage, where the difference was non significant (P>0.05).

3.4.6: Overall diversity  

3.4.6.1: Overall diversity of insect fauna

The overall values for S, N, H, D and J were 520, 535812, 4.3310, 0.0335 and 0.6925, respectively (Table 3.18).

A high value of (H) indicated that rice harbors a big number of abundant species besides supporting a high proportion of rare (D) species. The species in rice crop were distributed with 69% eveness. This comparatively low evenness was due to more number of rare species. There were about 76 abundant species (N1) among which 29 were very maximum in abundance (N2) (Appendix-III & VI).

Table 3.18: Overall diversity of insect fauna associated with rice crop in the Kallar tract.

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
<th>J</th>
<th>N1</th>
<th>N2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>520</td>
<td>535812</td>
<td>4.3310</td>
<td>0.0335</td>
<td>0.6925</td>
<td>76</td>
<td>29</td>
</tr>
</tbody>
</table>

S=Species richness, N=Species abundance, H=Shannon’s index, D=Simson’s index, J=Evenness, N1 & N2=Hill’s numbers of diversity (N1=Number of abundant species & N2=Number of species maximum in abundance. Their values were rounded off to nearest whole numbers).

The results showed that rice crop agroecosystem supported high levels of insect biodiversity which definitely played an important role in the productivity of this systems (Yasumatsu, 1950; Heckman, 1974, 1979; Fernando, 1977; Yano, 1978; Heong et al., 1991; Lim, 1992; Cohen et al., 1994; Fernando, 1995, 1996; Schoenly et al., 1998; Lawler, 2001; Bambaradeniya and Amerasinghe, 2003; Bambaradeniya et al., 2004; Edirisinghe and Bambaradeniya, 2006; Wilby et al., 2006).

3.4.6.2 Comparison of insect diversity between LIP and HIP rice crop agroecosystems

Total number of insect species collected from HIP rice crop were 468 with 218307 specimens (abundance) while it was 515 with 317505 abundance from LIP rice. The values of H for HIP and LIP systems were 4.2834 and 4.3175 whereas values of D were 0.0343 and 0.0340, respectively. Insect species in both of the systems were distributed with almost equal eveness. The number of abundant species
(N1) was 74 in case of LIP but was 72 for HIP. However, number of species maximum in abundance (N2) was same (29) for both of the systems. The difference in the value of diversity between HIP and LIP systems was significant (P<0.05) (Table 3.19, Fig. 3.13).

Table 3.19: Comparison of insect diversity between LIP and HIP rice crop agroecosystems.

<table>
<thead>
<tr>
<th>Inputs Level</th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
<th>J</th>
<th>N1</th>
<th>N2</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>468</td>
<td>218307</td>
<td>4.2834</td>
<td>0.0343</td>
<td>0.6967</td>
<td>72</td>
<td>29</td>
<td>0.00</td>
</tr>
<tr>
<td>Low</td>
<td>515</td>
<td>317505</td>
<td>4.3175</td>
<td>0.0340</td>
<td>0.6914</td>
<td>74</td>
<td>29</td>
<td></td>
</tr>
</tbody>
</table>

S=Species richness, N=Species abundance, H=Shannon’s index, D=Simson’s index, J=Evenness, N1 & N2=Hill’s numbers of diversity (N1=Number of abundant species & N2= species maximum in abundance. Their values were rounded off to nearest whole numbers), Level of significance=5%.

Fig: 3.13: Comparison of (a) species richness and (b) abundance between LIP and HIP rice fields

In LIP a high value of (H) depicted that number of abundant species was high and a low value of (D) reflected that rare species were less in number in comparison with HIP. It means there was a difference not only in insect species richness but also a great difference of insect abundance between LIP and HIP rice farms. The LIP farms had 47(9.03%) more species with 99198 (18.52%) insect specimens as compared to HIP rice farms. Results of similar pattern are also obtained by Letourneau and Goldstein (2001).

The less number of rare species in LIP also showed that in this system owing to lack of stress due to agrochemicals all species were present in sufficient good abundance, resultanty rarity (D) was less and number of abundant species was high. The value of (J) represented that species in HIP systems were distributed with a trifling high evenness and this may be due to the absence of rare species which were present in high number in LIP systems where due to more number of rare species evenness was slightly low.
From table 3.19, it became clear that HIP system supported a less diverse insect fauna with low species richness and abundance as compared to organic (LIP) fields and this difference may be due to the harms of agriculture intensification practices involving greater amount of agrochemicals (Barrett, 1969; Dritschilo and Wanner, 1980; Paoletti, 1988; Brown and Adler, 1989; Kromp, 1989, 1990; El-Titi and Ipach, 1989; Goh and Lange, 1989; Crossley et al., 1992; Paoletti et al., 1991, 1992; Fan and Liebman, 1993; Way and Heong, 1994; Berry et al., 1996; Settle et al., 1996; Fahrig and Jonsen, 1998; Schoenly, 1998; Lawton et al., 1998; Krebs et al., 1999; di Giulio et al., 2001; Stoate et al., 2001; Benton et al., 2002a, b, 2003; Bambaradeniya et al., 2004; Wickramasinghe et al., 2004; Bengtsson et al., 2005; Jana et al., 2006; Attwood et al., 2008; Wilson et al., 2008). However the results of present study were against the findings of Hesler et al., (1993).

Some insect species, as a result of deleterious effects of modern agricultural practices were absent in systems receiving greater amount agrochemicals (HIP) because of their toxic effects. On the contrary some species also adapted to a polluted environment. The results (Appendix-III & IV) showed that five species (0.96%) under five families viz., *Chlaenius circumdatus* (Carabidae), *Leptocorisa oratorius* (Alydidae), *Hishimonus phycitis* (Cicadellidae) *Eumenes sp.* (Vespidae), *Scirpophaga auriflua* (Pyralidae) were absent in samples obtained from LIP fields. These species were present in HIP fields but in low number. These species might have preference or adapted to HIP and were present in HIP systems only (Jeffries, 1997).

Whereas, fifty-two (10%) species of the total 520 were absent from samples of HIP fields (Appendix-III & IV). These included *Xylonites praeustus* (Bostrichidae), *Ophionea sp.*, *Scarites nanus* (Carabidae), *Aeolesthes sarta*, *Chlorophorus annularis* (Cerambycidae), *Dicladispa armigera* (Chrysomelidae), *Cicindela undulata* (Cicindelidae), *Dytiscus sp.5*, *Laccophilus parvulus* (Dytiscidae), *Heterocerus sp.1* (Heteroceridae), *Hydraena sp.* (Hydraenidae), *Cybocephalus semiflavus* (Nitidulidae), *Copris repertes* (Scarabaeidae), *Camerimena rugosiatriatus* (Tenebrionidae), *Labidura riparia* (Labiduridae), *Ogodes sp.1* (Acroceridae), *Atherix sp.* (Athericidae), *Brontaea tonitrui* (Muscidae), *Tritoxa sp.* (Otitidae), *Syrphid sp.*, *Syrphus confrater* (Syrphidae), *Tabanus sp.* (Tabanidae), *Tachinid sp.3* (Tachinidae), *Belostoma indica* (Belostomatidae), *Physopelta gutta* (Largidae),
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3.4.7: Seasonal colonization and succession of insect fauna in rice fields

The agricultural production system is supported by the organisms such as scavengers, pest controlling species and pollinators, whereas others, such as pests could be harmful to these systems. Some organisms use rice fields as habitat ranging from marginal use to complete dependence on this system or use other habitats which could be affected by chemical run off into aquatic systems from the rice fields. Most of the species inhabiting rice fields are able to react physiologically and behaviorally to drastic conditions in rice fields. As they possess ability to recover rapidly from various disturbances so, they are regarded as organisms with high resilience stability (Bambaradeniya and Amerasinghe, 2003). Different species react differently to the changing conditions in rice fields. The succession of species occur through the rice growing season as the system transforms from an open littoral environment to a vegetated littoral system as the rice plants grow and canopy closed (Heckman, 1979; Fernando 1995, 1996; Takagi *et al*., 1996; Parris, 2001; Bambaradeniya and Amerasinghe, 2003).

The insect fauna recorded from the rice field were observed to follow a uniform pattern of seasonal colonization and succession during the study period. The major insect taxa that colonized or visited the rice field and collected during different stages/phases of a rice crop are presented in Appendix-V.
The events of seasonal colonization and succession summarized under two major ecological phases: the aquatic phases (pre-nursery, nursery, tillering-booting, flowering-milking) and the dry phase (grain ripening stage), as follows:

**The Aquatic phase**

**Pre-nursery stage:** At the beginning of rice crop agronomic practices associated with the preparation of fields resulted in the complete destruction of the fallow vegetation in the fields, causing mortality of many species of organisms that were present in the fields. When the fields were flooded after land preparation insects from adjoining non-rice habitats colonized the fields, e.g., rice pest belonging to Orthopera (*Oxya chinensis* and *Chrotogonus trachypterus*) invaded at this stage but as rice plants were not present in the field at that time so these insects mostly shifted on grasses grown on rice field bunds. During this phase the major rice pest insects i.e., *Scirpophaga incertulas* & *S. innotata* and Ichneumonidae were also collected. Among the NRP Culicidae and among the scavengers the collembolan and dipteran (Chironomidae & Ephydridae) were most abundant colonizers. It had often been argued that the abundance of lower trophic levels controlled the diversity of higher trophic levels (bottom-up effect) and vice versa (top-down effect) (Hunter and Price, 1992; Siemann, 1998). The predators belonging to Ephemeroptera, Dermaptera, Anthicidae, Carabidae, Corixidae, and Hydrophilidae visited rice fields and remained present at end of crop. During this period predatory ants also invaded the fields in large numbers to feed on the dying arthropods trapped in the mud of ploughed fields. It means that at this first phase of the flooding period insect groups with efficient survival or colonization mostly phytophagous or scavengers/detrivores dominated the insect community. The results are in conformity with those of Williams (1987) and Suhling *et al.* (2000).

**Nursery stage:** Before sowing of nursery, fields were flooded in open littoral condition. During this early period of rice cultivation, the rice herbivores which colonized the rice nurseries formed the first wave of rice pests included: Acrididae (*Oxya chinensis*, *O. nitidula* and *O. fuscovittata*), Chrysomelidae (*Haltica cyanea* and *Phyllotreta chotanica*), Nephotettix spp., *Nilaparwata lugens*, *Sogatella furcifera*,

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*Scotinophara* spp.*, and Nymphula depunctalis* (not after tillering booting) *S. incertulas* ans *S. innotata* alongwith parasitoids belonging to Ichneumonidae, Mymaridae and Scelionidae and predators belonging to Odonata, Diptera, Coleoptera, Hemiptera and Ephemeroptera, etc also invaded rice nurseries before crop establishment. The NRP included Culicidae & Apidae whereas scavengers belonged to Collembola and Diptera also colonized the field.

**Tillering-booting stage:** Primary consumers such as mosquito larvae, corixids, and chironomids reached at their initial peak levels during the early aquatic phase of 30 DAT. After transplanting when rice plants had established a variety of arthropods colonized the rice fields from surrounding areas, moving in either by flying (adult insects) or through irrigation water.

The pest species which colonized the fields during the active tillering-booting stage included *Cnaphalocrocis medinalis, Sogatella furcifera, and Nilaparvata lugens, Dicladispa armigera, Melanitis leda* (peak in Oct.), *Orseoli* sp.(end tillering), *Thrips oryzae, Parnara mathias* (peak in Sep.-Oct.) and rice stem borers. The booting stage of the rice plant was colonized mostly by predators, including, ephemeropterans, odonats, hydrometrids, hydrophilids, ascalaphids coccinellids, *Cicindela repanda, Chrysoperla carnea, Belostoma indica, Cyrtorhinus lividipennis, Conocephalus maculates*, coccinellid & carabid beetles (*Opheonia* spp.) and hymenopteran parasitoids belonging to Braconidae, Mymaridae, Scelionidae & Trichogrammatidae and collembolan scavengers. The NRP mostly included butterflies (*Precis almanac* and *Valeria valeria*).

It is worth to mention that only three specimens of giant water bug, *Belostoma indica*, were captured during present study. It was concluded that this important predatory insect was disappearing from rice fields of the Kallar tract and might be in danger. Also a number of studies in other countries had declared some other species of giant water bug (*Lethocerus deyrollelei*) as endangered in rice fields (Hidaka, 1998; Toshiaki and Hidaka, 2002).

Results and Discussion Section 3

**Flowering-milking stage:** During the flowering stage of the rice plant, sap feeding hemipterous pests (mainly *Leptocorisa oratorius*, *Cletus punctiger* and Pentatomids) along with other major lepidopterous and homopterous pest colonized the rice field. The predators invaded rice crop at this stage mostly belonged to Reduviidae, Hydrophilidae and Vespidae while parasitoids belonged to Braconidae and scavengers to Collombola. The NRP at this stage were mostly from Apidae, Arctidae, Culicidae, *Dysdercus koengii*, *Athalia lugans*, *Physopelta gutta* and many butterflies (*Atella phalantha phalantha*, *Aulocera loha*, *Papilio demolius demolius*, *Eurema hecabe*, *Pieris brassicae*, *Valeria valeria* and *Zizeeria maha*).

**The Dry phase**

**Grain ripening stage:** At grain ripening stage irrigation to rice crop was stopped and fields were allowed to dry. These practices during the grain ripening stage resulted in a short semi-aquatic stage ranging from 5 to 10 days. After that field became dry with moist soils (up to crop harvest) and a number of grass hopper species invaded the rice crop. Among these *Oxya chinensis*, *O. nitidula* and *O. fuscovittata* in order of abundance were more important. The other insect pest species were mostly sucking bugs (Pentatomids and *Leptocorisa* spp.) sucking sap from ripening grains. Carabid beetles were among the most abundant (in Coleoptera) and important predators and braconid wasps were among the parasitoids. Among the scavengers collombolan and chironomids were most abundant. Chironomids remained abundant up to dry stage because they are resistant to drought (Kenk, 1949; Hinton, 1953; Williams, 1987; Kikawada, et al., 2005).

During the dry phase, many aquatic insects were found trapped in small puddles of water in the fields and these gradually perished, as the puddles dried. At this stage again the predatory ants invaded the fields in large numbers to feed on the dying/died insects trapped in puddles. It was also observed that these organisms were occupying mainly the relatively moist soil medium, in and around the root system of the dry stubble of the rice plant. The dry rice stubbles provide an ideal habitat for stem-nesting insects such as wasps, so burning of rice stubbles destroy these organisms and hence is a threat to biodiversity conservation. Results on similar pattern are also obtained by Bambaradeniya *et al.* (2004) and Sachan *et al.* (2006).
3.4.8: Estimation of species richness

The species richness values generated by chao 1 estimator were a little higher in both LIP and HIP systems as compared to the actual (observed) richness values. The highest difference in value was estimated at Sheikhupura with HIP (Table 3.20).

The slight differences in the estimated and observed values of species richness revealed that sampling efforts were quite enough to reveal the true number of species diversity at all sites. However, these differences indicated the necessity to conduct more intensive collection with modification of sampling techniques, viz., use of some other sampling techniques, sampling during different times of the day, extended sampling time, to capture the maximum number of remaining species.

### Table 3.20: Comparison of observed and estimated species richness among the localities of the Kaller tract.

<table>
<thead>
<tr>
<th>District</th>
<th>Inputs</th>
<th>No. of observed species</th>
<th>No. of Estimated species (Chao 1)</th>
<th>No of Unique species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sialkot</td>
<td>Total</td>
<td>479</td>
<td>481.13</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>385</td>
<td>395.53</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>464</td>
<td>473.03</td>
<td>19</td>
</tr>
<tr>
<td>Gujranwala</td>
<td>Total</td>
<td>494</td>
<td>501.36</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>397</td>
<td>407.02</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>478</td>
<td>487.79</td>
<td>23</td>
</tr>
<tr>
<td>Sheikhupura</td>
<td>Total</td>
<td>501</td>
<td>507.57</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>409</td>
<td>421.22</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>492</td>
<td>500.17</td>
<td>21</td>
</tr>
</tbody>
</table>

The number of unique species in case of Sialkot (LIP) was low as compared to that of HIP. Whereas, in all other sites over all number of unique species was high for LIP systems. The occurrence of unique species showed that there was some unique microhabitat explored by these species (Jana et al., 2006).

3.4.9: Cluster analysis

The patterns of clustering of the six localities are summarized in the dendrograms in figures 3.14 & 3.15 based on quantitative and qualitative data respectively and are explained as below:
Section 3

3.4.9.1: Cluster analysis based on quantitative data

The species level analysis revealed two main clusters. Both clusters consisted of three sites each. In first cluster three sites with HIP were included while in second cluster three other sites with LIP were included.

In case of first cluster at a chord distance of 4.5 two groups emerged. The first group consisted of sites of Sialkot and Gujranwala receiving HIP which met at a chord distance of 1.5 and second consisted of one site of Sheikhupura receiving HIP.

In case of second cluster at a chord distance of 6.25 again two groups emerged. The first group consisted of sites of Gujranwala and Sheikhupura receiving LIP which met at a chord distance of 1.5 and second group consisted of one site of Sialkot receiving LIP. The similarity level among the localities was about 24.9.

Fig. 3.14: Dendrogram of the cluster analysis based on quantitative data of the six sampling sites

From the dendrogram (Fig. 3.14) it is evident that the localities receiving same input level formed one group in the cluster analysis. It means localities with LIP were different from localities with HIP. The HIP receiving localities in Sialkot and Gujranwala were found to be similar in occurrence of species while locality in Sheikhupura with HIP behaved differently in species composition. Similarly, in the second cluster consisting of LIP receiving localities, Gujranwala and Sheikhupura were similar while Sialkot was different. So, it could be said that in case of HIP Sheikhupura and in case of LIP Sialkot behaved differently.
3.4.9.2: Cluster analysis based on qualitative data

Two main clusters separating HIP and LIP localities were formed by analyzing the binary data of species found in all six localities. The similarity level among the localities was nearly 14.7. In both of the clusters Sheikhupura and Gujranwala were similar whereas Sialkot was different.

Ward’s method
Euclidean distances

![Dendrogram of the cluster analysis based on qualitative data of the six sampling sites.](image)

On comparison with clusters based on quantitative data in case of HIP Sheikhupura was different, but in case of LIP results were similar in both types of analysis. By observing both dendrograms it also became clear that on the basis of quantitative data HIP sites were more similar (Fig. 3.14) whereas on the basis of qualitative data LIP sites were more similar (Fig. 3.15).
Anyhow, separate clustering of HIP and LIP sites reflects differences in diversity pattern. From the above results it was thus inferred that farming systems had influence on insect’s faunal composition.

**3.4.10: Sorensen similarity index**

All the study sites were located in the same ecological zone having almost same homogeneous environment, where vegetation, temperature, rainfall, humidity, nature of soil and physiography were nearly similar. In such environment, homogeneity in community structure was expected to exist and similarity indices theoretically should be 1. Such perfect similarity had been calculated for some HIP and LIP systems. Sorensen’s similarity index suggested that the study sites in HIP and LIP systems were strongly similar in distribution of insect fauna and both of the systems exhibited maximum similarity in their faunal composition.

It is also clear from tables 3.21-3.32 that in almost all insect orders the values for high vs high and low vs low sites were higher as compared to values for high vs low. Also the values for low vs low were higher as compared to values for high vs high indicating that almost all insect orders showed preference for LIP systems except Dermaptera, Orthoptera and Thysanoptera which preferred HIP. So the important insect orders namely Coleoptera, Diptera, Homoptera, Hemiptera, Hymenoptera, Lepidoptera and Odonata commonly and the insect species among these insect orders specifically (which were completely absent in HIP systems) (Appendix-III & IV) could be considered as bioindicators because of their preference for LIP systems.

According to Jeffries (1997) natural and anthropogenic disturbances were important factors in either the creation or destruction of local diversity. According to the results of present study the agricultural fields with higher disturbances (application of agrochemicals) frequently showed lower overall insect species richness (Fahrig and Jonsen, 1998) which results into low values for high vs high or high vs low indices in comparison with low vs low. However, the insect orders Dermaptera, Orthoptera and Thysanoptera, perhaps, were affected less by the harms
and disturbance from HIP farming systems and exhibited higher insect abundance (Table 3.3) in HIP systems. Resultantly, these insect orders also had higher values for similarity indices for HIP. Such variation probably may be due to the adaptability of the concerned insect group and thus followed the pattern described by Jeffries (1997).

Results and Discussion Section 3

Table 3.21: Similarity index for different pairs of sites for Coleoptera

<table>
<thead>
<tr>
<th>Sial_L</th>
<th>Guj_L</th>
<th>Shk_L</th>
<th>Sial_H</th>
<th>Guj_H</th>
<th>Shk_H</th>
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</thead>
<tbody>
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<td>0.89</td>
<td>0.84</td>
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</tr>
<tr>
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Table 3.22: Similarity index for different pairs of sites for Lepidoptera

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<th>Guj_H</th>
<th>Shk_H</th>
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<td>0.84</td>
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Table 3.23: Similarity index for different pairs of sites for Hymenoptera

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<th>Guj_H</th>
<th>Shk_H</th>
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Table 3.24: Similarity index for different pairs of sites for Diptera

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<th>Guj_H</th>
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Table 3.25: Similarity index for different pairs of sites for Hemiptera

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<th>Guj_H</th>
<th>Shk_H</th>
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Table 3.26: Similarity index for different pairs of sites for Homoptera

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Table 3.27: Similarity index for different pairs of sites for Orthoptera

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Table 3.28: Similarity index for different pairs of sites for Odonata

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Table 3.29: Similarity index for different pairs of sites for Dermaptera

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Table 3.30: Similarity index for different pairs of sites for Dictyoptera

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Table 3.31: Similarity index for different pairs of sites for Neuroptera

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Table 3.32: Similarity index for different pairs of sites for Thysanoptera

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<th>Guj_L</th>
<th>Shk_L</th>
<th>Sial_H</th>
<th>Guj_H</th>
<th>Shk_H</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.67</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>0.67</td>
<td>0.67</td>
<td>0.67</td>
<td>0.67</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

158
3.4.11: Principal Component Analysis (PCA)

In order to identify the direction of change of species richness principal component analysis was used. The results of PCA could be considered as an indicator of species alignment in respect to sampling sites. The fig. 3.16 demonstrated that HIP and LIP receiving localities showed separate components in score plots. It is also clear that in case of LIP Sheikhupura and Gujranwala whereas in case of HIP Gujranwala and Sialkot were more similar for species composition.

3.4.12: Correlation between environmental factors and insect population

The environment where an organism lives inevitably influences all of its vital functions, physiology, behavior and interactions with the individuals of same or other species which in turn are also influenced by environmental factors. Modern
population dynamics theory suggests that animals' fluctuations in nature are the result of the combined forces of intrinsic and exogenous factors (Berryman, 2003; Turchin, 2003). Population ecology, since its very origin, has acknowledged the importance of these factors and has concentrated on efforts to understand them (Elton, 1924; Andrewartha and Birch, 1954). A classical example of an exogenous force is the weather. Climate of area variably modifies species richness of many organisms. The seasonal activity and distribution pattern of most insects are influence by prevailing climatic conditions. Therefore, climate is a key factor explaining the spatial synchrony in insect species (Sutherst, 1990; Hanski and Woiwod, 1993, Rosenzweig, 1992, 1995; Williams and Liebhold, 2000; Peltonen et al., 2002; Stenseth et al., 2002; Saldana et al., 2007).

The common approach for analyzing the relationship between population size and climatic variables could be by simple correlation or using the climate as an additive co-variable in statistical models (Stenseth et al., 2002). In the present study the effect of different environmental factors i.e. average temperature, rainfall and relative humidity, were evaluated on overall insect species richness and abundance in the Kallar tract.

The mean and standard deviations of average temperature (Avg. Temp), rainfall (RF) and relative humidity (RH) of the three districts are given in table 3.33.

<table>
<thead>
<tr>
<th>Districts</th>
<th>Avg. Temp</th>
<th>Rainfall</th>
<th>Relative humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>St. Dev.</td>
<td>P</td>
</tr>
<tr>
<td>Sialkot</td>
<td>32.1</td>
<td>2.7</td>
<td>0.77</td>
</tr>
<tr>
<td>Gujranwala</td>
<td>32.3</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>Sheikhupura</td>
<td>32.8</td>
<td>2.4</td>
<td></td>
</tr>
</tbody>
</table>

Note: All values are mean of two years Level of significance=5%.

From table 3.33 it is clear that all climatic factors were statistically non significant among the three districts during the study period. The reason behind this could be the fact that these three districts of the Kallar tract were located in the same climatic zone, having rice season extending through out monsoon. Due to this reason the climatic conditions of the three districts remained almost the same. As there was no statistical difference among various environmental factors of the said districts so...
the average for the environmental factors of these three districts (Appendix-VIII) was
calculated and correlated with overall species richness and abundance and other
diversity components. The results are given in the table 3.34.

Results and Discussion Section 3

<table>
<thead>
<tr>
<th>Env. factors</th>
<th>S</th>
<th>N</th>
<th>H</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. Temp</td>
<td>-0.057</td>
<td>0.499</td>
<td>-0.278</td>
<td>0.020</td>
</tr>
<tr>
<td>RF</td>
<td>0.099</td>
<td>0.620*</td>
<td>0.140</td>
<td>-0.379</td>
</tr>
<tr>
<td>RH</td>
<td>0.528</td>
<td>0.775**</td>
<td>0.669</td>
<td>-0.746</td>
</tr>
</tbody>
</table>

* Significant at 0.05 level  ** Significant at 0.01 level
S=Species richness, N=Species abundance, H=Shannon’s index, D=Simson’s index.

From table 3.34 it is evident that average temperature had negative but non-
significant (NS) correlation with (S) and (H) but NS positive correlation with (N) and
(D). Rainfall and relative humidity were found having positive correlation with all
diversity components except N, which had positive and significant correlation and D
had negative and NS correlation. All these results are in conformity with the findings
of Williams, 1952, 1961; Abdullah, 1961; Taylor, 1963; Chaudhry, 1976; Wolda,
1978, Adler, 1994; Rai et al., 2002; Sharma, 2002 and Bambaradeniya and

3.4.13: Cost/benefit ratio

Sustainable agriculture is receiving a great attention in many developing
countries because of the degradation of agricultural resources, quality of food and life
which are deteriorating with high input farming practices (MacRae et al., 1990) and
has inspired comparative research program.

The major aim of human economic activities including agriculture is to enjoy
a better livelihood through economic prosperity. Similarly in case of LIP and HIP rice
farming systems farmers adopt the method which apparently produces higher profit
and HIP farming system (Dawe, 2002, 2008).
The comparison of costs and benefits (in Pak. rupees) of LIP and HIP rice fields of the Kallar tract of the Punjab showed that the net profit acre\(^{-1}\) was high in HIP and low in case of LIP. The difference of rice yields between LIP and HIP rice farming systems were calculated to be having worth of Rs. 2167 acre\(^{-1}\) (Table 3.35).

Results and Discussion         Section 3

Referred back, in case of both of the production systems, farms’ production and support to insect biodiversity was high in LIP rice fields (Table 3.19). It means that 52 (9.03%) insect species with 99198 (18.52%) number of individuals (Appendix- III & IV) had the cost of Rs. 2167 acre\(^{-1}\). It also means that low input sustainable rice farming (LISRF) conserve 47 insect species whose actual worth is not known. On the other hand HIP systems besides causing soil erosion, degradation, chemical pollution, polluting to surface and subsurface water sources are also a big threat and cause of loss of a number of insect species. The difficulties in quantifying and assigning monetary values to ecological degradation and species loss has not allowed scientists to prove quantitatively and convincingly the hidden costs behind the gains in yields in conventional farming (Kwa, 2001). These hidden costs are the facts to be explored (at one to one and one to more than one taxonomic level interaction) in future.

Although in case of HIP farming current costs of production (per unit of commodity) have grown alarmingly (Table 3.35) and in many places have passed the point of diminishing returns, even if such externalities are disregarded. Moreover, at high input levels adverse environmental effects are becoming of a serious concern. Greater use of these inputs is thus becoming less productive (Altieri, 1999; Nissanka and Bandara, 2004; Uphoff, 2005).

Therefore, just on the basis of cost/benefit the HIP system should not be preferred over LIP system. As many pairs of actions remain incompatible because when an action is better than the other for some criteria, it is usually worse for others. Anyhow, there is no equation optimizing all the actions at the same time. Hence decision-making implies finding compromising solution. In this case we have to compromise a slight decrease in profit just not only for sustainability of the rice crop ecosystem but also for the coming future generations. If we were able to calculate the
costs to health, environment and insect biodiversity and had considered them in the equation the LIP (organic) approach would get even more attraction.
Table 3.35: Comparison of economics of LIP and HIP rice farming.

<table>
<thead>
<tr>
<th>Crop stage</th>
<th>Head of expenditure</th>
<th>LIP</th>
<th>HIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>At nursery stage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seed 5kg @Rs. 50kg⁻¹</td>
<td>250</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>Land preparation</td>
<td>125</td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td>250</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>Seed treatment</td>
<td>48</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>FYM</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Urea @ 1/2kg marla⁻¹</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Cartap + application charges</td>
<td>0</td>
<td>148</td>
<td></td>
</tr>
<tr>
<td>Before and after crop establishment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Ploughing+2 Planking (Land preparation)</td>
<td>1750</td>
<td>1750</td>
<td></td>
</tr>
<tr>
<td>Nursery transplanting (Uprooting+Transplanting)</td>
<td>1000</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>Weedicide (Butachlor)+application charges</td>
<td>220</td>
<td>220</td>
<td></td>
</tr>
<tr>
<td>Zinc 21% @5kg acre⁻¹</td>
<td>155</td>
<td>155</td>
<td></td>
</tr>
<tr>
<td>Zinc application charges acre⁻¹</td>
<td>50</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>DAP</td>
<td>575</td>
<td>2300</td>
<td></td>
</tr>
<tr>
<td>Urea</td>
<td>462</td>
<td>925</td>
<td></td>
</tr>
<tr>
<td>Potash</td>
<td>338</td>
<td>675</td>
<td></td>
</tr>
<tr>
<td>Fertilizers application charges</td>
<td>200</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Cartap 4%G @ 9kg acre⁻¹</td>
<td>0</td>
<td>450</td>
<td></td>
</tr>
<tr>
<td>Application of cartap acre⁻¹</td>
<td>0</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Use of lambdacyhalothrine for Leaffolder</td>
<td>0</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>Application of insecticides for RLF</td>
<td>0</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Use of copperoxychloride for BLB</td>
<td>0</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>Application charges of copperoxychloride</td>
<td>0</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Irrigation for crop</td>
<td>3750</td>
<td>3750</td>
<td></td>
</tr>
<tr>
<td>Irrigation labor charges</td>
<td>1500</td>
<td>1500</td>
<td></td>
</tr>
<tr>
<td>Land rent acre⁻¹</td>
<td>7000</td>
<td>7000</td>
<td></td>
</tr>
<tr>
<td>Harvesting acre⁻¹</td>
<td>1300</td>
<td>1300</td>
<td></td>
</tr>
<tr>
<td>Total expenditures (A)</td>
<td>19073</td>
<td>23206</td>
<td></td>
</tr>
<tr>
<td>Yield in monds acre⁻¹</td>
<td>41</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>Total Income (B)</td>
<td>36900</td>
<td>43200</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>6300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net Profit (C) acre⁻¹ = Total income(B) - Total expenditure(A)</td>
<td>17827</td>
<td>19994</td>
<td></td>
</tr>
<tr>
<td>Net profit ha⁻¹</td>
<td>44032</td>
<td>49385</td>
<td></td>
</tr>
<tr>
<td>Difference (Profit acre⁻¹)</td>
<td>2167</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production cost of 1kg rice</td>
<td>21.96</td>
<td>25.71</td>
<td></td>
</tr>
</tbody>
</table>

Note: Prices of all commodities are in Pakistan rupees.
In 2006 DAP 1 bag @ Rs.900 and in 2007 1 bag @ Rs.1400.
In 2006 Urea 1 bag @ Rs.425 and in 2007 1 bag @ Rs.500.
In 2006 Potash 1 bag @ Rs.600 and in 2007 1 bag @ Rs.750.
In LIP 1/2 bag of DAP, 1 of Urea and 1/2 bag of Potash were used.
In HIP 2 bags of DAP, 2 of Urea and 1 bag of Potash were used.
In 2006 and in 2007 paddy rate was Rs.1000 mond⁻¹ (according to market).
3.5: SUMMARY AND CONCLUSION

Summary

Studies pertaining to the biodiversity of insects associated with rice (*Oryza sativa* L.) crop agroecosystem were conducted in two successive rice growing seasons (from May to October in 2006 & 2007) in the Kallar tract (consisting of three districts viz., Sialkot, Gujranwala and Sheikhupura) the traditional rice growing area of the Punjab, Pakistan. The studies were focused to collect & identify the insects and compare species richness, abundance and other diversity components of insect fauna collected, by using various sampling techniques, from rice fields (cv. Super basmati) with low (organic) and high (conventional) inputs.

During the study, a total of 535812 insect specimens in 520 insect species, 143 insect families and 16 insect orders were collected. Coleoptera was the most diverse among insects’ order with 145 species followed by Lepidoptera (76), Hymenoptera (74), Diptera (60), Hemiptera (58), Homoptera (37), Orthoptera (20), Odonata (16), Dermaptera (9), Dictyoptera (9) Collembola (4), Neuroptera (4), Ephemeroptera (2), Thysanoptera (2), Isoptera (2) and Plecoptera (1). The insect families with high number of species were: Carabidae with 29 species, Cicadellidae (22), Scarabaeidae (16), Pyralidae (15), Culicidae (15), Noctuidae (14), Hydrophilidae (14), Braconidae (14), Dytiscidae (13) and Libellulidae consisted of 12 insect species, as compared to other families.

The species richness and abundance increased with crop age and reached their maximum values at flowering-milking and tillering-booting stages of rice crop (and then declined as the crop grew towards maturity). This maximum diversity was also supported by the increased temperature, rainfall and relative humidity during this period.

The collected insects were categorized into five different trophic categories: rice herbivores, non rice pest, predators, parasitoids and scavengers/detritivores/decomposers. The highest (32.5%) contribution to total insect diversity was of predators followed by rice herbivores (26.5%), non rice pest (22.9%), parasitoids
Summary

Section 3

(9.2%) and scavengers (8.8%). The species richness and abundance of all these trophic guilds increased with crop age and was maximum at tillering-booting and flowering-milking stage of rice crop and then fell slightly. This pattern showed that all insect fauna collected during the present study had strong relation with rice crop as its diversity was least at the beginning of crop, reached at climax at tillering-booting and flowering-milking stages and then declined as the crop matured.

Early in the rice growing season the population of scavengers was very high and it supported the population of generalist predators by acting as alternative prey for them (because early in the season the herbivores were very less in number). Scavengers, thus, helped in population build up of predators which played an important role in natural control of rice pest insects in later crop stages.

The population of natural enemies, non rice pest and scavengers reached highest at tillering-booting stage and then declined which was due to the application of insecticides at that stage which affected the trophic guilds a lot. However, at that stage the population of rice herbivores increased and could be attributed to the reduction in number of natural enemies because of pesticide usage. After some time with the reduction in harmful effects of pesticides, the populations of parasitoids and scavengers increased again along with rice herbivores. Populations of all important trophic guilds (herbivores, predators, parasitoids and scavenger) were higher in LIP systems except of scavengers. The population of scavengers bloomed up at tillering-booting stage because of low predation by the reduction of the predators’ population due to the application of insecticides at that stage of the crop.

The insect fauna recorded from the rice fields followed a uniform pattern of seasonal colonization and succession during rice cultivation. The events of seasonal colonization and succession were summarized under two major ecological phases: the aquatic phases (pre-nursery, nursery, tillering-booting, flowering-milking) and the dry phase (grain ripening stage). Each of these phases harbors a specific type of insect fauna, viz., pre-nursery (carabids, corixids, chironomids, ephydrids, collembolans and Scirpophaga spp.), nursery (Scirpophaga spp., acridids, culicids, Cyrtorhinus lividipennis, Opheonia spp. and Ichneumonidae), tillering-booting (Scirpophaga spp., Cnaphalocrosis medinalis, hesperiids, coccinellids, hydrometrids, hydrophilids, braconids, trichogrammatids and ephemeropterans) flowering-milking (Scirpophaga
spp, pentatomids, reduviids, braconids and collembolans) and grain ripening stage 
(Leptocorisa spp., carabids, formicids, collembolans and chironomids).

All insect groups studied were not equally sensitive to agrochemicals whereas 
some insects showed remarkable decline in species diversity due to the harmful 
effects of HIP but were found in higher densities in LIP systems. These insects’ 
species could be regarded as bioindicator species and could be used for biomonitoring 
(rapid assessment of the degrading communities). It was found that some species of 
Coleoptera, Lepidoptera, Hemiptera, Odonata, Orthoptera and Ephemeroptera were 
susceptible to agrochemicals and hence these orders could be considered as 
bioindicator groups. Some species Ophionea sp., Cicindela undulate (Coleoptera), 
Atella phalantha phalantha, Zizeeria maha, Pieris sp., Valeria valeria (Lepidoptera), 
Belostoma indica (Hemiptera), Orthetrum pruinosem neglectum, Orthetrum Sabina 
(Odonata), Acrotylus insubricus, Aiolopus thalassinus and Mesotettix nobrei 
(Orthoptera) of these orders were completely absent in HIP systems and could be 
designated as bioindicator species for habitat quality assessment in HIP irrigated rice 
fields.

In nut shell, the study showed that irrigated rice fields in the Kallar tract 
housed a relatively diverse and abundant insect fauna. At present, the alarm bells 
signaling the loss of biodiversity ring loud and clear throughout the world. The rich 
insect biodiversity associated with rice crop clearly pointed out that irrigated rice crop 
could be compatible with maintaining and conserving insect biodiversity of this 
agroecosystem. The insect community associated with rice exhibited characteristics of 
seasonal differences in trophic guilds through the cropping season. As, expected, 
insect diversity with HIP generally declined, however, this effect was somewhat weak 
due to a compensating positive effect of vast cover of rice in the area. HIP systems 
largely affected insect abundance than diversity. Management of the potential tradeoff 
between insect biodiversity (maintenance and conservation) and intensification had 
emerged as a major challenge in sustainability of the system. Anyhow, in irrigated 
rice the diversity of natural enemies and its pest control function could be maintained 
by using low external inputs (pesticides and fertilizers).
In general, this study highlighted the considerable effects of HIP on insect diversity and suggested a wiser way based on the philosophy of low input sustainable agriculture (LISA) for its maintenance and enhancement. As the overall effect of agrochemicals was significant on insect faunal diversity which was high in LIP fields and all the multivariate analysis and diversity indices also showed that faunal composition and diversity in HIP and LIP systems was different and significantly higher in LIP system. The present study also provided a unique example of ‘ecosystem distress syndrome’ where extreme reduction in insect biodiversity had taken place due to habitat alteration by excessive use of agrochemicals. Thus the proposed hypothesis, “agricultural intensification” like HIP farming systems has impaired the insect biodiversity associated with rice crop agroecosystem” proved as true.

Conclusions

Insect fauna abundance

1. Irrigated rice fields hosted a relatively abundant and diverse insect fauna which was significantly higher in low input fields of rice crop.

2. Species which were abundant at one site were also widespread on other sites, which was quite in accordance with universal ecological pattern.

3. The insect population fluctuated with the growth of the crop and decreased at the crop maturity. A particular trophic guild was dominant at a particular growth stage of the crop.

4. Occupation of vacant niche, a universal phenomenon, was frequently observed among closely related taxa.

5. The insect groups collected during the study did not exhibit similar richness and abundance pattern. This phenomenon suggested that diversity patterns varied widely among taxa and that relying on just a few groups of insects would not optimally provide information to preserve others.

6. The presence of rare species (indicated that due to some anthropogenic practices these species have decreased in number and their lower population needed help for conservation) could be used as a guide for management and conservation of biodiversity.
7. The results would also be useful to consider changes in a popular paradigm “from integrated pest management (IPM) toward integrated biodiversity management (IBM) in rice fields” as a fundamental principle in agricultural sustainability and agroecosystem management. In IBM as an alternative to the ETL, another ETL in which the “E” refers to “ecological or environmental” could be used (these ETL yet to be established).

**Entomophagous insect diversity**

1. It became evident that rice crop harbors a rich fauna of natural enemies which could be exploited for the biological control of rice pest insects. Whereas, the aquatic representatives of the Odonata, Hemiptera and Coleoptera were all predatory insects.

2. The generalist predators (organize communities of rice fields) colonized the rice crops early in the growing season and the scavengers allowed them to establish and multiply in rice fields before rice pest insects colonized the rice fields, thus acted as linking species. The scavengers, predator-prey and parasitoid-host ratios, in LIP systems were 1.5 times higher than HIP. So, pest control strategies in rice crop should be revised to put higher priority on natural biological control.

3. The study indicated that knowledge of relative abundance of generalist predators with respect to rice herbivores was a prerequisite as a tool of biological control program. A high species richness and abundance of insect fauna would also be helpful in ecological based pest management in rice ecosystem and a benefit for natural pest control of mixed cropping landscapes in this region.

**Insect faunal diversity response to LIP and HIP**

1. The insect groups studied were not equally sensitive to agrochemicals and other environmental changes. Even in homogeneous ecological conditions, species richness and abundance could drastically change under the influence of agrochemicals.

2. Multivariate analysis and the diversity indices showed that the anthropogenic activities in rice crop agroecosystem had major impact on the species richness and abundance. The significantly higher diversity in organic habitats was probably due to its good quality (i.e., the absence of synthetic chemical runoff).

3. In future, the overall effect of excessive use of the agrochemicals on crop production and protection should be studied carefully and separately in the light of effects on species diversity. Application of agrochemicals in excess of actual need: leads to develop and rapid multiplication of pest and diseases of the rice plant, damage to the environment and lower the profit from rice farming.
4. Low input sustainable agriculture (LISA) farming system has got less attention in the mainstream strategy. The LISA (organic farming) could show equal, if not more, profit for the producers even with occasional low yield. From this low yield one may think that it could lead to world hunger. But, in reality the cause of world hunger is the injustice distribution of wealth and agricultural policy priorities.

Insect biodiversity studies comprised the examination of the full array of different kinds of insects together with the technology by which the diversity can be maintained and used for the benefit of humanity. As HIP systems had detrimental effects on insect diversity so, a wiser way to dilute this effect is LISA. The essence of LISA (organic agriculture) is soil management and fertility maintenance: feed the soil not to plant, the soil will feed the plant in much better way. So it is time to swing the pendulum of conventional agriculture towards organic (LISA) farming. Increase in rice production should not be achieved at the expense of future generation and should fulfill the concept of sustainability.

The overall conclusion is that LIP organic rice farming system not only produced reasonable rice harvest but also supported a significantly higher insect diversity and abundance, including declined species, than HIP farms. It should, therefore be appreciated, encouraged and popularized to a greater extent by Government, Media and NGOs’.
LITERATURE CITED
Literature Cited


Literature Cited


Literature Cited


Literature Cited


Literature Cited


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Literature Cited


Literature Cited


Literature Cited


Literature Cited


Literature Cited


Literature Cited


MSTAT-C, 1989. MSTAT-C a microcomputer program for the design, management and analysis of agronomic research experiments. Michigan State University, East Lansing, MI.


Literature Cited


Park, Hong-Hyun and Joon-Ho Lee, 2006. Arthropod trophic relationships in a temperate rice ecosystem: a stable isotope analysis with $\delta^{13}$C and $\delta^{15}$N. Environ. Entomol., 35(3): 684-693.


Literature Cited


Literature Cited


Literature Cited


Literature Cited


Literature Cited


Literature Cited


Appendix-I

Questionnaire proforma for the survey of rice farmers in the Kallar tract of the Punjab, Pakistan.
Appendix-II

Manuscript: Determination of economics threshold levels to be published in
International Journal of Agriculture and Biology

threshold levels for the stem borers (Scirpophaga sp.) and leaffolder
(Cnaphalocrosis medinalis) of rice (Oryza sativa) in the kallar tract of
Proforma for the survey of rice farmers of the Kallar tract of the Punjab, Pakistan (Total farmers interviewed=150)

(1). Name of the farmer ………………………………………

(2). Location …………………………………………………

(3). Age (years)
   1). Young (upto 30 years) .........................
   2). Middle (upto 31-45 years) .................
   3). Old (above 45 years) .........................

(4). Educational level
   1). Illiterate ................................
   2). Up to primary. ........................
   3). Up to middle .........................
   4). Matriculation & above .........

(5). Land holding (Acres) .........................

(6). Why are you not adopting organic farming? (MRA)*
   1). Govt. restriction ........................
   2). More weeds ........................
   3). Non availability organic market ..........
   4). Insect pest problem .................
   5). Disease problem ...................
   6). Take more time and water to mature ......
   7). Less yield ........................
   8). Difficult to harvest .................
   9). Have no confidence to grow ...........

(7). What do you know about the safety of organic farming? (MRA)
   1). Safe for humans ..............
   2). Safe for animals ..............
   3). Safe for beneficial insects ....
   4). Safe to environment ..........

MRA* Multiple responses were allowed
(8). To what extent you Favor

<table>
<thead>
<tr>
<th></th>
<th>High inputs farming</th>
<th>Organic farming</th>
</tr>
</thead>
<tbody>
<tr>
<td>1). Full favor</td>
<td>...................</td>
<td>..................</td>
</tr>
<tr>
<td>2). Partially favor</td>
<td>...................</td>
<td>..................</td>
</tr>
<tr>
<td>3). No favor</td>
<td>...................</td>
<td>..................</td>
</tr>
</tbody>
</table>

(9). What do you know about harmful effects of high input farming? (MRA)

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1). Diseases in human.</td>
<td>....</td>
<td>.....</td>
<td>........</td>
</tr>
<tr>
<td>2). Diseases in animals</td>
<td>....</td>
<td>.....</td>
<td>........</td>
</tr>
<tr>
<td>3). Environmental pollution</td>
<td>....</td>
<td>.....</td>
<td>........</td>
</tr>
<tr>
<td>4). No harmful affect</td>
<td>....</td>
<td>......</td>
<td>........</td>
</tr>
</tbody>
</table>

(10). Best method of farming is

1). Organic………………...
2). High inputs……………
3). Low inputs……………
4). No answer……………

(11). What do you know about the pest insects attack in rice crop?

<table>
<thead>
<tr>
<th></th>
<th>No attack (1)</th>
<th>Low (2)</th>
<th>Medium (3)</th>
<th>High (4)</th>
<th>No response (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem borers</td>
<td>........</td>
<td>..........</td>
<td>...........</td>
<td>.........</td>
<td>........</td>
</tr>
<tr>
<td>Leaffolder</td>
<td>........</td>
<td>..........</td>
<td>...........</td>
<td>.........</td>
<td>........</td>
</tr>
<tr>
<td>Leaf &amp; plant hoppers</td>
<td>........</td>
<td>..........</td>
<td>...........</td>
<td>.........</td>
<td>........</td>
</tr>
<tr>
<td>Grasshoppers</td>
<td>........</td>
<td>..........</td>
<td>...........</td>
<td>.........</td>
<td>........</td>
</tr>
<tr>
<td>Others</td>
<td>........</td>
<td>..........</td>
<td>...........</td>
<td>.........</td>
<td>........</td>
</tr>
</tbody>
</table>

(12). How would you rank the diseases attack in rice field?

<table>
<thead>
<tr>
<th></th>
<th>No attack (1)</th>
<th>Low (2)</th>
<th>Medium (3)</th>
<th>High (4)</th>
<th>No response (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacterial Leaf Blight</td>
<td>........</td>
<td>..........</td>
<td>...........</td>
<td>.........</td>
<td>........</td>
</tr>
<tr>
<td>Brown Leaf Spot</td>
<td>........</td>
<td>..........</td>
<td>...........</td>
<td>.........</td>
<td>........</td>
</tr>
<tr>
<td>Rice Blast</td>
<td>........</td>
<td>..........</td>
<td>...........</td>
<td>.........</td>
<td>........</td>
</tr>
<tr>
<td>Bakanae</td>
<td>........</td>
<td>..........</td>
<td>...........</td>
<td>.........</td>
<td>........</td>
</tr>
</tbody>
</table>
(13). How would you rank the presence of natural enemies in rice crop?

<table>
<thead>
<tr>
<th></th>
<th>Not present (1)</th>
<th>Low (2)</th>
<th>Medium (3)</th>
<th>High (4)</th>
<th>No response (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lace wing</td>
<td>…………….</td>
<td>…………….</td>
<td>…………….</td>
<td>…………….</td>
<td>…………….</td>
</tr>
<tr>
<td>Lady bird beetle</td>
<td>…………….</td>
<td>…………….</td>
<td>…………….</td>
<td>…………….</td>
<td>…………….</td>
</tr>
<tr>
<td>Wasps</td>
<td>…………….</td>
<td>…………….</td>
<td>…………….</td>
<td>…………….</td>
<td>…………….</td>
</tr>
<tr>
<td>Dragonflies</td>
<td>…………….</td>
<td>…………….</td>
<td>…………….</td>
<td>…………….</td>
<td>…………….</td>
</tr>
<tr>
<td>Spiders</td>
<td>…………….</td>
<td>…………….</td>
<td>…………….</td>
<td>…………….</td>
<td>…………….</td>
</tr>
<tr>
<td>Birds</td>
<td>…………….</td>
<td>…………….</td>
<td>…………….</td>
<td>…………….</td>
<td>…………….</td>
</tr>
</tbody>
</table>

(14). After how many years pest attack is severe

1). After each 5yrs………
2). After10 yrs……………
3). No such cycle………..
4). No response……………

(15). Name most problematic pest

1). Insects………………
2). Diseases…………….  
3). Weeds………………..
4). Rats…………………
5). No response………..

(16). Name most problematic pest insect

1). Stem borer………..
2). Leaffolder………..
3). Grass hopper……..
4). Hoppers……………

(17). Name most problematic disease

1). Bacterial leaf blight……
2). Brown leaf spot……….  
3). Rice blast……………..
4). Bakanae………………
5). No response……………

(18). If weeds are more insect are mostly

1). Less in no………..
2). More in no………..
3). No effect………..
4). Not known………..
(19). Why are you using insecticides in rice crop? (MRA)

1). To kill the insects ............................
2). To protect the crop from insect attack........
3). To increase the yield...........................
4). No response..................................

(20). What are the main problems related to pesticides?

1). Their costs.................................
2). Health hazards..............................
3). Environment deterioration............
4). No answer....................................

(21). Which of the pesticides is most problematic to health

1). Insecticides.......
2). Fungicides........
3). Weedicides.......
4). No response......

(22). What is the average number of various pesticides used by you in rice crop?

<table>
<thead>
<tr>
<th>Name of pesticides</th>
<th>Use once</th>
<th>Use twice</th>
<th>Not use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1). Insecticides</td>
<td>.........</td>
<td>.........</td>
<td>.........</td>
</tr>
<tr>
<td>2). Fungicides</td>
<td>.........</td>
<td>.........</td>
<td>.........</td>
</tr>
<tr>
<td>3). Weedicides</td>
<td>.........</td>
<td>.........</td>
<td>.........</td>
</tr>
</tbody>
</table>

(23). Is there any change in pesticide use during the last 5 years?

1). Increased............
2). Decreased............
3). No change............
4). No response............

(24). Name the pesticide which has been used in maximum

1). Insecticides.......
2). Weedicides.......
3). Fungicides.......
4). No response.....
(25). What do you do when pest insects are found in your rice crop? (MRA)

1. Not use insecticide
2. After looking pest
3. After looking damage/symptoms
4. Consult the Agriculture department
5. Follow the neighbors
6. Routine wise (irrespective of pest attack)
7. Use insecticide at economic threshold level (ETL)

(26). Are you in favor of aerial sprays for rice crop pest insects?

1. Yes
2. No
3. No response

(27). Do you treat rice seeds before nursery sowing?

1. Yes
2. No
3. Name of fungicide used

(28). Which of the following fungicide you use against rice crop diseases?

1. Any Copper based
2. Mancozeb
3. Diconazole
4. Not use

(29). Do you use weedicides in rice?

1. Yes
2. No
3. Name weedicide used
4. Manual weeding

(30). Name the insecticide you use against rice crop pest insects?

1. Cartap
2. Padan
3. Mono
4. Karate
5. Chlorpyrifos
6. Cypermethrine
7. Others
(31). How many bags of fertilizers are used for rice crop by you?

<table>
<thead>
<tr>
<th>Name of fertilizer</th>
<th>Number of bags used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea</td>
<td>......</td>
</tr>
<tr>
<td>DAP</td>
<td>......</td>
</tr>
<tr>
<td>Potash</td>
<td>......</td>
</tr>
<tr>
<td>Organic/green manure</td>
<td>......</td>
</tr>
</tbody>
</table>

(32). What are your sources of rice seed acquisition? (MRA)

1). Research stations ............  
2). Seed companies ...............  
3). Home retained .................  
4). Other farmers .................  
5). Markets.......................  
6). Markets.......................  

(33). What is the estimated plant population in your fields.................

(34). Whether weedicides have some effects on crop? (MRA)

1). Growth................................  
2). Yield..................................  
3). No effect............................  
4). Not known............................

(35). What are your sources of irrigation for rice crop? (MRA)

1). Tube well.....................  
2). Canal.............................  
3). Tubewell+canal...............  

(36). How do you dispose off rice straw? (MRA)

1). By burning.......................  
2). By ploughing in the fields........  
3). Sale in market....................  
4). Grazing & feeding to cattle.......
(37). What are your main sources of information regarding protection measures against rice pest insects? (MRA)

1). Own experience........................................
2). Agriculture Department (name)...................
3). Pesticide dealers/venders etc.....................
4). Fellow farmers...........................................
5). Media (Radio, TV, Newspapers etc).............

(38). How many acres of your land are under

1). B-Super..............
2). B.385..............
3). B.2000..............
4). IRRI.6..............
5). IRRI 9..............
6). Hybrid Rice...........
7). BT. Rice...........
8). Others..............
Determination of Economics Threshold Levels for the Stem Borers (*Scirpophaga* sp.) and Leaffolder (*Cnaphalocrosis medialis*) of Rice (*Oryza sativa*) in the Kallar tract of Punjab, Pakistan

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¹Corresponding authors’ e-mail: miang786@yahoo.com; dranjumsuhailuaf@yahoo.com

ABSTRACT

Effective and economic suppression of insect pests in rice ecosystem by the judicial use of pesticides on the basis of economics threshold levels (ETL) is very essential. This study was conducted to determine the ETLs for the chemical control of rice stem borers, (*Scirpophaga incertulus* Wlk. & *S. innotata* Wlk.) and rice leaffolder (*Cnaphalocrosis medialis* Gn.) in the traditional Basmati rice growing area the Kallar tract of the Punjab, Pakistan. On the basis of cost benefit ratio an action threshold of 5% dead-hearts (DH) and 3% folded leaves for stem borers and rice leaffolder, respectively were developed and use of insecticides to control these insects on need basis despite calendar based insecticides application was stressed.

Key Words: ETL; Stem borers; Leaffolders; Basmati rice

INTRODUCTION

Rice crop is attacked and damages by large number of pest insects from nursery to harvest but only a few of them are considered key pest, which cause severe yield losses. In Pakistan about 128 different species of insects have been reported to attack rice crop however 20 of these are of major economic significance (Ahmad, 1981). Among these major pest insects rice stem borers, (*Scirpophaga incertulas* & *S. innotata*) and rice leaffolder (*Cnaphalocrosis medialis*) considered as dominant pest insects of rice, throughout the rice growing areas. They induce highly discernible damage symptoms (Chaudhary *et al*., 1984; Heong *et al*., 1994; Bhatti, 1995; Alvi *et al*., 2003). Among the various methods used by the farmers to protect the rice crop from these economically important pests the chemical control remains the only mean of economical and rapid method for suppression of insect pests infestation. This is because other methods of pest control are laborious, time consuming and less effective (EJF, 2002). However the indiscriminate use of insecticides has caused many side effects, including, loss of biodiversity, biological imbalance, resulting in changes in community structure the problem of secondary pests, insecticide resistance, residual toxicity, proliferation and resurgence of selected insect pests and environmental pollution (Roger & Kurihara, 1988; Wilson & Tisdell, 2001; Tahir & Butt, 2009).

Determination of economic threshold levels (ETLs) is the main tool, which is helpful in making decisions about whether the insecticides are to be applied or not. But the farmers ignore the ETLs and use insecticides according to calendar-based program to overcome the losses caused by pest insects. Such indiscriminate uses of pesticides not only drain the exchequer but also are a growing threat to the people and environment of the country. It is therefore, important to define the pest population levels, which stresses on immediate intervention mostly by rational insecticide application (Srivastava *et al*., 2004). This practice in turn will help protect the biodiversity and environment from being deteriorated by indulging poisons and lessening the weights of pesticides on country’s import along with savings of health and wealth of the farmer ‘the mechanic’ of agroecosystem.

These studies were planned to determine the ETLs for most commonly known major lepidopterous insect pests of rice, against, which maximum insecticides are being used by rice farmers, so that rational use of insecticides would be employed rather than calendar base use.

MATERIALS AND METHODS

The experiments were conducted at farmer’s fields in traditional rice area i.e., Kallar tract during 2004-2006 to determine ETLs of rice stem borers (*Scirpophaga* sp.) and leaffolder (*Cnaphalocrosis medialis*) of rice (*Oryza sativa*) in the kallar tract of Punjab, Pakistan.
incertulas, S. Innotata) and rice leaf folder (Cnaphalocrosis medennis). The experiments were laid out in randomized complete block design (RCBD) with six treatments for rice stem borers (0, 1, 3, 5, 7 & 9% infestation) and leaffolder (0, 2, 4, 6, 8 & 10% infestation) with three replications. Nursery of rice (Oryza sativa L. cv. Super Basmati) was sown and transplanted with row to row and plant to plant distance of 22 cm in well prepared soil according to the traditional land puddling practices of the area as recommended. The plot size was 1 m² for each treatment in each replication. All the agronomic practices and input used were same for all the treatments, except different infestation levels. To mimic the damage behavior of rice stem borers and leaffolder the simulative injury technique was used (Anonymous, 2003). The treatments were applied at 55 days after transplanting (DAT).

Due to the attack of stem borers, dead-hearts are formed at early crop stages, so artificial dead-hearts were produced with the help of dissecting needle. The number of tillers injured to produce dead-hearts, was calculated by using the following formula:

\[
\text{No of tillers to be injured} = \text{Treatment (\%value)} \times \frac{\text{Total tiller count}}{100}
\]

Whereas in case of rice leaffolder, a 10 cm area of flag leaf, leaving about 4 cm from the tip, was covered with black adhesive tape very carefully to mimic the symptoms of rice leaffolder’s attack. The number of leaves, treated artificially, was calculated by using the following formula:

\[
\text{No of leaves to be treated} = \text{Treatment (\%value)} \times \frac{\text{Total leaves count}}{100}
\]

After harvesting, data on paddy yield (at 14% moisture) and other yield components i.e., number of panicles per m², number of ripened grains per panicle and 1000 grain weight, were recorded and subjected to statistical analysis by using the program MSTAT-C (1989). The means of significant treatments were compared at 5% level of significance through Duncan’s multiple range test (DMRT) following the procedure outlined by Steel and Torrie (1984). Economic analysis of yield losses was done to determine the ETLs for chemical control of these major pest insects of rice crop.

RESULTS AND DISCUSSION

The rice yield is predicted by number of panicles per m², number of ripened grains per panicle and 1000 grain weight (Srivastava et al., 2004). The analysis of variance of yield shows that treatments (% infestation level) had significant effect on number of productive tillers per m² (P < 0.05) and yield per m² (P < 0.01), whereas non-significant effect on number of grains per panicle (P > 0.05) and 1000 grain weight (P > 0.05) in case of rice stem borer (Table I). However, the treatments induced significant variation in number of grains per panicle (P < 0.05), 1000 grain weight (P < 0.05) and yield per m² (P < 0.05), whereas no significant variation in number of productive tillers per m² (P > 0.05) in case of rice leaffolder (Table II).

The number of productive tillers per m² in case of rice stem borers decreased significantly with increasing level of infestation, except for 1% infestation level, which indicated the increased number of productive tillers per m². Mean number of productive tillers per m² was maximum (223) for 1% infestation level, followed by 221, 219, 217, 210 and 208 tillers per m² for 0, 3, 5, 7 and 9% infestation levels, respectively (Table I).

The number of ripened grains per panicles and 1000 grain weight were not affected significantly by increasing infestation levels (Table I). This non-significant effect may be attributed to the fact that rice plant compensates for stem borer injury not only by translocation of its photosynthetic assimilates from damaged tillers to healthy tillers and increasing photosynthesis rate of leaves, adjacent to stem borer killed-tiller’s leaves (Rubia et al., 1996). However their values decreased slightly with increasing the number of damaged tillers per plant (Chen et al., 1982).

The grain yield increased with decrease in infestation level (Table I & III). The highest grain yield (4730.35 kg ha⁻¹) was obtained from 1% infestation followed by 0, 3, 5, 7 and 9% infestations with 4727.58, 4675.71, 4638.66, 4446.98 and 4347.20 kg ha⁻¹, respectively. Higher yield at 1% infestation level than 0% infestation level (T0) may be attributed to the fact that rice plant has the ability to compensate the rice stem borer damage by increasing the production of new tillers (Rubia et al., 1989 & 1996; Islam & Karim, 1997; Heong & Escalada, 1999). These additional tillers contributed to increase the paddy yield. So, enhancing plant compensating mechanism to stem borer injury may be a better strategy for stem borer management than insecticide application (Rubia et al., 1996). Our results also suggested that at low level attack of rice stem borer, control measure should not be adopted at all in any case, because it will be mere wastage of resources. This practice will not only save expenditure incurred in the form of insecticide application, but will also favor the conservation potential of insect biodiversity of rice fields.

The paddy yield data were put for economic analysis by considering the reduction in yields in monetary terms for each treatment and the cost of chemical control involved. The ETL was worked out as 5% damaged tillers for carrying out the necessary control measures against rice stem borers (RSB) (Table III). At this level reduction in yield was 88.92 kg ha⁻¹ worth Rs. 2223 (considering paddy@Rs.25 kg⁻¹) and cost of control was Rs. 2100 ha⁻¹, which was nearly equal to benefit drawn, hence it was more economical. The results confirm to the findings of Inayatullah et al. (1986), Anonymous (2002 & 2003) and Suhail et al. (2008), who also determined 5% damaged tillers as ETL for RSB control. However the results were different from those of Sherawat et al. (2007) who recommended 7.5% damaged stem as ETL to control this pest insect.
grains per panicle and 1000 grain weight decreased by increasing infestation by rice leaffolder. However number of productive tillers were not affected significantly with increasing infestation level (%).

### Table I. Comparison of mean values of different yield components for rice stem borers

<table>
<thead>
<tr>
<th>Infestation level (%)</th>
<th>Stem borer</th>
<th>No. of productive tillers (m⁻²)</th>
<th>No. of grains per panicle</th>
<th>1000-grain weight (g)</th>
<th>Average yield (g m⁻²)</th>
<th>Average yield (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>221a</td>
<td>103.22a</td>
<td>20.96a</td>
<td>478.50a</td>
<td>4727.58a</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>223a</td>
<td>103.11a</td>
<td>20.90a</td>
<td>478.70a</td>
<td>4730.35a</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>219ab</td>
<td>103.11a</td>
<td>21.00a</td>
<td>473.25a</td>
<td>4675.71a</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>217abc</td>
<td>102.00a</td>
<td>20.95a</td>
<td>469.50a</td>
<td>4638.66a</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>210bc</td>
<td>101.22a</td>
<td>20.90a</td>
<td>450.10b</td>
<td>4446.98b</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>208c</td>
<td>100.33a</td>
<td>20.71a</td>
<td>440.00b</td>
<td>4347.20c</td>
<td></td>
</tr>
</tbody>
</table>

LSD = 9.199 LSD = 3.010 LSD = 1.588 LSD = 9.247 LSD = 91.36

### Table II. Comparison of mean values of different yield components for rice leaffolder

<table>
<thead>
<tr>
<th>Infestation level (%)</th>
<th>No. of productive tillers (m⁻²)</th>
<th>No. of grains per panicle</th>
<th>1000-grain weight (g)</th>
<th>Average yield (g m⁻²)</th>
<th>Average yield (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>218a</td>
<td>104.0a</td>
<td>20.90a</td>
<td>470.1a</td>
<td>4644.588a</td>
</tr>
<tr>
<td>1</td>
<td>218a</td>
<td>103.9a</td>
<td>20.50a</td>
<td>465.9a</td>
<td>4599.140a</td>
</tr>
<tr>
<td>2</td>
<td>219a</td>
<td>103.1a</td>
<td>20.20a</td>
<td>458.0a</td>
<td>4525.040ab</td>
</tr>
<tr>
<td>3</td>
<td>218a</td>
<td>102.9a</td>
<td>20.15ab</td>
<td>454.2ab</td>
<td>4487.496ab</td>
</tr>
<tr>
<td>4</td>
<td>218a</td>
<td>101.5a</td>
<td>17.90b</td>
<td>435.3b</td>
<td>4300.764b</td>
</tr>
<tr>
<td>5</td>
<td>216a</td>
<td>96.33b</td>
<td>15.85c</td>
<td>431.7b</td>
<td>4265.196b</td>
</tr>
</tbody>
</table>

LSD = 5.356 LSD = 4.963 LSD = 2.703 LSD = 24.60 LSD = 243.1

### Table III. Economics of chemical control for rice stem borers

<table>
<thead>
<tr>
<th>Infestation level (%)</th>
<th>Average (kg ha⁻¹)</th>
<th>Reduction in yield (kg ha⁻¹)</th>
<th>Cost of control (Rs. ha⁻¹)</th>
<th>Cost/benefit ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4727.58</td>
<td>0</td>
<td>2100</td>
<td>1.00</td>
</tr>
<tr>
<td>1</td>
<td>4730.35</td>
<td>+2.77</td>
<td>2100</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>4675.71</td>
<td>51.87</td>
<td>2100</td>
<td>1.00</td>
</tr>
<tr>
<td>3</td>
<td>4638.66</td>
<td>88.92</td>
<td>2100</td>
<td>1.00</td>
</tr>
<tr>
<td>4</td>
<td>4446.98</td>
<td>200.60</td>
<td>2100</td>
<td>1.00</td>
</tr>
<tr>
<td>5</td>
<td>4547.20</td>
<td>300.38</td>
<td>2100</td>
<td>1.00</td>
</tr>
</tbody>
</table>

### Table IV. Economics of chemical control for rice leaffolder

<table>
<thead>
<tr>
<th>Infestation level (%)</th>
<th>Average (kg ha⁻¹)</th>
<th>Reduction in yield (kg ha⁻¹)</th>
<th>Cost of control (Rs. ha⁻¹)</th>
<th>Cost/benefit ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4644.59</td>
<td>-</td>
<td>2100</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>4599.14</td>
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Note: 1. Means sharing the same letter do not differ significantly.

2. As cost of production was the same for all treatment that is why it was not considered during economic analysis and only cost of protection through insecticide and reduction in yield in monetary terms were considered. In case of chemical control measures Padan 4G @ 22.50 kg ha⁻¹, costs Rs. 1750 ha⁻¹ ((@ Rs.700 bag⁻¹ weighing 9 kg), net transportation charges Rs.100 and application charges @250 ha⁻¹. The paddy price was taken @ Rs. 25 kg⁻¹.

In case of rice leaffolder the mean values for productive tillers were not affected significantly with increasing infestation by rice leaffolder. However number of grains per panicle and 1000 grain weight decreased gradually with increasing leaffolder damage, which ultimately decreased average yield with a slight significant difference. The highest yield was obtained with full control having 0% infestation followed by 2, 4, 6, 8 and 10% damaged leaves, respectively (Table II).

As evident from the Table II low infestation levels of rice leaffolder produced small decrease in paddy yield as compared to its control, because partial defoliation can cause increased photosynthesis in remaining leaves (Wareing et al., 1968). Rice farmers overestimate the losses caused by rice leaffolder and become much frightened due to visible damage symptoms by rice leaffolder and thus often overuse insecticide from fear of losses (Litsinger et al., 2005). They mostly spray even at low infestation levels, because of the easy availability of insecticides at low prices in Kallar tract of Punjab. Compared to granular insecticides foliar sprayable insecticides, besides killing rice insects harm to natural enemies to a greater extent, which tend to keep these pests at low densities. This practice, however, is not only a cause of environmental pollution but also is harmful to both farmers and ecosystem (Fernando, 1970).

The paddy yields data were put to economic analysis by considering the reduction in yields in monetary terms for each treatment and the cost of chemical treatment involved to control rice leaffolder. From Table IV it is clear that for 2% infested leaves cost of control was more and at 4% infestation loss was more as compared to cost of its control. This implied that ETL for rice leaffolder lied in between these two infestation levels. So, the ETL was worked out as 3% damaged leaves for carrying out the necessary control measures against rice leaffolder by using granular insecticide Padan (cartap 4G). At this infestation level cost of control and benefits were almost equal, hence more economical. The results of the present study are in accordance to those of Tu et al. (1985) and Anonymous (2002) but different from those of Bautista et al. (1984), who reported 5% damage leaves as action threshold.

### CONCLUSION

Chemicals based control measures should be adopted when infestation reaches 5% dead-hearts and 3% damaged leaves for the control of rice stem borers and leaffolder, respectively. For developing ETLs as only economic costs and losses were considered. However, if we also include costs to natural enemies, health, environment and difficulties in performing insecticide application task the higher will be the thresholds.

**Acknowledgement.** We thank Dr. Muhammad Athar Rafi, National Insect Museum, Islamabad, Pakistan, Mr. Muhammad Mushtaque, Rice Research Institute, Kala Shah Kaku, Mr. Sher Muhammad Sherawat, Adaptive Research Farm, Sheikhupura, Pakistan, Mr. Muhammad Arshad and Mr. Dildar Gogi, Lecturer Department of Agri. Entomology, University of Agriculture, Faisalabad, for providing relevant literature to develop methodology for the experiments and
helpful guidance to improve the manuscript. The research was supported by the Higher Education Commission, Islamabad, Pakistan.

REFERENCES

Ahmad, I., 1981. Studies on the Rice Insects of Pakistan with Reference to Systematics and Pheromone Glands, pp: 388. Department of Zoology, University of Karachi, Pakistan


## Appendix III - Over all abundance of insect fauna and effect of input levels on it.

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<th>ORDER/ FAMILY/ SPECIES NAME</th>
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<th>SKEIKHUPURA</th>
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<th>G. Total</th>
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<td><strong>Plecoptera</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perlidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perla sp.</td>
<td>5</td>
<td>18</td>
<td>3</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td><strong>Thysanoptera</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phlaeothripidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haplothrips sp.</td>
<td>8</td>
<td>0</td>
<td>10</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td><strong>Thripidae</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thrips oryzae Williams</td>
<td>38</td>
<td>39</td>
<td>21</td>
<td>19</td>
<td>77</td>
</tr>
</tbody>
</table>

Note: All values are mean of the years 2006 & 2007.
### Appendix IV - Insect species absent in HIP rice fields.

<table>
<thead>
<tr>
<th>Insect Group</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Xylonites praeustus <em>(Bostrichidae)</em>, Ophionea sp., Scarites nanus <em>(Carabidae)</em>, Aeolesthes sarta, Chlorophorus annularis <em>(Cerambycidae)</em>, Dicladispa armigera <em>(Chrysomelidae)</em>, Cicindela undulata <em>(Cicindelidae)</em>, Dyticus sp.5, Laccophilus parvulus <em>(Dytiscidae)</em>, Heterocerus sp.1 <em>(Heteroceridae)</em>, Hydraena sp. <em>(Hydraenidae)</em>, Cybocephalus semiflavus <em>(Nitidulidae)</em>, Copris repertes <em>(Scarabaeidae)</em>, Camerimena rugosiatriatus <em>(Tenebrionidae)</em></td>
</tr>
<tr>
<td><strong>Lepidoptera</strong></td>
<td>Neozephyrus sp., Zizeeria maha <em>(Lycaenidae)</em>, Trosia obsolescens <em>(Megalopygidae)</em>, Atella phalantha phalantha <em>(Nymphalidae)</em>, Pieris brassicae, Pieris napi, Valeria valeria <em>(Pieridae)</em>, Auilocera loha <em>(Satyridae)</em></td>
</tr>
<tr>
<td><strong>Hymenoptera</strong></td>
<td>Anthophora sp., Apis florea <em>(Apidae)</em> Microlistis sp. <em>(Braconidae)</em>, Halictus farinosus <em>(Halictidae)</em>, Aporus sp. <em>(Pompilidae)</em>, Athalia lugans <em>(Tenthredinidae)</em>, Myzini sp. <em>(Tiphidae)</em>, Vespa sp. <em>(Vespidae)</em></td>
</tr>
<tr>
<td><strong>Diptera</strong></td>
<td>Ogcodes sp.1 <em>(Acroceridae)</em>, Atherix sp. <em>(Athericidae)</em>, Brontaea tonitrui <em>(Muscidae)</em>, Tritoxa sp. <em>(Otitidae)</em>, Syrphid sp., Syrphus confrater <em>(Syrphidae)</em>, Tabanus sp. <em>(Tabanidae)</em> Tachind sp.3 <em>(Tachinidae)</em></td>
</tr>
<tr>
<td><strong>Hemiptera</strong></td>
<td>Belostoma indica <em>(Belostomatidae)</em> Physopelta gutta <em>(Largidae)</em>, Ragnus flavomaculatus <em>(Miridae)</em>, Sirthenea flavipes <em>(Reduviidae)</em></td>
</tr>
<tr>
<td><strong>Homoptera</strong></td>
<td>Dictyophara pallida <em>(Dictyopharidae)</em></td>
</tr>
<tr>
<td><strong>Odonata</strong></td>
<td>Ishnura forcipata <em>(Coenagrionidae)</em>, Crocothemis sp., Orthetrum prunosum neglectum, Orthetrum sabina <em>(Libellulidae)</em></td>
</tr>
<tr>
<td><strong>Orthoptera</strong></td>
<td>Acrotylus insubricus, Aiolopus thalassinus <em>(Acrididae)</em>, Gryllotalpa orientalis <em>(Gryllotalpidae)</em>, Mesotettix nobrei <em>(Tetrigidae)</em></td>
</tr>
<tr>
<td><strong>Dermaptera</strong></td>
<td>Labidura riparia <em>(Labiduridae)</em></td>
</tr>
</tbody>
</table>

### Insect species absent in LIP rice fields

<table>
<thead>
<tr>
<th>Insect Group</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Chlaenius circumdatus <em>(Carabidae)</em></td>
</tr>
<tr>
<td><strong>Lepidoptera</strong></td>
<td>Scirpophaga auriflua <em>(Pyralidae)</em></td>
</tr>
<tr>
<td><strong>Hymenoptera</strong></td>
<td>Eumeses sp. <em>(Vespidae)</em></td>
</tr>
<tr>
<td><strong>Hemiptera</strong></td>
<td>Leptocorisa oratorius <em>(Alydidae)</em></td>
</tr>
<tr>
<td><strong>Homoptera</strong></td>
<td>Hishimonus phycitis <em>(Cicadellidae)</em></td>
</tr>
</tbody>
</table>
## Appendix V - The important insect taxa collected from rice fields during different stages of a rice crop.

<table>
<thead>
<tr>
<th>Stage/phase</th>
<th>Important insects collected</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-Nursery (Semi-aquatic)</strong></td>
<td>Rice Herbivores: Orthoptera, <em>Scirpophaga innotata</em>, <em>S. incertulas</em>, <em>Sesamia inferens</em></td>
</tr>
<tr>
<td>(field preparation)</td>
<td>NRP: <em>Culicidae, Athous</em> sp.</td>
</tr>
<tr>
<td></td>
<td>Parasitoids: Ichneumonidae</td>
</tr>
<tr>
<td></td>
<td>Scavengers: <em>B. germanica</em>, <em>Periplanata</em> spp., <em>Chironomidae</em>, <em>Ephydridae</em>, <em>Collembola</em></td>
</tr>
<tr>
<td><strong>Nursery (aquatic)</strong></td>
<td>Rice Herbivores: Acriddae, <em>Cofana spectra</em>, <em>Chrysomelidae</em>, <em>Hydromonidius molitor</em>, <em>Nephotettix</em> spp., <em>Recilia dorsalis</em>, <em>Orseolia</em> sp., <em>Nilaparvata lugens</em>, <em>Nymphula depunctalis</em>, <em>S. incertulas</em>, <em>S. innotata</em>, <em>Scotinophara</em> spp., <em>Sofatella furcifera</em></td>
</tr>
<tr>
<td></td>
<td>NRP: <em>Culicidae, Apidae</em></td>
</tr>
<tr>
<td></td>
<td>Parasitoids: Ichneumonidae, Mymaridae, Scelionidae</td>
</tr>
<tr>
<td></td>
<td>Scavengers: <em>Collembola</em>, <em>Chironomidae</em></td>
</tr>
<tr>
<td><strong>Tillering-Booting (aquatic)</strong></td>
<td>Rice Herbivores: Alydidae (<em>Leptocorisa</em> sp), <em>Atherigona</em> spp., <em>Cletus punctiger</em>, <em>Chrysomelidae</em>, <em>Cnaphalocrosis medinalis</em>, <em>Chilo suppressalis</em>, <em>Dicladispa armigera</em>, <em>Hesperidae</em> (<em>Parnara mathias</em>), <em>N. lugens</em>, <em>S. furcifera</em>, <em>Melanitis leda</em>, <em>Orseoli</em> sp., <em>Thrips oryzae</em>, <em>S. incertulas</em>, <em>S. innotata</em></td>
</tr>
<tr>
<td>(including flooded fields prior to transplanting)</td>
<td>NRP: <em>Arctidae, Culicidae</em>, <em>Dictyopharidae, Precis almana, Valeria valeria</em></td>
</tr>
<tr>
<td>Stage/phase</td>
<td>Important insects collected</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Parasitoids: Braconidae, Mymaridae, <em>Myzimum</em> sp., Scelionidae, Trichogrammatidae</td>
</tr>
<tr>
<td></td>
<td>Scavengers: Collembola, Chironomidae</td>
</tr>
<tr>
<td><strong>Flowering-milking (aquatic)</strong></td>
<td>Rice Herbivores: <em>Chilo suppressalis, Cletus punctiger, Leptocorisa oratorius, S. furcifera, Sesamia inferens, Pentatomidae, Thysanoptera, Scirpophaga spp.</em></td>
</tr>
<tr>
<td></td>
<td>Predators: Reduviidae, Hydrophilidae, Vespidae</td>
</tr>
<tr>
<td></td>
<td>Parasitoids: Braconidae</td>
</tr>
<tr>
<td></td>
<td>Scavengers: Collembola</td>
</tr>
<tr>
<td><strong>Grain ripening (semi-aquatic and dry)</strong></td>
<td>Rice Herbivores: <em>Chilo suppressalis, Pentatomidae, Leptocorisa spp., Scirpophaga spp.</em></td>
</tr>
<tr>
<td></td>
<td>NRP: Apidae, <em>Earias</em> spp., <em>Zizeeria maha</em></td>
</tr>
<tr>
<td></td>
<td>Predators: Carabidae, <em>Goonomdanepa</em> sp., Formicidae</td>
</tr>
<tr>
<td></td>
<td>Parasitoids: Braconidae, <em>Gregopimpla</em> sp.</td>
</tr>
<tr>
<td></td>
<td>Scavengers: Collembola, Chironomidae</td>
</tr>
</tbody>
</table>
## Appendix VI—List of abundant species and the species maximum in abundance in overall insect fauna of rice crop.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Number of individuals</th>
<th>Name of species</th>
<th>Sr. No.</th>
<th>Number of individuals</th>
<th>Name of species</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1032</td>
<td><em>Dascillus</em> sp.</td>
<td>39</td>
<td>2507</td>
<td><em>Ephydrid</em> sp.1</td>
</tr>
<tr>
<td>2</td>
<td>1034</td>
<td><em>Tropisternus orvus</em> Leech</td>
<td>40</td>
<td>2683</td>
<td><em>Culex Quinquefasciatus</em> Say</td>
</tr>
<tr>
<td>3</td>
<td>1036</td>
<td><em>Euplectrus</em> sp.</td>
<td>41</td>
<td>2700</td>
<td><em>Menochilus sexmaculatus</em> Fabricius</td>
</tr>
<tr>
<td>4</td>
<td>1079</td>
<td><em>Calosoma maderae</em> Fabricius</td>
<td>42</td>
<td>2877</td>
<td><em>Chlaenius</em> sp.2</td>
</tr>
<tr>
<td>5</td>
<td>1099</td>
<td><em>Oscinella frut</em> Linnaeus</td>
<td>43</td>
<td>2945</td>
<td><em>Nilaparvata lugens</em> (Stal)</td>
</tr>
<tr>
<td>6</td>
<td>1102</td>
<td><em>Nephotettix sp.2</em></td>
<td>44</td>
<td>3014</td>
<td><em>Ephydrid</em> sp.3</td>
</tr>
<tr>
<td>7</td>
<td>1109</td>
<td><em>Cnaphalocrocis medinalis</em> Guenee</td>
<td>45</td>
<td>3292</td>
<td><em>Temelucha</em> sp.</td>
</tr>
<tr>
<td>8</td>
<td>1126</td>
<td><em>Antisolabis annulipes</em> (Lucas)</td>
<td>46</td>
<td>3390</td>
<td><em>Laccophilus flexuosus</em> (Aube)</td>
</tr>
<tr>
<td>9</td>
<td>1143</td>
<td><em>Sycmus</em> sp.</td>
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<td>3438</td>
<td><em>Dytiscus</em> sp.1</td>
</tr>
<tr>
<td>10</td>
<td>1143</td>
<td><em>Ephydrid</em> sp.3</td>
<td>48</td>
<td>3531</td>
<td><em>Laccophilus chinensis inefficiens</em> Walker</td>
</tr>
<tr>
<td>11</td>
<td>1155</td>
<td><em>Aphanus sordidus</em> Fabricius</td>
<td>49</td>
<td>3631</td>
<td><em>Microtermes obesi</em> Holmgren</td>
</tr>
<tr>
<td>12</td>
<td>1215</td>
<td><em>Chironomid</em> sp.3</td>
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<td>3666</td>
<td><em>Scydmaenid</em> sp.</td>
</tr>
<tr>
<td>13</td>
<td>1226</td>
<td><em>Anopheles stephensi</em> Liston</td>
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<td>3698</td>
<td><em>Cardiophorus</em> sp.1</td>
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<tr>
<td>14</td>
<td>1229</td>
<td><em>Chaetochnema basalis</em> (Baly)</td>
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<td>3747</td>
<td><em>Scythophorus</em> sp.1</td>
</tr>
<tr>
<td>15</td>
<td>1278</td>
<td><em>Oxycarenus</em> sp.</td>
<td>53</td>
<td>3814</td>
<td><em>Hydropilus</em> sp.2</td>
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<tr>
<td>16</td>
<td>1308</td>
<td><em>Lartridid</em> sp.</td>
<td>54</td>
<td>4114</td>
<td><em>Leptocorisa acuta</em> (Thunberg.)</td>
</tr>
<tr>
<td>17</td>
<td>1353</td>
<td><em>Nysius</em> sp.1</td>
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<td>4313</td>
<td><em>Philenthus cinctulus</em> (Grav)</td>
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<td><em>Bradyisia</em> sp.</td>
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<td>4346</td>
<td><em>Coenosia humilis</em> Meigen</td>
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<tr>
<td>19</td>
<td>1387</td>
<td><em>Pachnephorus</em> sp.</td>
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<td>4490</td>
<td><em>Chironomid</em> sp.2</td>
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<td>1406</td>
<td><em>Culex tarsalis</em></td>
<td>58</td>
<td>4625</td>
<td><em>Hydrophilus</em> sp.2</td>
</tr>
<tr>
<td>21</td>
<td>1514</td>
<td><em>Aedes albopictus</em> (Skuse)</td>
<td>59</td>
<td>4936</td>
<td><em>Chlaenius</em> sp.1</td>
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<tr>
<td>22</td>
<td>1522</td>
<td><em>Agriocnemis</em> sp.</td>
<td>60</td>
<td>5160</td>
<td><em>Troglophorus indicus</em> Kratz</td>
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<td>23</td>
<td>1738</td>
<td><em>Orthotrichus indicus</em> Bates</td>
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<td>5790</td>
<td><em>Micronecta</em> sp.</td>
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<tr>
<td>24</td>
<td>1749</td>
<td><em>Anticus</em> sp.1</td>
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<td>8772</td>
<td><em>Formicomus sulcipes</em> Pic.</td>
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<tr>
<td>25</td>
<td>1776</td>
<td><em>Forficula auricularia</em> Linnaeus</td>
<td>63</td>
<td>11093</td>
<td><em>Odontotermes obesus</em> (Rambur)</td>
</tr>
<tr>
<td>26</td>
<td>1980</td>
<td><em>Ephydrid</em> sp.2</td>
<td>64</td>
<td>11400</td>
<td><em>Odontotermes obesus</em> (Rambur)</td>
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<td>27</td>
<td>2031</td>
<td><em>Chelonus</em> sp.</td>
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<td>12340</td>
<td><em>Psammobioides</em> sp.</td>
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<tr>
<td>28</td>
<td>2072</td>
<td><em>Culex pipiens</em> Linnaeus</td>
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<td>17550</td>
<td><em>Psammobioides</em> sp.</td>
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<td>29</td>
<td>2087</td>
<td><em>Aedes aegypti</em> Linnaeus</td>
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<td>20930</td>
<td><em>Psammobioides</em> sp.</td>
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<tr>
<td>30</td>
<td>2139</td>
<td>*Cotesia sp.2</td>
<td>68</td>
<td>21107</td>
<td><em>Psammobioides</em> sp.</td>
</tr>
<tr>
<td>31</td>
<td>2174</td>
<td>*Calosoma sp.1</td>
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<td>22199</td>
<td><em>Psammobioides</em> sp.</td>
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<td>2196</td>
<td><em>Hydropsyllus</em> sp.3</td>
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<td>23228</td>
<td><em>Psammobioides</em> sp.</td>
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<td><em>Colpodes buchanani</em> Hope</td>
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<td>24399</td>
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<td>25265</td>
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<td><em>Megalodacne</em> sp.</td>
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<td><em>Cleefia bimaculatus</em> Dejean</td>
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<td><em>Psammobioides</em> sp.</td>
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<td>2504</td>
<td><em>Anopheles maculates</em> Theobald</td>
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<td>59383</td>
<td><em>Psammobioides</em> sp.</td>
</tr>
</tbody>
</table>

**Note:** Normal font indicates abundant species and bold indicates species maximum in abundance
Appendix-VII


## Appendix VIII - Climatic factors of the Kallar tract (Mean for the years 2006 & 2007).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
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</tr>
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<tbody>
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<td>21.80</td>
<td>30.07</td>
<td>4.04</td>
<td>43.17</td>
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<td>3</td>
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<td>21.27</td>
<td>30.00</td>
<td>14.56</td>
<td>44.23</td>
</tr>
<tr>
<td>May</td>
<td>4</td>
<td>40.07</td>
<td>24.46</td>
<td>32.26</td>
<td>7.83</td>
<td>44.57</td>
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<td>25.70</td>
<td>33.75</td>
<td>4.15</td>
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<td>June</td>
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<td>27.47</td>
<td>35.00</td>
<td>2.33</td>
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<tr>
<td>June</td>
<td>3</td>
<td>42.57</td>
<td>25.73</td>
<td>34.15</td>
<td>32.56</td>
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<tr>
<td>June</td>
<td>4</td>
<td>42.70</td>
<td>26.43</td>
<td>34.56</td>
<td>29.33</td>
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<tr>
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<td>23.85</td>
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<tr>
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<td>41.52</td>
<td>26.98</td>
<td>34.25</td>
<td>45.57</td>
<td>71.24</td>
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<tr>
<td>August</td>
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<td>43.05</td>
<td>28.87</td>
<td>35.96</td>
<td>40.03</td>
<td>71.57</td>
</tr>
<tr>
<td>August</td>
<td>4</td>
<td>43.45</td>
<td>29.25</td>
<td>36.35</td>
<td>52.95</td>
<td>74.25</td>
</tr>
<tr>
<td>September</td>
<td>2</td>
<td>39.05</td>
<td>21.72</td>
<td>30.38</td>
<td>45.73</td>
<td>75.22</td>
</tr>
<tr>
<td>September</td>
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## Values of climatic factors on monthly basis (Mean for the years 2006 & 2007).

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