Lund University

LUMES, Lund University International Master's Programme in Environmental Science

Analysis of pest management methods used for Rice stem borer (*Scirpophaga incertulas*) in Sri Lanka based on the concept of Sustainable Development

Master's Thesis

Compiled By

Indike Amuwitagama.

Address: 44/45A, Dambahena Road,
Maharagama, Colombo,
Sri Lanka.

E-mail: indike94@yahoo.com

Telephone: 0046-70-251-043-5.

Supervisor:

Dr.Fredrik Schlyter
Chemical Ecology
Department of Crop Sciences
Swedish University of Agricultural Sciences
P.O. Box 44, SE-230 53 Alnarp, Sweden
Tel: +46-40-415 303
Fax: +46-40-46 21 66
E-mail: Fredrik.schlyter@vv.slu.se

LUMES
P.O.Box 170, S-221 00, Lund.
Tel: +46-46-222 0470
Fax: +46-46-222 0475
Internet: http://www.lumes.lu.se
E-mail: lumes@envir.lu.se

November 2002

Abstract

Due to the high demand for pest control in Sri Lankas' rice paddy cultivation practices, the number of new pesticides has been recently introduced. However, the new pesticides, which are flowing into the agriculture sector of Sri Lanka, appeared to be used by farmers without obtaining proper application guidance from the suppliers or from extension services. As a result, the exposure to harmful pesticides is increasing and the excessive use of them generates environmental, social, and economical problems. Therefore, a commitment to new strategy in pest management is needed, in order to ensure the suitable and efficient pest management method in Sri Lankas' rice farming sector, along with maintenance of the environmental standards in the country. The aim of this thesis is to analyse the current pest management methods used in Sri Lanka to control the out breaks of Rice Stem borers (*Scirpophaga incertulas)* and their short and long term impacts on environment, economical and social sectors. Moreover, this study investigates the possibilities of introduction of a combination of pest management methods into the agriculture sector of Sri Lanka, in order to overcome the negative impacts on environment, economic, and social sectors. The findings are that the existing conventional pest control methods contradict with the sustainable agriculture concept. This study suggests that traditional pest management practices could play an important role in achieving sustainable pest management method by influencing the decrease of excessive usage of pesticides

Key words: Rice stem borer (*Scirpophaga incertulas)*, rice paddy cultivation, traditional pest control methods, conventional pest control methods, novel pest control methods, integrated pest management, sustainable agriculture.

Acknowledgments

I am very grateful to LUMES for giving me this magnificent opportunity to study in the programme and receive the latest knowledge and experience in the field of Environment.

I would like to express my sincere thanks and gratitude to my supervisor Dr.Fredrik Schlyter, Department of Crop Sciences, Swedish University of Agricultural Sciences, Alnarp, Sweden, for his constructive and patient support in completing this work.

My thanks are due to all those who have given help and information freely for the compilation of this paper. In particular I thank the following, Dr. Sumith Abeysiriwardane (Deputy Director, RRI of Sri Lanka), Dr. L. Nugaliyadda, (Chief Entomologist, RRI of Sri Lanka) and Mr.Sunil Sarth Perera (Additional Director, Ministry of Forestry & Environment-Sri Lanka).

I am equally thankful for the Swedish Institute for the financial support throughout the LUMES programme that made it possible for me to carry through the studies in Lund University.

Finally, I would like to give my gratefulness to my loving parents, wife and mother-in-law for their moral and heartened support in all these work. Without their love, I wouldn't be able to accomplish this task.

Table of contents

List of Acronyms

ASC	Agrarian Service Centres
BG450, BG11-11, BG379-2, BG350 and BG 300	Bathalegoda Rice Varieties
BHC	Hexachlorocyclohexane
BT	*Bacillus thuringiensis*
CLD	Causal loop diagram
DDT	Dichlorodiphenyltrichloroethane
DOASL	Department of Agriculture in Sri Lanka
ETL	Economic Threshold Level
FAO	Food and Agriculture Organization
IPM	Integrated Pest Management
IRRI	International Rice Research Institute
NGO's	Non-Governmental Organizations
RH	Relative Humidity
RRI	Rice Research Institute of Sri Lanka
UNEP	United Nations Environment Programme
WHO	World Health Organization

I. Introduction

The increase of the volume in production of rice is an immediate requirement in Sri Lanka due to its rapidly growing population. However, achieving this task seems impossible due to various obstacles. One of the main problems is the different kind of pest attacks on the rice fields. According to this issue, one of the important rice pests in Sri Lanka is the rice stem borer (*Scirpophaga incertulas).* Farmers use different methods in Sri Lanka to control the out breaks of Rice Stem borers. This study will analyse the available pest management methods in Sri Lanka and their short and long term impacts on environment, economical and social sectors under the sustainable agriculture concept. There are many definitions of sustainable development, including this landmark one which first appeared in 1987, in the world commission on Environment and Development's (The Brundtland Commission) report Our Common Future "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."*(Oxford*: Oxford University Press, 1987). Agriculture receives a very important place in the sustainable development concept as it is closely involved with ecosystems, natural resources, and human beings. Also agriculture requires large amount of natural resources in its practices. Therefore sustainable agriculture practices would be one of the key factors for the survival of future generations.

Rice paddy cultivation receives the highest attention in the agriculture sector in Sri Lanka. Rice constitutes the staple food of the population. The agriculture landscape of the country consists mainly of the rice fields, covering 780,000 ha of cultivated land. (Ministry of Forestry & Environment, 1999). Farmers in Sri Lanka are mainly practicing small-scale cultivation and there are few large-scale farms available in the country. Therefore applying of above mentioned pest management methods are different from farm to farm. Sri Lanka's rice lands are mostly in the inland valleys and, to a limited extent, on coastal plains, flood plains, and terraced slopes. Variable seasonal rains and a variety of soils, elevations, temperatures, and drainage patterns create complex and varying environments for rice production (Will 1989).

II. Objectives

The objective of this study is to analyse the present pest management methods used by Sri Lankan farmers to control the outbreaks of rice stem borer (*Scirpophaga incertulas).* The study will observe the most feasible method that can apply in rice paddy farming in Sri Lanka from the societal, economic and ecological perspective. Accordingly, it is implied in this research, to apply the fundamental principles of sustainable agriculture. Moreover, the objective of this thesis is to study the possibilities of applying Integrated Pest Management (IPM) method to control the rice stem borer outbreaks in Sri Lankan paddy farming sector. In addition to the environmental implications, the intention is to investigate social and economical aspects behind rice paddy farming in Sri Lanka. Furthermore, the main attention will be paid to the investigation of the practical pest management methods, which are currently practiced by Sri Lankan farmers, namely, Traditional and Conventional pest control methods and their short and long term impacts on environment, economical and social sectors, which would be critical for introduction of a new concept of sustainable pest management method.

III. Scope and Limitations

The issue of sustainable agriculture is a relatively new concept in Sri Lanka. Therefore this research will investigate the possibilities of introducing a combination of pest management methods, which would be considered from the social, economic and ecological domains. However, the scope is limited by time available to carry out the research as well as the human resources available. Furthermore rice paddy fields are a complex system and require practical application of different pest management methods to observe the precise outcomes of various actors when applied in the field, which was not carried out in this study due to limited time factor.

IV. Importance of Rice Stem Borer as a Pest

Rice stem borers occur in different ecosystems. In Sri Lanka three species of stem borers attack deepwater rice, but the major pest is undoubtedly the yellow stem borer (*Scirpophaga incertulas)*. It is completely dominant in the flood season; none of the other species are adapted to aquatic conditions. The yellow stem borer may be considered as one of mankind's worst pest, since in Asia it is the major pest of the most important staple food crop. Living exclusively on the *Oryza* cultigens and *Oryza* wild rice, it has been associated with cultivated rice for thousands of years (Yazumatsu, 1976) and probably originated within the broad belt stretching from Northern India to North Vietnam where rice is endemic. The highly specific insect – host plant relationship and the adaptive characteristics to an aquatic environment strongly suggest that yellow stem borer originated in the deepwater rice environment (Catling, 1992).

In Asia, yield losses due to the two most important species, the yellow and striped stem borers range from 1-20%. However, during outbreak conditions, yield losses may range from 30 to 100%. Except for the yellow stem borer, which is monophagous to rice, the other species also feed on corn, sorghum, sugarcane, wild rice and other species of grasses (IRRI website). In Sri Lanka stem borer damage had been estimated to reduce up to 50% of the potential harvest of rice. The stem borers belong to the Order Lepidoptera, which is characterised by the presence of sucking mouthparts in the form of a proboscis and scales on the wings. At present three species of lepidopteran stem borers are known to occur in Sri Lankan paddy fields (Fernando, 1964). Two of them are pyralid moths, i.e. yellow stem borer, *Scirpophaga incertulas*, which comprises almost 90% of the stem borer populations and a *Crambus* sp., which is rare. A noctuid, *Sesamia inferens*, forms about eight percent of the local stem borer populations (Ranasinghe, 1992).

V. Nature of damage

Scirpophaga incertulas could attack most of the growing stages of rice plant, beginning with seedling through tillering and up to ear setting (Ranasinghe, 1992). *Scirpophaga incertulas* caterpillars bore into the rice stem and hollow out the stem completely. The damage symptoms vary according to the stage of growth of the plant. During the very early stages of growth the larvae damage the growing point in the terminal shoot. This condition is known as 'Dead heart'. The larvae also feed internally within the leaf sheath and damage the vascular tissue by feeding inside the stem. The damage to stem results in the entry holes around. If the borer attack occurs at the flowering stage the resulting panicles become white and empty, a condition known as the 'white head'. Among the other symptoms of damage of this pest is the presence of egg clusters on the leaves, presence of adult moth either flying around or floating on water and the curling of the young leaves (Pathak, 1970).

Image 01: Adult, Larvae and Egg mass.

Image 02: Rice stem borer attack. (White head stage).

Yield loss is caused by (01) a loss of bearing stems due to the production of dead hearts (the outright death of stems), or from damaged but symptom less stems attacked in the vegetative state that are covered by rising water, (02) the smaller panicles borne by compensatory nodal tillers, (03) white heads (empty panicles) caused by attack in the reproductive phase, and (04) A decrease in filled grains and lowering of panicle weight from late damage (Catling 1992).

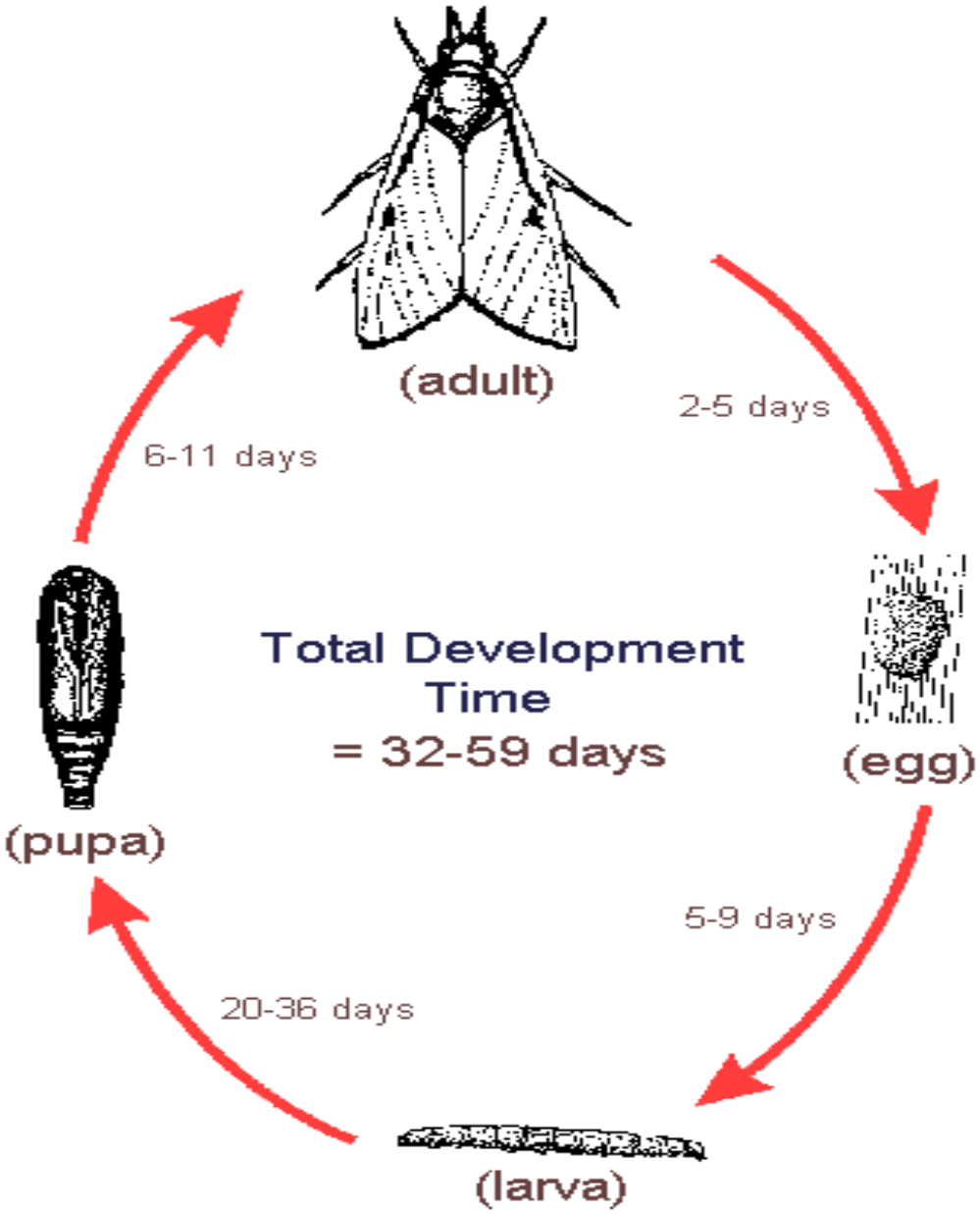


Image 03: Life cycle of the rice stem borer (Source: IRRI Website).

The eggs are laid in oval clusters of 80-150 on either the lower or the upper surface of the leaf. Usually the egg clusters are found 7.5-10.0 cm from the tip of the leaf. The eggs hatch in 5-9 days depending on the ambient temperature.

There are five larval instars. In Sri Lanka, the first instars do not migrate; the second and fourth instars show little migration. But the third instar migrates actively. The fifth instar migrates only rarely (Fernando, 1964). The larvae get transported either by wind currents or the raft like pieces of leaf floating on water. Some larvae may diapause in the stubble.
The pupation occurs at the base of the larval tunnel, which sometimes may be below the water level. From this tunnel a silken tube is found to extend to the exit hole. The Adults show sexual dimorphism. They do not feed and are short lived with a life span of 4-5 days. The female lays 2-5 egg clusters (Ranasinghe, 1992)

Rice Stem borer is considered a major pest of rice in many Asian countries. Fernando (1964) and Wickramasinghe (1980) have reported on the population dynamics of this insect pest in Sri Lanka. According to these authors the first brood reaches a peak during early planting to tillering stages. A second brood occurs from late shooting to heading and a third after the harvest.

This species is monophagous with no known alternate hosts. In Sri Lanka their survival between rice cultivating seasons is on the ratoon crop, stubble and on the volunteer plants that originate from the seeds, which are shed during harvesting. Thus the boggy tracts support their off season occurrence and the dry conditions decrease the same (Ranasinghe, 1992).

The egg parasites of this insect are relatively more active compared to the larval and pupal parasites. In Sri Lanka, four species of egg parasites are known to occur. These include two species of eulophids: *Tetrastichus schoenobii* Ferriere (10 percent), *T.Israeli* Mani and Kurain (2 percent), a scelionid: *Telenomus dignus* (70-90%) and a rare trichogrammatid, *Trichogramma sp*. From above, *Telenomus dignus* is the most active, sometimes parasiting as much as 100% of the egg masses and up to 90% of eggs in an egg mass. The introduction of the egg parasite, *T.japonica* has been attempted but was a failure in Sri Lanka (Wickramasinghe, 1980).

Apanteles flavipes Cameron, *A. Schoenobii* Wilkinson, *Shiraka schoenobii* Viereck, an eulophid: *Aprotocetus sp*. are among the larval parasites of yellow stem borer known to exist in Sri Lanka. Two other larval parasites have been reported to occur locally (Wickramasinghe, 1980). Overall though, the larval parasitism is low mainly due to the protected habitat of the larvae. Only one pupal parasite of the yellow stem borer is known to occur locally (Wickramasinghe, 1980).

The limiting factors for each development stage of the main broods of this insect affected are summarized in the table shown below. In the preflood period, the dominant factors are the synchrony between the emergence of brood 1 at the end of the dry season and the newly sown deepwater rice crop, and the prevailing weather before flood inundation.
Weather extremes are particularly critical for the eggs and first instars when temperatures rise above 34^{oC} with RH below 70 %, these conditions were called 'lethal days' (Catling 1992).

Table01: Major factors limiting the populations of yellow stem borer, *Scirpophaga incertulas*, in deepwater rice according to insect stage and brood, Agrakhola, Bangladesh. Brood 1 in boro rice, broods 2-6 in deepwater rice, brood 6 diapausing.

Stage	Limiting factor [a]		Major broods
Eggs	Weather	**Desiccation** (>34^{o}C, <70% RH)	1,2
	Parasites	**Mainly 2 chalcids**	all
	Predators	Orthoptera, Spiders	all
	Flooding	**Drowning of submerged eggs**	3,4
Instar I	Weather	**Desiccation before entering stem**	2
	Plant condition	**Tough stems, drought-stressed**	2
	Predation	Mainly spiders	all
Instars II-VI	Parasites	Hymenoptera, Instars V-VI	all
	Predators	Ants, beetles	1,2,6
	Weather	**Desiccation of diapausing IV-VI**	6
	Flooding	Drowning in submerged stems	3,4
All	Cultivation	Raking and weeding	2

immature Stages	Crop residue treatment	Threshing, stacking, burning	6
Adults	Predators	Spiders, damsel flies, birds	all
	Flooding	Drowning of teneral moths	3,4
	Weather	High temperature inhibits egg-laying	2

(Source: Catling, 1992). [a] Severe limiting factors shown in bold type.

Long-horned grasshopper and crickets prey on stem borer eggs. Carabid ground beetles prey on larvae while spiders and dragonflies prey on moths. Microbial Agents: Stem borer larvae get infected with some species of bacteria, fungi, viruses, and nematodes. (IRRI website).

VI. Different Pest management methods used to control *Scirpophaga incertulas*

A. Traditional methods-

Traditional knowledge has been used down the line from one generation to the other in rice paddy cultivation. This knowledge, which contains a very specific traditional method called "Kem Krama", is widely used even in this modern time by Sri Lankan farmers. There is no specific word for "Kem Krama" in the English language; however, the meaning could be elaborated as a "tactful, traditional method of treatment and prevention".

These practices are followed in a very peculiar manner, mostly in a secretive way and the knowledge is shared only among close relatives and friends. The traditional farmer had a belief that if these methods were revealed to the public, the power or the effectiveness of those methods could be reduced or gone. (Rathnapala, 1995). These traditional methods have come into practice as a result of long term experience in rice farming. However, the latest technology in farming is becoming more common in a developing country like Sri Lanka and more and more farmers tend to use agro-chemicals and fertilizers in their farming practices. These traditional methods were closer to nature and its balance. Most of the materials used in practicing these techniques were found from the natural environment. Therefore the negative effects on the nature were minimum.

B. Conventional methods-

Sri Lankan farmers are mainly relying on pesticides during major pest attacks. The area of the field, whether large or small scale does not matter. There are extension officers who can advice the relevant pesticide for particular pests but farmers mainly rely on going directly to the pesticide dealer and getting information from him.

Table 02: The pesticides approved by the registrar of Pesticides in Sri Lanka to use against Rice stem borer.

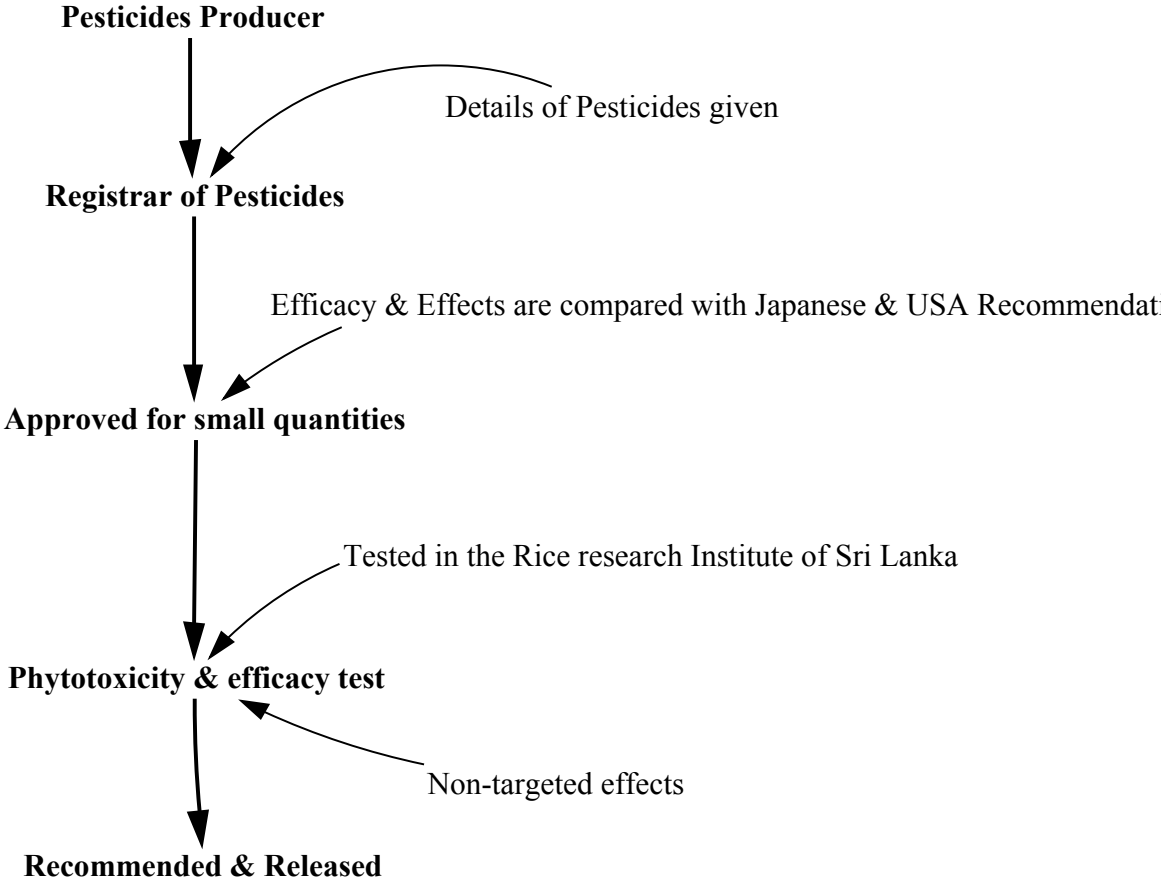
Common (Generic) Name	Dilution	Rate of Application (product/ha)	Remarks-
Fipronil 0.3% GR	-	16kg	Apply insecticides only when damage exceeds 10% dead hearts or 5% white heads.
Carbofuran 3% GR	-	17-22kg	
Carbosulfan 200g/l EC/SC	30ml/10 l	1500ml	
Diazinon 5% GR	-	17-22kg	
Chlorpyrifos 400g/l EC	10-25ml/10 l	500-1000ml	
Chlorpyrifos 200g/l EC	20-50ml/10 l	1000-2000ml	
Phenthoate 500g/l EC	20ml/10 l	800ml	
Quinalphos 250g/l EC	30ml/10 l	1500ml	

(Source: DOASL, 2002a).

Most of the above are used as insecticide granules applied to the standing water. (Wickremasinghe, 1980). The usage of DDT as a method of controlling pests is banned by the government regulations of Sri Lanka. The Registrar of Pesticides is responsible for testing new pesticides before introducing to the farmers. The improvements made so far on pesticide recommendations have been encouraging. The DOASL has constantly updated the recommendations. In 1971, the DOASL covered two organochlorines (DDT and BHC) and six organophosphates (Diazinon, fenthion, malathion, monocrotophos, phenthoate and

trichlorfon). This recommendation was revised in 1979 to add three carbamates (fenobucarb, carbaryl, and propoxur). A 1983 revision deleted all organochlorines from the pesticide recommendation (Fernando, 1989).

The formal procedure followed by the Sri Lankan Department of Agriculture, when introducing a new pesticide to the locals, is as follows:
Figure 01: (Source: DOASL, 2002b).



When a new pesticide is introduced to the Registrar of Pesticides the following procedure has to be followed before releasing it to the farmers. This procedure could take about 2 to 3 years. Pesticide producers introduce the technical data sheets to the Registrar of Pesticides. His or her responsibility is to compare its efficacy and effects with Japanese and USA recommendations. Then it is tested at the Rice Research Institute of Sri Lanka for its chemical properties. Then the new pesticide is approved for small-scale use on research level. It is tested to observe the effects on non-targeted insects. The new pesticide is applied in two

seasons and in multi locations on research level. After following the above-mentioned research procedure, the newer pesticide is applied to observe its, Phytotoxicity & efficacy at the farmer level in large scales under the supervision of the Registrar of Pesticide. If no adverse effects were found, then the particular pesticide is recommended and released for farmer level (large scale use).

C. Novel methods-

A landmark event in the history of pest management was the publication in 1962 of the book *Silent Spring* by Rachel Carson, which was not really important from the point of view of its technical content but rather from its impacts on the general public. *Silent Spring* brought pest management practices into the public domain for the first time and provided the springboard for an increase in the awareness of the general public of the problems associated with chemical insecticide use. (Nelissen et al.1997). This growing environmental concern, combined with the philosophy of integrated control advocated by an increasing vocal band of scientists provided openings for the funding and development of alternative, more environmentally friendly approaches such as insect pheromones, sterile insect techniques, microbial insecticides and host plant resistance.

Modern approaches to crop protection rely on management rather than control or eradication. In this approach, a pest species is considered a pest only when it reaches numbers that can cause yield reduction. Natural factors such as natural enemies that prevent a pest species from increasing are emphasized. Pesticides are used only as a last resort to bring abnormal pest densities down when crop loss is expected to exceed the cost of treatment. In addition, the use of rice cultivars that are resistant to major pest species is encouraged. These cultivars do not need prophylactic treatment to control the insects or diseases to which they are resistant. Using a combination of control tactics instead of relying on just one tactic such as host plant resistance or pesticides and basing the decisions for control on sound economic grounds is called integrated pest management or IPM

Currently, Pheromones, BT, Kairomones, sterilization of insects, IPM techniques etc. have been widely used all around the world in managing stem borer attacks. For example, a common, naturally occurring bacterium, *Bacillus thuringiensis* (BT), produces a substance

that is toxic to some types of moths and butterflies that in the caterpillar stage of their life cycle eat and damage the leaves of crops. BT bacterial genes have been implanted into crops so that their cells produce the toxin. Because spiders also produce toxins that kill insects, researchers are planning to insert the appropriate spider genes into the cells of suitable crops (Miller, 2002).

An increasing number of pest control experts and farmers believe that the best way to control crop pests is a carefully designed Integrated Pest Management (IPM) program. In this approach, each crop and its pests are evaluated as parts of an ecological system. Then a control program is developed that includes a mix of cultivation, biological, and chemical methods applied in proper sequence and with the proper timing (Miller, 2002).

Smith and Reynolds, (1966) Define IPM as a 'Pest management system that in the context of the associated environment and population dynamics of the pest species, utilizes as suitable techniques and methods in as compatible manner as possible and maintains the pest population levels below those causing economic injury'.

Economic threshold level (ETL) is a major tool used in IPM to properly time pest control practices particularly, application of chemicals. Its usefulness relates to the need-based application of pesticides so as to minimize negative effects of agricultural chemicals on the environment and public health. ETL is defined as the pest damage level where the value of incremental reduction of yield is equal to the cost of preventing its occurrence. A farmer who adopts this technology operates at a situation where the marginal revenue equates marginal costs. Department of Agriculture in Sri Lanka has not developed ETL values for all the major pests in rice. DOASL has adopted values from other countries in the region for research purposes.

ETL for Stem borer is determined as follows,
At the Vegetative stage of the crop- 10% dead hearts or 20 egg masses,
At the Reproductive stage of the crop-5% white heads. (DOASL, 2002a).

The improvement of crop protection technologies that are cheaper, more efficient, and environmentally sound is becoming urgent. But inadequate crop protection techniques, the lack of appropriate agronomic practices, insufficient extension services, and socio-economic constraints are the main problems associated with implementing integrated pest management techniques in developing countries. Therefore, emphasis has been given in developing rice varieties with resistance to the major pests-yellow stem borer, rice thrips, gall midge, brown plant hopper-and studying the natural control mechanisms of these pests, analysing farmers' pest management decision making and practices, and introducing different IPM approaches to improve farmers' practices in order to develop sustainable IPM in rice.
However, it is only the IPM technique that has at least reached the level of research in Sri Lanka, let alone any consideration. The reasons behind this are the non-introduction of Bio safety regulations in Sri Lanka, the financial constraints and the lack of technology to carry out any research work. (Interview with the director of the RRI of Sri Lanka, July 2002). The research activities of the Department of Agriculture, Sri Lanka (DOASL), focus mainly on generating research information on IPM components to help strengthen farmer training. (Kudagamage and Nugaliyadde. 1995).

VII. Materials and Methods

In order to provide the analytical background in comparison of above-mentioned three pest management methods with regard to sustainable development principles, this study uses systematic approach to analysis the quantitative and qualitative outcomes in above-mentioned farming practises by means of literature surveys, interviews, and field observations. Secondary data such as scientific articles, books, and web information were also used.

Five administrative districts- Anuradhapura, Kurunegala, Kandy, Rathnapura and Hambantota-were selected to represent different agroecological regions. Accessibility to the sample areas was also considered in selecting these districts. Anuradhapura and Hambantota are mainly dry zones, whereas the others run across wet, intermediate and dry zones. These five districts cover about 30% of the total rice lands in the country.

There are five Agro Ecological regions in Sri Lanka, Namely,

(a). Wet Zone Up Country-WU

(b). Wet Zone Low Country-WL

(c). Intermediate Zone Up Country-IM

(d). Intermediate Zone Low Country-IL

(e). Dry Zone Low Country-DL

The agroclimatic features of the country are strongly influenced by the interaction of two monsoons- the northeast (October-March) and the southwest (May-September) and the mountainous landmass in the south-central areas. Climatic zones are grouped on the basis of annual rainfall into dry (900-1,500mm), intermediate (1,500-2,200mm) and wet (>2,200mm), and on the basis of altitude into low country (<300m), mid country (300-1,000m), and up country (>1,000m).
(Panabokke and Kannangara, 1975)

A farmer survey is an important data gathering process for assessing the needs of intended beneficiaries to determine their knowledge and perceptions of a pest problem, their constrains in dealing with the problem, and their attitudes and practices in pest management.
The role of such surveys is to determine the nature of farmer practices that can guide both research and extension work. If carefully designed and implemented, farmer surveys can identify gaps in knowledge, misconceptions, or inappropriate practices that need to be addressed by research (Escalada and Heong, 1996). Therefore it was useful to select the method of farmer survey by interviews in five administrative districts.

A) Selection of farmers:

Farmers who cultivate irrigated rice in the dry and intermediate zones and favourable rainfed rice in the wet zone were selected for the survey. Two or three Agrarian Service Centers (ASC) were selected on purpose from each administrative district to represent different agroecological regions. About 6 farmers, selected at random, were interviewed from each ASC range. A total of 30 farmers from the five administrative districts of Anuradhapura, Kurunegala, Kandy, Rathnapura and Hambantota were interviewed.

B) Survey Instrument:

The survey was designed to describe the sociodemographic profile of rice farmers in the selected districts, record the agronomic and pest management practices followed during the main season of 2001-02 (October 2001 to March 2002), and obtained detailed information about farmers' knowledge and attitudes on insect pests and natural enemies of rice and their use of pesticides. Their knowledge in traditional pest control methods was also inquired.

A standard questionnaire was taken as the base document to interview farmers to avoid being biased. (Appendix 01, Ref: Questionnaire). The questionnaire was translated into the Singhalese language and adapted to reflect local situations.

C) Survey Procedure:

To ensure consistency in responses, a uniform questioning and recording procedure was followed. The survey was done mainly during weekends and on holidays in order to find as many farmers as possible. Initially, the interviewer gave farmers a brief introduction to the survey objectives and requested their cooperation for its success.

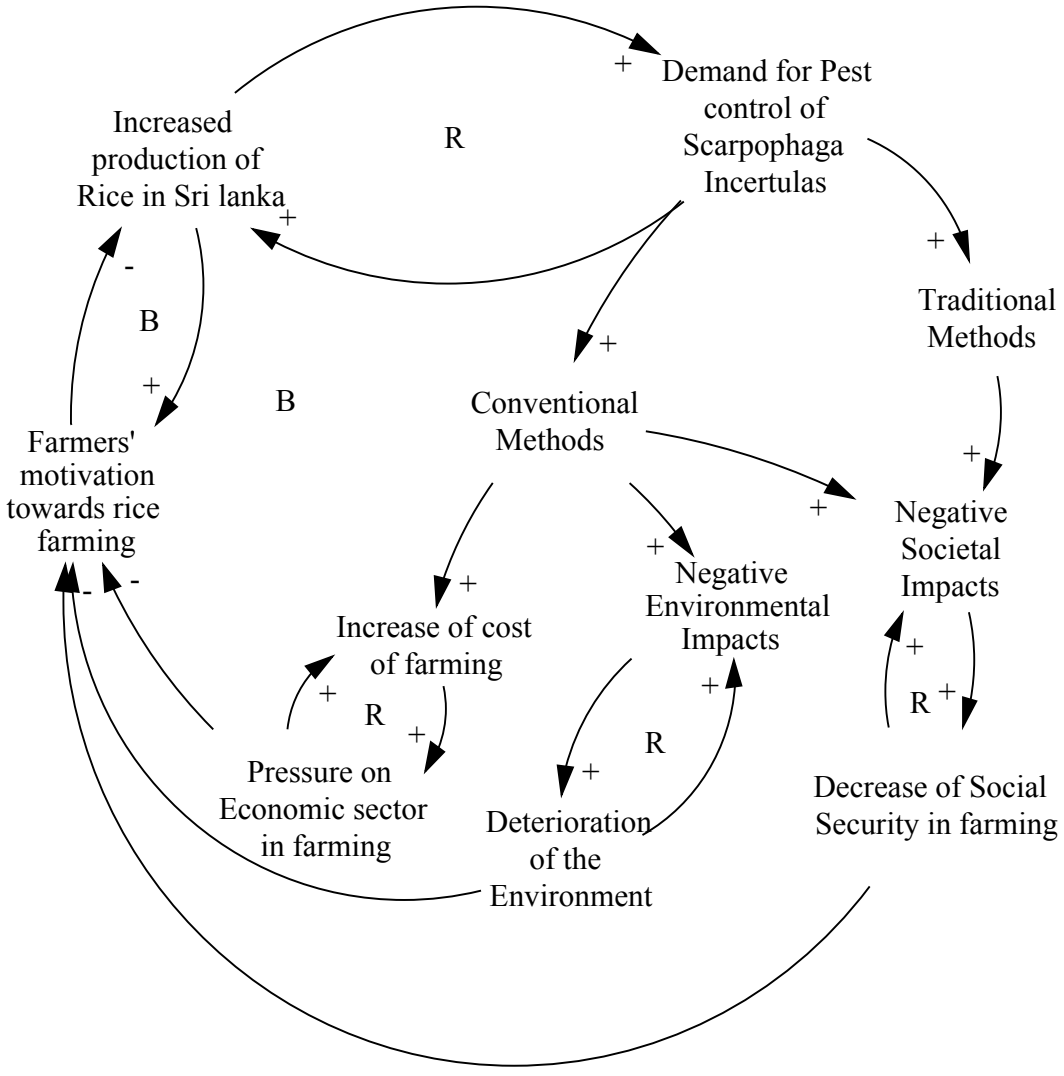
The scope of a farmer survey needs not to be limited to farmers' pest management knowledge, attitudes and practices, but it could also cover aspects such as decision-making patterns, agronomic practices and socio-economic profiles (Escalada and Heong, 1996). Therefore after following the formal questionnaire, the interviewer also considered in obtaining some information regarding farmers' socio-economic levels.

VIII. Analytical Framework

With the increasing awareness of detrimental effects of chemical - based pest management on natural control mechanisms, environment and human health, research efforts were directed towards the identification of environment friendly pest management strategies and dissemination of such technologies to rice paddy farmers in Sri Lanka. However, before the identification of environment friendly pest management strategies, it is necessary to present the analysis of existing situation regarding our research problem. In that purpose it is relevant to use the system analysis approach in order to determine the main environmental and other factors, which would determine the sustainability in rice paddy cultivation. Here it should be mentioned that consideration of sustainability of rice production implies the analysis of the relevant social, economical, and environmental factors which are critical in interactions

between the complex human system and all directly implicated environmental systems. A causal loop diagram (CLD) was created which represents a systematic vision of the problem.

Figure 02: How does the problem generate (CLD-01).



The causal loop diagram (CLD) shown above consists of two balancing (B) and four reinforcing (R) loops and represents the hypothetical model of interactions of factors behind the rice paddy cultivation in Sri Lanka. According to CLD-01, current high demand for rice production in Sri Lanka causes increase of paddy cultivation throughout the island. When the

overall production increases, the possibilities of occurring pest infestations increase, and therefore increases the demand for pest management methods for *Scirpophaga incertulas*. In order to control *Scirpophaga incertulas* infestations, farmers have a trend in selecting conventional methods or traditional methods. However, it should be mentioned here that the overall rate of using traditional control methods is comparatively low.

Following the logic of CLD-01, use of conventional method will increase the cost of rice paddy farming and causes financial difficulties among the farmer society. Also the applied pesticides will accumulate in the water streams and lands, which will cause deterioration of the environment. The negative societal impacts that can occur due to conventional pest control methods are, poisoning of pesticides among children and adults, high suicidal rate by using pesticides etc. Also farmers obtain bank loans and borrow money from businessmen to buy pesticides and fertilizers. When they cannot obtain a reasonable yield due to many reasons they have a trend in committing suicide to escape from the problem. The social security system is not established to secure the farmer and the present situation is unstable. Therefore there is a trend in quitting from rice cultivation, as there is no motivation from the responsible authorities. On the other hand, Very few farmers select the Traditional ways of controlling *Scirpophaga incertulas*. The traditional methods practically have no negative environmental impacts when compared with the conventional pest control methods. However, these traditional methods of pest control have side social impacts in terms of difficulties in access to the knowledge and finding the required raw materials to follow them. This will create insecurity in the social sector and decrease the motivation in practicing traditional methods as well as the rice paddy cultivation. In sum, all above-mentioned causes behind the conventional methods as well as the traditional methods in controlling *Scirpophaga incertulas* will negatively influence the overall rice paddy production in Sri Lanka.

IX. Results

A) Sociodemographic profile of farmers

The ages of selected rice farmers ranged from <20 to >60. Some 58.8% of the farmers were owner operators and 26.4 were tenants. Only 9.2% were lessees, 1.1% were hired labourers and 4.5% fell into other categories. Of the 30 farmers interviewed, 38.9% had more than 20 years of experience in rice farming and 61.1% had cultivated rice for more than 5 years.
Farm sizes ranged from <0.25ha to >1.5ha. More farmers interviewed in Anuradhapura and Hambantota were members of farmer organizations than those in Kandy (8%) and Kurunegala (31%).

When gathering information on traditional pest control methods, we mainly considered obtaining information from farmers who have cultivated rice for more than 20 years.
Reason being, mostly the older generation believes in the traditional control methods.

B) Agronomic practices

More than 90% of the rice lands in Anuradhapura and Hambantota districts are under irrigated cultivation compared with those in Kurunegala (63%), Kandy (63%) and Rathnapura (63%). A significant proportion of the rice lands in Kurunegala, Kandy and Rathnapura is under rain fed cultivation (Gunatilaka and Somasiri, 1995). More than 98% of the ricelands observed are cultivated by improved varieties developed by the DOASL; about 68% of the farmers knew the names of the varieties they grew, and more than 85% of the farmers also knew the maturity period of the varieties. Some farmers identified improved varieties by their local names. The five most popular varieties grown in the survey areas were BG450, BG11-11, BG379-2, BG350, and BG 300. In the survey areas, 86% of the crop was broadcasted. Broadcasting was more popular in Hambantota (100%) and Anuradhapura (85%) than in Kandy (39%) and Rathnapura (25%).

One third of the farmers obtained yields below 3t $ha^{-1,}$ the national average, and 12% produced more than 5t ha^{-1}. More than 70% of the farmers in Anuradhapura and Hambantota obtained yield of 4-5t ha^{-1} compared with those in Kurunegala, Rathnapura and Kandy of 3-4t ha^{-1}.

C) Rice farmers' pest management knowledge

Most of the farmers (95%) were unaware of the pest-resistant characteristics of rice varieties. Of the 30 farmers interviewed, 80% reported at least one pest infestation during the past season (October 2001 to March 2002). The rest (20%) mentioned no pest damage or ignored low infestation levels. About 87% of the farmers (all those who direct seeded their crop) reported weeds as their main problem during the past season.

When farmers were asked to indicate the most important pest problem, 33% mentioned rice leaf folder (*Cnapholocrocis medinalis)*, the other most important pest problems mentioned were rice bug-*Scotinophora sp*. (31%) and Stem borer- *Scirpophaga incertulas* (25%). Of the 24 farmers who reported insect pest problems, 86% have applied insecticides to control them, 7% did nothing, 3.4% used baiting, 2% used water management and a small portion (1.6%) resorted to hand picking and other traditional methods, including spraying of neem seed extracts.

D) Pesticide application pattern

Of the total pesticides applications, 83% were made to control pests and 15% to prevent pest infestations, the remaining 2% were made with uncertainty. Furthermore, most of the pesticide applications were made at the seedling stage (42%) and vegetative stage (40%). Only 18% of the applications were made at the reproductive stage of the crop.

During the main crop season, farmers spent from < \$10 ha^{-1} to \$35 ha^{-1} for pesticides. The highest amount recorded by a farmer for insecticides was \$35ha^{-1}. About 52% of the farmers spent \$25-35 $ha^{-1}$and about 25% between \$10 and \$25 ha^{-1}. The rest spent less than \$10 ha^{-1}. These amounts were found to be comparable with those figures recorded for the crop year 1999-2000. (DOASL 2001).

E) Farmers' selection of insecticides for rice stem borer control

The most commonly used insecticides in controlling stem borer were carbofuran (10.4%), chlorypyrifos (7.4%), phenthoate (6.9%), monocrotophos-this has been banned in Sri Lanka since 1995 and is not recommended for rice pest control (4.7%), Quinalphos (1.5%) and diazinon (3.2%). Most of the farmers were unable to remember the name of the pesticide. Furthermore, farmers often do not follow the recommended application rates (DOASL 1995). During the survey, it could be observed that more than 75% of the farmers never followed the

recommended dosage and dilution. Farmers gave many explanations for not following the recommendations indicated on the label of the pesticide container. In addition, the higher cost of pesticides and labour caused farmers to use lower dosages at the first sign of insect infestation. Close to two-third of the farmers across all districts believed that insecticides were needed to control rice pests and that spraying should be done early to avoid severe crop losses.

F) Farmers' knowledge of natural enemies of rice pests

About 50.2% of the farmers recognized the presence of a group of organisms called natural enemies in rice fields (Table03). In Hambantota district, 86% of the farmers knew about natural enemies, in contrast, farmer awareness of natural enemies was comparatively poor in Kandy (31%), Anuradhapura (33%), Kurunegala (48%) and Rathnapura (53%).

Table 03: Farmers Perceptions about natural enemies of rice pests (Main season October 2001 to March 2002).

Criterion	District [a] (farmers responding, %)				
	AP	Kur	Kay	Rat	Ham
Know the presence Of natural enemies	33	48	31	53	86
Average number of Natural enemies named by farmers	2.5	4.1	3.3	2.7	5.2
Know the role of Natural enemies	31	40	31	52	86
Know the effect of insecticides on natural enemies	30	41	26	51	85
Know that killing natural Enemies will increase Pest infestations	10	33	10	11	15

[a] Ap= Anuradhapura, Kur= Kurunegala, Kay= Kandy, Rat= Rathnapura, Ham= Hambantota.

Almost all the farmers who recognized the presence of natural enemies could describe their role in the rice environment. 48% of the farmers knew that natural enemies feed on other insects such as pests. Many farmers were able to name at least three natural enemies of rice pests. The most common natural enemies mentioned by farmers were spiders, dragonflies, birds, snakes, different types of beetles and flies. Fifty percent of the farmers were aware of the adverse effects of insecticides on natural enemies. Farmer awareness of the negative effects of insecticides was high in Hambantota district (85%). Farmers' responses to further questions on the effect of the insecticide application on pest populations were poor. This was evident in the low proportion of farmers who answered a question on pest resurgence after insecticide application. Only 15.8% of the farmers agreed that killing natural enemies would increase pest infestations.

G) Traditional methods used by farmers to control rice pest attacks

There are hundreds of traditional pest control methods available for different rice pests. The following methods are mostly used in controlling major insect pest attacks including the rice stem borer, farmers revealed these methods during the interviews, which were carried out in 5 different administrative districts in Sri Lanka. Slight variations in practice can be occurred from district to district when these methods are applied in different districts.

- Devoting of rice, (Bath Pay kiriima)- When a pest infestation is notified by a farmer he goes around the village and collect small portions of uncooked rice. Then he will go near the main water stream or the lake, which supplies water for the field and will cook rice, which will include coconut milk in it. While cooking this milk rice he has to chant specific prayers and offer flowers to God. Then the farmer puts cooked milk rice in to an open traditional basket, called the "Kuruniya", carries it on his head and walks along the rice field throwing them around. Finally the farmer has to plant a thorny plant branch in the middle of the paddy field and clap three times. By doing this they believe that all the insect pest infestations would disappear. (Interview with Pandulagama, Eppawala Mr. Herath in September 2002).
- Placing of Coconut Husks and Branches of trees- Coconut husks are fixed in to short poles and placed in the field in a scattered manner. Branches of trees are also placed in the field in a scattered manner. (Interview with Pandulagama, Eppawala Mr. Herath in 2002). This method will help birds to come and stand on them.

- Burying of Orange- the farmer has to wake up early in the morning and go to the field without talking to anyone. The oranges are put in the ground in different places in the paddy field. (Interview with Damunumulla Mr. Jayathilaka WMAG in September 2002).
- Daluk *(Euphorbia antiquorum)* treatment- this plant branches are crushed and mixed with water that is available in the upper side of the field. *Euphorbia antiquorum* is a small tree. Leaves: very small, fleshy, deciduous. Trunk: stout, cylindrical, very rough, corrugated. Latex: Milky, Uses: whole plant-medicinal (Ashton M. etal.1997). (Interview with Pandulagama, Eppawala Mr. Herath in September 2002)
- Spraying of neem (*Azadirachta indica*) seed oil or crushed seeds- when a pest infestation is observed farmers crush the neem seeds and spread that in the field. Also neem seed oil is sprayed. *Azadirachta indica* is a tree. Leave: Crowded, pinnate, leaflets paired with terminal, opposite or alternate. Uses: termite resistant, whole plant medicinal, seed- insecticidal (Ashton M. etal.1997). (Interview with Matara Mr. Sirisena HK in August 2002).
- Five latex treatment- five types of latex namely, a) *Alstonia scholaris*, b) *Pagiantha dichotoma*, c) *Artocarpus altilis*, d) *Artocarpus heterophyllus*, e) *Cocos nucifera* have to be collected. The following items are also needed to perform this practice. Nine bamboo trees, nine Coconut leaves, one Coconut and one panicle of rice from the infested field. One bamboo trunk has to be placed in the middle of the field. Then the other eight bamboo trunks were placed surrounding the middle one. Nine coconuts leaves tie on to nine bamboo trees. Then the coconut is cut, open from one end and the five types of latex have to pour in to it. Then that has to be fixed on the middle bamboo tree. Finally the panicle, which was taken from the affected field, has to place on the coconut. (Interview with Damunumulla Mrs.Ukku manike DA in September 2002)
- Oil lamp treatment- when the stem borers attack is observed, farmer takes four coconuts and make four lamps from those by putting oil in to those. Then those four lamps are placed in the four corners of the field in the evening. After doing that, a small portion of sand is sprayed all over the field. It is important to stay away from talking throughout the process, starting from making of four lamps from coconuts. (Interview with Bathalegoda Mr.Piyadasa PHGCK in July 2002).

- Wood ash treatment- to secure the field from insect pest attacks, farmers spray wood ash taken from traditional hearth around the field. The spraying is started from one particular point and it goes one circular round and ends at the same point. The spraying is done in the evenings and it is strictly forbidden to talk while following the method and also for people to jump over the sprayed wood ash circle. (Interview with Pandulagama, Eppawala Mr. Herath in September 2002).
- *Cycas circinalis* treatment- when a pest attack is observed, the reproductive parts of *Cycas circinalis* is crushed and mixed with the water remaining in the field. (Interview with Rathnapura, Wimalakeerthi E in September 2002).
- *Shorea zeylanica* or *Vateria copallifera* resin treatment- old cloth is taken and small strips of fabric pieces are made from it. Then they are dipped in resin collected from *Shorea zeylanica* or *Vateria copallifera*. After dipping in the resin those pieces are tied in a long rope in equal short distance.

  Afterwards two farmers hold that rope from each end and they drag that rope from one side to the other over the field. (Interview with Pandulagama, Eppawala Mr.Herath in September 2002).

X. Discussion

The use of host plant resistance as a method to control rice stem borer has hitherto not been possible. In general, the *indica* varieties are more susceptible than the *japonica* varieties. In Sri Lanka, some of the local varieties viz. Kaluheenati have been found to be less susceptible (Fernando, 1964). Table 01 indicates that the Plant condition, Ex: Tough stems etc. can disturb the growth of stem borer instar I stage. Therefore, the rich wild rice germplasm should be explored to find sources of resistance to *Scirpophaga incertulas,* as resistant varieties are still not available. Rapidly developing techniques in biotechnology should be used to overcome barriers in crossing wild rice with cultivated rice.

A. Short & long term impacts on environment caused by

Traditional control methods-

When we analyse the method of Devoting of rice, (Bath Pay kiriima) it can be argued that when the rice is cooked, the smell of milk-rice would spread all around the field and surrounding areas. Due to the smell of milk-rice, bird flocks will move towards the rice field. When the farmer puts cooked milk-rice in to an open traditional basket, called the "Kuruniya", and carries it on his head and walks along the rice field throwing them around, birds will reach the field to eat that rice. At the same time they would prey on the adult moths of rice stem borers and other insect pests available in the field. Because of this effect the pest populations would be reduced.

"Placing of Coconut husks and branches of trees" would enable birds to come down and sit on the structures available on the rice field. This will help the birds to rest on the fixed coconut husks, tree branches and feed on pests including different stages of stem borers at the same time.

It can be assumed that the "Burying of Orange" will help to mix different types of compounds that are available in oranges to the soil of rice fields. That can have an adverse effect on pest populations.

Daluk *(Euphorbia antiquorum)* treatment- when the plant branches are crushed and mixed with water, which is available in the upper side of the field, the latex of *Euphorbia antiquorum* could have some repellent effect on insect pests. Therefore the insect pest population could be decreased.

Spraying of neem (*Azadirachta indica*) seed oil or crushed seeds has an insecticidal effect on pest populations. (Ashton etal, 1997). Numerous studies in many countries have demonstrated the effectiveness of extracts of neem (*Azadirachta indica*) against more than 100 species of insects, mites and nematodes (Dhanapala, 1989). Unlike most insecticides having one active ingredient only, the bioactive principles of neem represent a complex array of compounds

with diverse behavioral and physiological effects on insects. Therefore the population number of *Scirpophaga incertulas* could be reduced below the economic threshold level.

In the five latex treatment- five types of latex a) *Alstonia scholaris*, b) *Pagiantha dichotoma*, c) *Artocarpus altilis*, d) *Artocarpus heterophyllus*, e) *Cocos nucifera* are used in performing this method. Latex of *Pagiantha dichotoma* is milky and poisonous (Ashton M. etal.1997). Also the other milky latex could have different kind of insecticidal effects on pest populations.

When the oil lamp treatment is performed, the adults of *Scirpophaga incertulas* and other pest species attract to the light and destroy themselves. When sand is sprayed over the field after lighting the lamps the adults of *Scirpophaga incertulas* gets disturbed and starts to fly. This helps to attract more adults towards lamps and to reduce the pest populations. The volume of the coconut, which is used to make the oil lamp, is larger than the normal oil lamps and this will facilitate to keep the lamp lit for a longer duration to attract more insects.

We can assume that when the Reproductive parts of *Cycas circinalis* are crushed and mixed with water, the chemical compounds remaining in that would mix with water and adversely affect on pest populations.

Shorea zeylanica or *Vateria copallifera* resins are sticky and when this treatment is performed, the adults and egg masses of *Scirpophaga incertulas* would stick on them and destroy. This will help to keep the pest population under the Economic Threshold level.
On the other hand, mixing of different types of plant parts will have a natural fertilizing effect when they decompose in the field.

Most of the materials used in traditional control methods are organic and biodegradable. Therefore the negative impact on the environment is minimum.

Conventional control methods-

Effective insecticides are available for Rice Stem borer control. But there has been a shift in research thinking from a complete reliance on broad-spectrum pesticides to a more selective usage of such chemicals to control above pest. Currently, in most cases, the primary goal of spraying with conventional pesticides is to eradicate pests in the area affected. However, the primary goal of any pest control strategy should be to reduce crop damage to an economically tolerable level. Because of the risk of increased genetic resistance and other problems, continuing to spray beyond the economic threshold level (ETL) can make matters worse and cost more than it is worth (Miller, 2002). When an uncontrolled application of pesticides against *Scirpophaga incertulas* is practiced, there is a possibility of developing a genetic resistance against the pesticides. Then the need for more frequent applications, larger doses or switching to a new chemical arises, which is again harmful to the environment as a whole. Therefore, further attention must be given in changing farmers thinking pattern through proper extension services and guiding.

According to the world Health Organization (WHO) and the UN Environment Programme (UNEP), an estimated 3 million agriculture workers in developing countries are seriously poisoned by pesticides each year, resulting in an estimated 180,000 deaths- an average of 490 premature deaths per day (Miller, 2002). As a developing country Sri Lanka is also facing the problem of pesticide poisoning among farming communities.

Another problem is that broad-spectrum insecticides kill natural predators and parasites that may have been maintaining the population of a pest species at a reasonable level (Miller, 2002). *Scirpophaga incertulas* has number of egg, larval and pupal parasites and predators available in the field. Table 01 shows the effect of different natural enemies on stem borer populations in various stages of its life cycle. The uncontrolled application of pesticides would directly affect them and the populations of parasites and predators would decrease rapidly.

Pesticides that miss their target pests end up in the air, surface water, ground water, bottom sediments, food and non-target organisms, including human and wildlife (Miller, 2002). Southwest region of Sri Lanka has been named as one of the 18-biodiversity hotspots in the

world, i.e. an area with high species diversity and high levels of endemism and where species are subject to exceptional levels of threat (Ministry of Forestry & Environment, 1999). The widespread dependence on subsistence agriculture and extensive use of pesticides has exerted considerable pressure on the biodiversity of the country.

Novel methods-

However, the novel methods like implanting of foreign genes could cause unexpected mutations in plants, which can create new and higher levels of toxins in food. Also it can cause rapid evolution of pesticide resistant insects, creating new plant diseases, and harming beneficial insects. Introducing chemicals into genetically modified plants that might kill predators and parasites of insect pests and thus decrease nature's natural biological control of certain pests. Introducing chemicals into the soil from the decomposition of plant parts may kill beneficial organisms living in the soil (Millar, 2002). There are various potential benefits of genetically modified crops. However, the knowledge on negative effects and potential harm to human health and ecosystems of genetically modified crops is minute. Therefore more controlled field experiments, more research and long-term safety testing to better understanding the risks have to be carried out before implementing them. However, placing light traps, using Integrated Pest Management techniques etc, have fewer impacts on natural environment.

B. Short & long term impacts on economic sector caused by

Traditional control methods-

The negative impact caused by traditional methods on the economic sector of the farming community is almost zero as all the required raw materials are collected from the surrounding nature of the field. Most of the materials are collected from the nearby forest. Only the labour is required to perform these practices and family members and/or friends complete that requirement.

Conventional control methods-

During the survey, some farmers were observed to consider pesticides as essential components of rice cultivation. Farmers purchased them at the beginning of the season along with other inputs such as seed, fertilizer etc. Farmers would go through financial hardships just to buy pesticides, which are not subsidized in Sri Lanka. During the main season October 2001 to March 2002 farmers spent from < \$10 ha^{-1} to \$35 ha^{-1} for pesticides. According to our CLD-01 (Figure 02) shows that how the increase of cost of farming put the pressure on the economic sector. Also it describes how the pressure on economic sector negatively influences the motivation towards rice paddy cultivation. Therefore continuous reliance on conventional methods to control pests is not the proper solution for increasing rice demand in Sri Lanka.

Novel methods-

Using of genetically modified crops, pheromones, and sterilization of insect pests are expensive and requires higher technological skills, which are not freely available in Sri Lanka. Therefore, so far there is no pressure on the Sri Lankan farming economic sector from the novel pest management issues. However, Integrated Pest Management techniques, Crop rotation, the use of naturally occurring biological control agents, using of light traps etc can be still implemented without spending large amount of capital.

C. Short & long term impacts on social sector

Traditional control methods-

There are some negative societal impacts in the traditional pest control methods. As they require large amount of natural herbs, plant parts, different kind of latex etc. Therefore every farmer does not have the same access to required raw materials to fulfil his need of pest control in the field. Also, the traditional knowledge on pest control is not freely available and most of the farmers do not want to share the knowledge with others. Therefore, using the traditional methods of pest control alone is not the best way to secure the rice farmers in Sri Lanka. However, when farmers practice the traditional methods they get a bondage to the field, and continuously observe the improvement of the crop. That can be called as a positive impact in practicing the traditional methods.

Conventional control methods-

Although the survey did not study farmers' fertilizer application patterns, we observed many variations in fertilizer use. Many farmers seem less interested in supplying the essential nutritional requirements to seedlings (to incorporate organic matter or to supply basal fertilizer), which are vital for early growth and to help withstand pest infestations. Farmers considered nutritional disorders, commonly observed in low-fertile soils, as pest problems requiring insecticide application. Therefore, A high percentage of farmers applied pesticides at the early vegetative stage of the crop. Prior to the beginning of the FAO intercountry Rice IPM Program in the early 1980s, insect pest control for rice was mainly based on pesticides. (Wickramasinghe, 1980). In addition to the extensive promotional activities of the pesticide industry, the well-established extension service network of the DOASL helped disseminate pesticide recommendations to farmers more effectively. This could be a main factor contributing to farmers over reliance on insecticides for rice pest control.

During the study, some farmers were found to mix granular insecticides (Usually one-fifth of the recommended dose) with fertilizers at the first topdressing without observing any insect pest damage. Therefore, to implement an ecologically based pest management program, it is essential to correct farmers' perceptions that pesticides are important and an essential component in rice farming.

It could be observed that a critical lack of farmer knowledge on recommended crop management practices. Awareness of appropriate crop management practices including fertilizer application etc. Furthermore, farmers should possess a sound knowledge of insect pests, including their natural control agents and influence on the yield, among other aspects, to effectively make management decisions. The many knowledge gaps, attitudes, which were observed among farmers, may have prevented them from making effective management decisions. The survey also indicated that farmers' knowledge of correct pesticide use is poor, including selection of the correct pesticide, dosage, dilution, timing and application techniques. This lack of knowledge on proper pesticide use could lead to environmental as well as socio-economic problems for rice farmers. Therefore, efforts should be made to wean farmers from misuse of pesticides.

Novel methods-

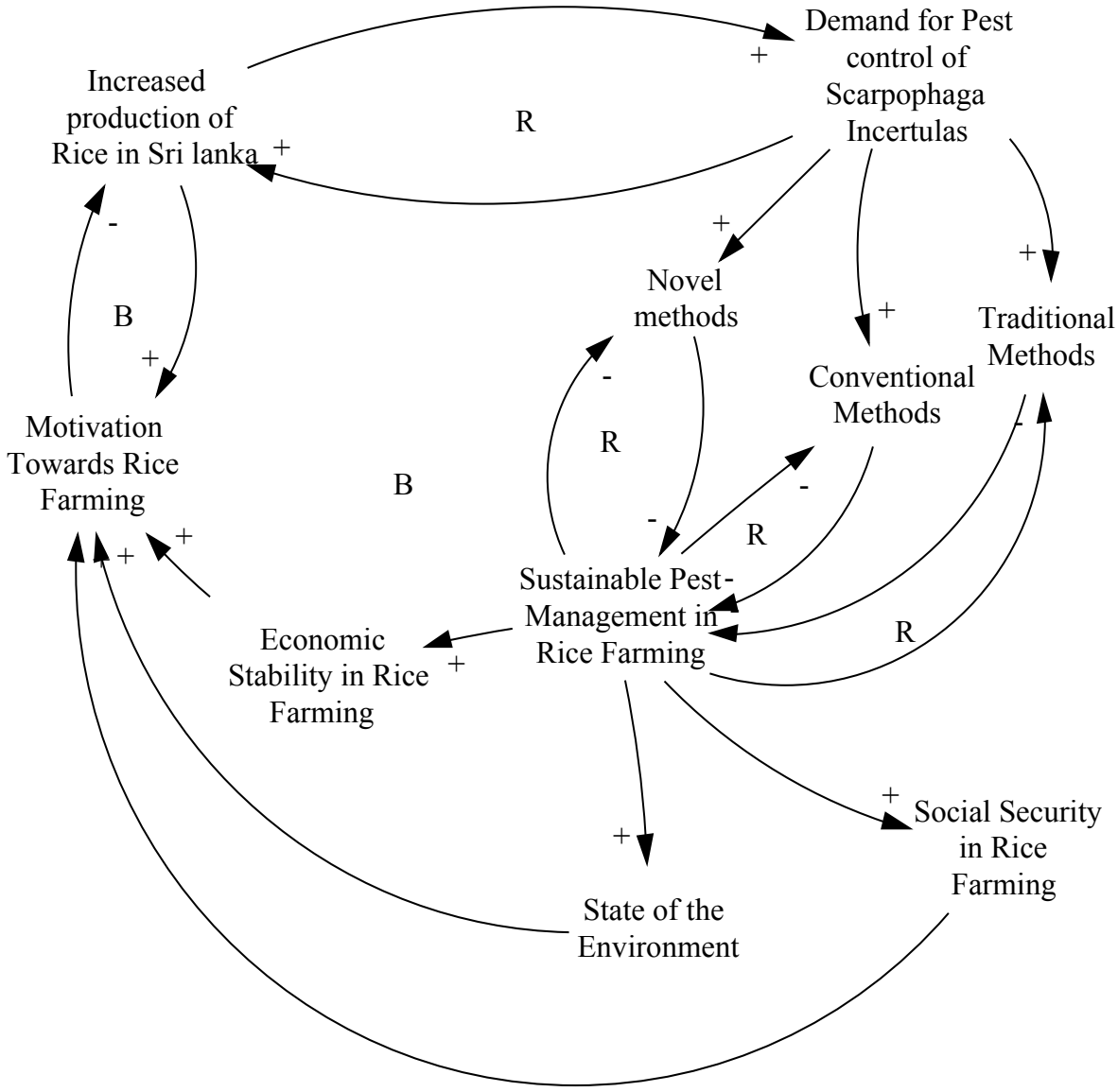
Because of the activities of NGOs and the research activities of the DOASL in Hambantota area, farmers' awareness of natural enemies was found to be high in Hambantota district (Table 03). Efforts should therefore be made to introduce similar programs in other areas as well.

The ability to forecast pest populations would be of immense value to pest management programmes, as it would enable intelligent application of control measures to prevent population increases above ETL. When practicing IPM techniques in Sri Lanka, the farmers would have to evaluate the ETL before applying pesticides. However, thresholds are location specific. The severity of pest infestation, degree of crop response to pest damage and control differ from location to location. Prices of chemicals, cost of labour and paddy and effectiveness of control would likewise vary. Further, it is necessary to test the acceptance of these threshold values by farmers. It may be necessary to convert these quantitative values to qualitative values for easy adoption by farmers. Furthermore, farmers' decision making will depend on their background experience and attitude towards risk. Such information should be available for the successful implementation of ETLs.

The use of naturally occurring biological control agents is the cheapest management option for stem borers. Hence, the conservation and enhancement of these agents must be given higher attention. This could be attained through reduced or cautious use of pesticides. Stem borers are difficult to control with insecticides because the larvae and pupae are concealed inside the stem. The eggs are also minimally killed. To determine when insecticide is needed, observing of the abundance of adults attracted to light before and after transplanting could be useful. This will indicate the population of adults and egg masses in the field. Clean cultivation, i.e. removal of stubble either by burning, by ploughing or a combination of these two can be an adequate method to keep stem borers under control where only one crop of short duration is grown. Harvesting of plants at ground level to remove stem borer habitat could be a good practices in rice cultivation. Ploughing and flooding of the field immediately after harvesting would help to kill larvae and pupae, which are remaining inside the stubbles. However, knowledge-intensive farmer training is an urgent need before introducing any sustainable agriculture practices.

Nevertheless, Farmers' inability to understand pest resurgence because of pesticides, the existence of an ecological balance among pests, natural enemies, and neutral fauna in rice fields, and the relationship between pest densities and yield should be taken into account when developing strategies to improve farmers' pest management decisions.

Figure :03: (CLD-02) Proposed sustainable pest management method for rice cultivation in Sri Lanka.



The above shown CLD-02 describes how a sustainable pest management method may facilitate the farmers' motivation towards rice farming.

Currently rice paddy farmers in Sri Lanka are practicing Pest Control rather than pest management. They expect the pesticides to act as complete eradication agents on pest populations. The farmers' knowledge in Economic Threshold Level (ETL) is poor and there is a huge knowledge gap among farmers, extension, and research services. A combination of the main pest management methods, namely, Traditional, Conventional and Novel methods would help to create a new sustainable pest management method in order to control *Scirpophaga incertulas* in paddy fields.

The above mentioned combined pest management method would help to release the farmer from economic burdens and risks in terms of social security. On the other hand, proposed new pest management method will keep the state of the environment with respect to a sustainable agricultural paradigm. According to the logic of CLD-02, the motivation towards rice paddy farming will increase when the social security and the economic stabilization are obtained in the whole system. Then the rice paddy farmers of Sri Lanka would be able to supplement the increasing demand for rice in the country.

XI. Conclusion

In this study it was important to recognize the obscure/hidden, but important consequences of the traditional pest management methods that are used in traditional farming that could be valuable in identifying a pest management method for sustainable agriculture practices.

As a result of the analysis conducted, this study revealed that the major problems in rice paddy cultivation in Sri Lanka regarding increased cost of farming, negative environmental impacts, and decreased social security, arise with increased use of conventional pest control methods. In view of that, this study suggests that the possible solutions of improvement in existing methods would positively affect the rice paddy farming in Sri Lanka under the sustainable agriculture concept.

The survey conducted helped to identify a combination of several positive practices that are available in the three pest management methods studied, namely, Traditional, Conventional and Novel. The combination of above-mentioned three pest management methods, which is similar to Integrated Pest Management technique, would be one of the most feasible pest management practices applying to rice cultivation. The possible Traditional methods that can be integrated in to the existing pest management methods are the placing of Coconut Husks and Branches of trees, Oil lamp treatment, Spraying of neem (*Azadirachta indica*) seed oil or crushed seeds, *Shorea zeylanica* or *Vateria copallifera* resins treatment which would help to reduce the adult moth populations of *Scirpophaga incertulas* and their egg masses in the rice field. This would facilitate the farmers to reduce the quantity of pesticides they have to use in the field.

This proposed method seems to be acceptable among farmer communities, as proven in this analysis that it is economical, environmentally sound and easy to practice. The new method would consist of Integrated Pest Management techniques and a collection of traditional pest management practices which are easy to practice in the field. This novel method will help the subsistence farmer to reduce his production cost. However, future advances of sustainable pest control techniques lie in further development of presently available components of Integrated Pest Management and development of new appropriate technologies.

Also, during the study it was found that the knowledge-intensive farmer training is an urgent need before introducing any sustainable agriculture practice in to the Sri Lankan farming community.

XII. Appendix

Questionnaire for survey in paddy farmer's knowledge on traditional and conventional pest management methods.

- Farmer Number-01, 02, 03, 04, 05.
- Agro ecological zone –
- The number of years of experience in paddy farming –
- Land ownership – 01) Self ownership
  02) Tenancy ship
  03) Other
- Do you hold a membership in any Farmer's Organization?
- Area cultivated during the last season-
- During the last season did you observe any pest attacks, if yes, which pests?
- How do you control pest attacks?
  01) Pesticides
  02) Traditional methods
  03) Water management
  04) Other
- If you use traditional methods what kind of practices do you follow?
- During the last season how many times did you apply pesticides?
- The rate pests were destroyed after applying pesticides
  01) 75% - 100%
  02) 50% - 75%
  03) Less than 50%
- From whom do you get advice at times of attacks by pests?
  01) From a farmer in the neighbourhood.
  02) From Extension officers.
  03) From a relative.

04) From a Pesticides Dealer.

05) Through the media.

- ✓ Leaflets
- ✓ Posters
- ✓ Papers and magazines
- ✓ Radio
- ✓ Television
- ✓ Meetings and seminars
- ✓ Label of the container
- ✓ Other

- From whom did you get to know about the current pesticides you use?

01) From a farmer in the neighbourhood.

02) From Extension officers.

03) From a relative.

04) From a Pesticides Dealer.

05) Through media.

- ✓ Leaflets
- ✓ Posters
- ✓ Papers and magazines
- ✓ Radio
- ✓ Television
- ✓ Meetings and seminars
- ✓ Label of the container
- ✓ Other

- Kno1wledge about natural enemies – Were there any insects that do not harm your crop? If 'yes' what kind of insects?

- What was the plight of those insects after applying pesticides?
  - ✓ They were destroyed.
  - ✓ They disappeared.
  - ✓ Do not know.
  - ✓ Other.

- Attitudes towards pesticides application-'By using pesticides the yield increases' –
  - ✓ Agree,
  - ✓ Disagree,
  - ✓ No comments.
- 'By applying pesticides even natural enemies of pests could be destroyed' –
  - ✓ Agree,
  - ✓ Disagree,
  - ✓ No comments.

- Killing natural enemies will increase pest infestations-
  - ✓ Agree,
  - ✓ Disagree,
  - ✓ No comments.

XIII. References

Ashton M, Gunatilleke S, Zoysa N, Dissanayake MD, Gunatilleke N, Wijesundera S.1997. *A field guide to the common Trees and Shrubs of Sri Lanka*. WHT Publications Ltd. Sri Lanka. P190-259-

Catling, D.1992. *Rice in Deep Water*, International Rice Research Institute, The Macmillan Press Ltd.P419-426.

Dhanapala, M.G.1989. Rice pests: Natural enemies and management practices in Sri Lanka. M.Phill Thesis, Unpublished. University of Wales, UK. P105.

DOASL (Department of Agriculture Sri Lanka). 1995. *Major crop pests and their control with pesticides*. Peradeniya (Sri Lanka): Extension and Communication Center, DOASL, P23

DOASL (Department of Agriculture Sri Lanka). 2001. *Cost of cultivation of agriculture crops*-maha 99-00. Peradeniya (Sri Lanka): Socio-economic and planning center, DOASL. P55.

DOASL (Department of Agriculture Sri Lanka). 2002a. *Pesticide Recommendations for Rice crop*, Peradeniya (Sri Lanka): DOASL.P2

DOASL (Department of Agriculture Sri Lanka). 2002b. *Pesticide Recommendations for Rice crop*, Peradeniya (Sri Lanka): DOASL.P5

Escalada, M.M, Heong K.L, 1996. *Methods for research on farmers' knowledge, attitudes and practices in pest management*. International Rice research Institute, Manila, Philippines. P 1-23.

Fernando, H.E. 1964. *Major insect pests of the rice plant in Ceylon*, John Hopkins press, Baltimore, Maryland. P.575.

Fernando R, 1989. Pesticides in Sri Lanka, *Documentation of selected literature and legal aspects.* Friedrich-Ebert press-Colombo. P27-34.

Gunatilaka GA, Somasiri S, 1995. *Rice growing ecosystems*. In: Amarasiri SL, Nagarajah S, Perera MBK, editors. Rice Congress 1990. Proceedings of the Rice Symposium, Kandy (Sri Lanka): DOASL. P39-54.

Kudagamage C, Nugaliyadde L. 1995. *Present status and future directions of insect pest management in rice.* In: Amarasiri SL, Nagarajah S, Perera MBK, editors. Rice

Congress 1990. Proceedings of the Rice Symposium, Kandy (Sri Lanka): DOASL. P39-54.

Miller, G T. 2002. *Living in the Environment, Principles, Connections and Solutions*. Brooks/Cole Publications. P 275, 508, 516

Ministry of Forestry & Environment.1999. *Biodiversity Conservation in Sri Lanka*, *A framework for action*. P 32-36.

Nelissen N, Jan Van Der Straaten, Klinkers L, (1997). *Classics in Environmental Studies*, International Books. P69-73.

Oxford University Press.1987. The report *Our Common Future*, World Commission on Environment and Development's, the Brundtland Commission.

Panabokke, CR and Kannagara, RPK. 1975. *The identification and demarcation of the agro-ecological regions of Sri Lanka*. Proceedings Section B. Ann. Session Assoc. Advmt. Sci. Sri Lanka Assoc. Advmt. Sci. Colombo 31(3): P49.

Pathak, MD.1970. *Insect pest and their control in Philippines Production Manual*. (Revised edition), University of Philippines and International Rice Research Institute, Los Banos, Philippines.

Ranasinghe, M.A.S.K.1992. *Paddy Pests in Sri Lanka*, Science education series No.30, Natural Resources energy & Science Authority of Colombo (Sri Lanka). P47-59.

Rathnapala, N. 1995. *Janashruthi Widyawa* (Folklore Science in Singhalese Language), S.Godage and Sons, Colombo. P15.

IRRI-International Rice Research Institute website-Philippine. http://www.philrice.gov.ph, Accessed on the 22nd of June 2002.

Smith, G and Reynolds L, 1966. *Integrated strategies for the biological control of major insect pests of rice in South East Asia*. Journal of Plant Protection in the Tropics. IRRI, Philippines 1, 19-37.

Wickremasinghe, N. 1980.*Fifteen years of progress in rice pest control*, Rice Symposium, Department of Agriculture-Sri Lanka. P49-66.

Will H. 1989. *Rice environmental classification in Sri Lanka*. UNDP/FAO Rain fed Rice Research and Development Project, SRL/84/024, Central Rice Breeding Station, Batalagoda, Ibbagamuwa, Sri Lanka. P40.

Yazumatsu, S. 1976.Fundamentals of rice crop science. IRRI, Philippines.P231-251.