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RICE ENTOMOLOGY: RECENT DEVELOPMENTS IN THE MANAGEMENT OF INSECT PESTS IN THE PHILIPPINES

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ABSTRACT

Rice ecosystems in the Philippines vary from upland, rainfed wetland, irrigated lowland and irrigated highland but regardless of types, all are sources of energy food for both humans and insects. Four guilds, namely: phytophages or herbivores (818 species), predators (774 species), parasites/parasitoids (317 species), and scavengers/tourists (171 species) constitute the arthropod community structure in rice. Food webs relate specific trophic resources and consumers to the structure and dynamics of ecological communities. New technologies and greater understanding of the rice ecosystems are contributing to more effective and sustainable integrated pest management (IPM). Recent developments in the management of insect pests of rice are viewed from the perspective of current pest management options available to farmers, namely: host plant resistance, biological control, cultural control and chemical control. Development of resistant varieties through genetic engineering has received emphasis in rice improvement programs involving biotechnology. Enhancing natural biological control in rice ecosystems is a current research thrust. Of the many cultural methods available, synchronous planting of resistant varieties, crop rotation, seedling age, mixed cropping, water and fertilizer management and planting time are effective in regulating pest populations. Farmer education through farmer field schools demonstrates the ecological cause-and-effect relationship associated with insecticide use. Integration of baseline knowledge on taxonomy, ecology, information technology and biotechnology with IPM strategies are recent developments in the management of insect pests in rice ecosystems in the Philippines.

Key words: Rice entomology, pest management, HPR, Biocontrol

INTRODUCTION

Rice (*Oryza sativa* L.) is the primary food grain consumed by roughly two-thirds or 2.4 billion world's human population, providing more than 20% of their calorie intake (Fischer, 1998). It accounts for 5% or more of the national plant food supply grown or imported by 55% of the 146 countries listed by FAO (Prescott-Allen, 1990). With a diminishing land base for rice farming due to land degradation and alternative uses, this means that a substantial increase in yield per unit land area is required. The Green Revolution of the 1970s resulted in remarkable increases in rice production. Since then, the rate of production in most rice-growing countries has slowed down and is presently stagnant (Hossain, 1994) while the population of rice consumers is increasing at a rate of 2% annually (Khush, 1995). It has been estimated that by the year 2020, world rice production must be increased by 36% of the production level of 540 million tons of rough rice (Rosegrant *et al.*,1995). It is expected to remain the biggest staple crop in the foreseeable future.

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Similarly, rice is also food to some 800-1400 species of insects (Walker, 1962; De Kraker, 1996). More than 200 million tons of rice are lost every year due to abiotic stresses and biotic factors. Among these, insect pests are estimated to account for about 14% of total global agricultural output (Oerke *et al.,*1994).

Humans and insects are always on the warpath and had faced countless confrontations. Forbes' (1915) article "The Insects, the Farmer, the Teacher, the Citizen, and the State" is an excellent account providing support to this conflict. Moreover, he pointed out that the struggle between the two forms of animals started even long before the dawn of civilization. Yet today the same scenario is confronting all of us and for as long as our interest and that of the insect pests are diametrically opposed, the fight goes on and on (Metcalf & Metcalf, 1993). Why? We surmise that this is attributable to many factors but for now we will cite at least four general factors, namely: (1) commonality of interest, (2) competition, (3) limited knowledge about the awesome and inherent ability of insects for adaptation, and (4) man's failure to recognize coexistence with most members of the insect world, the insect pests in particular.

In all rice ecosystems, men are in continuous races with the parasitic insect pests, races which are usually won by the latter due to either carelessness or ignorance of the former. The truth hurts but such is the real scenario. Men are ignorant or they ignore the natural fact that their so-called "insect pests" are actually one of the biospheric biotics which coexist with them. The interspecific competition between men and insects should be looked into as harmonious compromise for due shares of energy resources to ensure continuous survival and reproduction of both species. Such is the supposed guiding philosophy of insect pest management. How to put such ideology into actual action is the continuous challenge being addressed by the management of insect pests of rice.

This paper reviews some of the current developments and approaches in the management of rice insect pests in the context of Filipino farmers' decision-making process.

BASIC KNOWLEDGE IN RICE ENTOMOLOGY

The entomological research strategy in rice is typically similar to other agricultural crops. Pest management research focuses on the understanding of biological and ecological processes that occur in the agro-ecosystems. The primary objective is to control the insect pests in order to reduce yield loss. The strategies implemented involve varietal resistance, chemical, cultural, and other biological approaches. The availability of correct and valid basic knowledge about rice arthropods, such as taxonomy, biology and ecology, is of paramount importance in the successful implementation of all strategies intended to regulate rice pest populations below damaging levels.

Rice Arthropod Taxonomy

Way & Heong (1995) reviewed the roles of biodiversity in tropical integrated pest management. There exists a big vacuum on the knowledge of arthropod diversity in rice ecosystems, thus, the taxonomic reference collection was started at IRRI in 1974 with the objective of providing support to the research thrusts of the

Department of Entomology dealing with host plant resistance, ecology and biological control, chemical control and cropping systems entomology. In February 1974, 650 species of insects mostly collected from light traps were established as the first reference collection. Today, it is probably the single biggest rice arthropod collection in the world with nearly 300,000 specimens of pinned, card-pointed, alcohol-preserved and slide-mounted rice and rice-associated arthropods. It is now called the Rice-Associated Arthropod Collection (RAAC) maintained by the Entomology and Plant Pathology Division (EPPD). The RAAC is a knowledge-based bank of all arthropods [insects, mites, spiders and crustaceans] living in or associated with the rice ecosystems. As a whole, the collection represents 2080 species, 1129 genera and 291 families excluding the numerous still undetermined specimens. The below-water rice environment is under-represented. It is estimated that >5000 species of arthropods are associated with rice ecosystems.

The collection is grouped into four on the basis of feeding behavior or functional guild, namely: herbivores (818 species), predators (774 species), parasites/parasitoids (317 species) and scavengers/tourists (171 species). The large amount of beneficial species that help reduce insect pest populations is unique to the collection.

Ecology of Rice Arthropods

The design of pest management program should be based on a sound ecological understanding of factors related to cropping systems. Ecologists tend to think of agricultural systems as disturbed, depauperate and evolutionarily recent. Tropical Asian rice, however, is an important exception. Rice cultivation is thought to have originated in northeast Thailand nearly 9,000 years ago (Bray, 1986). This long ecological history, together with extensive geographical distribution and generally warm and wet climates, has resulted in an agricultural ecosystem unrivaled by any other in the world in terms of ecological complexity. Indeed, the arthropod species richness in many of the rice fields surpasses that of most natural temperate systems. Yet the ecological study of rice is at its neonate stage.

The vast majority of research related to arthropods in tropical rice has been directed towards only a small handful of "pest" species without examining the biotic linkages to the rest of the system. Considering the paramount importance of rice culture in the world today and in the foreseeable future, systematic investigation into the structure and function of rice-field ecology is long overdue.

In terms of recent development in the management of insect pests of rice, food web structure provides a quantitative framework in which to explore quantitative predictive models of pest population dynamics. Food webs relate specific trophic resources and consumers to the structure and dynamics of ecological communities. Since 1977, IRRI entomologists have been describing the food web of Philippine rice fields at and above the water line. The present cumulative version of the IRRI web contains 687 taxa (pathogens, nematodes, mites, spiders, insects, snails, vertebrates) and over 10,000 trophic (consumer-resource) links, gathered from 23 sites in the Philippines (Schoenly *et al.*,1996). Additional information on the food web of Philippine rice fields is available in Koch *et al.* (1990) and Settele *et al.* (1993).

Food webs of rice fields, like other food webs, vary in space and time. Schoenly

& Cohen (1991) distinguished between cumulative and time-specific webs. A cumulative web is a web gathered over many occasions within specified spatial limits. Meanwhile, a time-specific web is a web gathered over a single, relatively short time period (e.g. a specific crop growth stage). If the spatial limits include more than one site, then the site-specific webs can be defined, one per site. Field studies have compared time-and site specific webs of the same habitat type (Kitching, 1987), time-specific webs in different regions of the same habitat (Warren, 1989; Closs & Sake, 1994), and site-specific webs of the same habitat type in different locations (Beaver, 1985).

Investigation of the rice–arthropod food web of Philippine rice fields at and above the water line at five sites along an elevational gradient revealed that the taxonomic composition and food web structure were broadly similar across sites. At each site, herbivore population built faster than predators and parasitoids and predators arrived faster than parasitoids. Most sampled predator, parasitoid, and omnivore taxa potentially encountered only a subset of their lifetime prey and predator species at any particular time in the rice field. These observations have implications for biological pest control strategies.

Heong *et al.* (1991) analyzed the arthropod community structure of irrigated rice in five provinces in Luzon Island using the functional guild. The herbivore guild dominated by the leafhoppers [*Nephotettix virescens* (Distant) and *N. nigropictus* (Stal)] and the planthoppers [*Nilaparvata lugens* (Stal) and *Sogatella furcifera* (Horvath)] were the most preponderant. Among the predators, the semi-aquatic Heteroptera [*Microvelia douglasi atrolineata* Bergroth and *Mesovelia vittigera* (Horvath) and the green mirid bug *Cyrtorrhinus lividipennis* Reuter are the most dominant taxa. Spiders ranking second in the most abundant predators are represented by the wolf spider, *Pardosa pseudoannulata* (Boesenberg & Strand) and three species of long-jawed spiders, *Tetragnatha* spp.

A total of 212 species were documented from all five sites. The total species catch from each site varies from 87 in Cabanatuan to about 146 in Los Baños. Nonetheless, species richness was found to increase with rice crop stage. Successional trends in guild structure however, differed significantly at the five sites. The herbivores are the dominant early colonizers while the natural enemies, the predators and parasitoids colonize gradually attaining peak at 50 days after transplanting.

RECENT DEVELOPMENTS IN THE MANAGEMENT OF INSECT PESTS OF RICE IN THE PHILIPPINES

The twin technological pillars—information technology and biotechnology—and a greater understanding of the rice ecosystem are contributing to more effective and sustainable pest management in farmers' fields. Prioritizing research on rice pests has been made difficult by a lack of systematic survey data on pest losses in different ecosystems and under different production conditions (Cohen *et al.*,1998).

The foundation protocol of modern insect pest management, which is generally accepted worldwide, is IPM (integrated pest management). In its broadest sense, IPM is concerned with maximizing the use of indigenous resources for keeping pest population at non-economic levels and only when necessary, relies on the use of external inputs such as pesticides. It is an ecological approach to pest management, which in practice, relies on pest control through varietal resistance, natural enemies and cultural practices, augmented by pesticides when cropping systems in intensifying systems, do not adequately support the effectiveness of indigenous and internal means (Teng, 1994). Thus, IPM is essentially decision-making and taking action against one or more pests, after all available information on pest(s) and the ecosystems have been analyzed. The current concentration of different sectors on IPM is in accordance with what was stated by Luckmann (1982): "It is not enough to just accept IPM concepts and philosophy, they must be used."

One of the recent developments in IPM is attributed to biotechnology. Biotechnology is a set of technologies, ranging from genomics and bioinformatics to genetic engineering that enables precise manipulation of the genome of a species. Biotechnology provides the enabling tools for developing improved products and the information to use these products by practitioners. According to Teng & Baria (1999), the relevance and appropriateness of biotechnology to crop protection must therefore be viewed from the perspective of the current pest management options available to farmers, namely, (1) crop cultivars with resistance to one or more pests and the knowledge to use them effectively, (2) biological control, whether natural or introduced biological control agents, (3) cultural control, including mechanical and physical techniques, and (4) pesticides and the knowledge to optimally use them.

Biotechnology has demonstrated its usefulness to generate products and knowledge for improving resistance to pests, for improving the application of fungicides and for biological control. Underpinning biotechnology's role in crop protection is its appropriateness in IPM. It builds on existing genetic material to enhance the effectiveness of host plant resistance, which remains the main technique available to the majority of resource-poor farmers in developing countries like the Philippines. This task is accomplished in close coordination with Philippine Rice Research Institute, the Department of Agriculture and local farmer organizations to evaluate the impact of different IPM practices.

Host Plant Resistance

One approach to increase rice yield is to decrease insect damage through development of rice varieties with increased host plant resistance. The dominant pest-control strategy in tropical rice over the past 30 years has been the use of resistant varieties. Beginning in the late 1960s in many countries throughout Asia, rice production was greatly boosted by the introduction of short duration, high-yielding varieties (HYVs)- the product of research at the International Rice Research Institute (IRRI) together with national research programs in a number of Asian countries.

What is the recent development in HPR in insect pests of rice?

Research on host plant resistance focuses on understanding the pest population biology and genetics and characterizing resistance genes to develop strategies for durable resistance to pests through resistance breeding.

The development of resistant varieties through genetic engineering has received emphasis in rice improvement programs involving biotechnology. Insecticides derived from the common bacterium *Bacillus thuringiensis* Berliner [Bt] are becoming increasingly important for pest management. Bt-based insecticides pose less risk to the environment and are more compatible with biological control (Tabashnik *et al.*, 1999). However, the limitations of Bt sprays such as short persistence under field conditions and lack of effectiveness against many pest species have stimulated research on the improvement of Bt efficacy (Krattiger, 1997).

An attractive alternative for crop protection is the production of proteins with insecticidal activity by the rice plant itself. Bt transgenic crops can significantly reduce the use of insecticides, increasing the abundance of nontarget and beneficial species in crops, and reducing the need for insecticide sprays even for pests not targeted by the transgenics (Feldman & Stone, 1997).

Genetic engineering of crop plants now raises the possibility of achieving for the first time high levels of resistance to stem borers in rice. The first report of transformation of japonica rice with a Bt toxin gene and regeneration of fertile plants was published by Fujimoto *et al.*(1993). Since then, more genes from Bt controlled by different promoters have been successfully transferred into various types of rice (Shu *et al.*,2000). Whether transgenic insect resistant plants contain one toxin or multiple toxins, it is known that insect resistance to the toxins can be slowed down by the use of refuges (Cohen *et al.*,1998).

Where is Bt-rice now?

Bt-rice had undergone the preliminary screening in the IRRI transgenic greenhouse. It was evaluated based on effectiveness against insect pests such as *Scirpophaga incertulas* (Walker) and *Cnaphalocrocis medinalis* (Guenee) as well as stability of toxin production over generations. At present, the field-testing awaits approval by the National Committee on Biosafety. While other countries are making progress and generating results, the Philippine scene is in declension.

Biological Control

Most biological control programs focus on promoting one or two "premier" natural enemies as agents for the suppression of particular pests. However, based on works on pest management in tropical rice ecosystems, the recent recommendation was that consistently high levels of natural biological control may often result from a complex set of community-level interactions that lead to far more stable and robust systems, vis-à-vis insect pest populations, that have previously been considered (Settele *et al.*,1996).

In the light of the robust mechanisms supporting high levels of natural biological control, the best strategy for biological control in tropical rice is for farmers to conserve the diversity of existing species through major reduction in pesticide use, to keep dry fallow periods short, and to maintain the heterogeneity of small-scale rice landscapes.

What are the recent developments in biological control of insect pests of rice?

Studies on the distribution and abundance of predators in rice fields were conducted, for instance, the 62 species of ants from bunds of tropical irrigated and rainfed rice. Apart from the ubiquitous *Tapinoma* sp. nr. *indicum* Forel, the most widespread was the aggressive *Solenopsis geminata* (Fabricius). They were commonly observed preying on hemipteran and lepidopteran pests and on eggs and young golden apple snails, *Pomacea canaliculata* Lamarck which are serious pests in the Philippines (Way *et al.*,1998). Enhancing natural biological control in rice ecosystems through manipulation of non-rice habitats is a current research thrust.

Cultural Control

A thorough review of the 22 cultural control practices complemented by mechanical and physical methods of rice pest control is available (Litsinger, 1994). Of these, synchronous planting, crop rotation, seedling age, mixed cropping, water and fertilizer management are proven effective and currently practiced by farmers. The stem borers, whorl maggots and golden apple snails are a few examples of rice pests that are culturally controlled successfully.

What are the recent developments in cultural control of rice insect pests?

The yellow stem borer, *Scirpophaga incertulas* (Walker) and white stem borer, *Scirpophaga innotata* (Walker) problems had been reduced as farmers adopted synchronous planting in Central Luzon and Iloilo, respectively. In Negros Island, the synchronous planting of the susceptible japonica rice in lots of 10-15 ha area convincingly reduced the population of green leafhoppers, *Nephotettix virescens* (Distant) and planthoppers, *Nilaparvata lugens* (Stal), *Sogatella furcifera* (Horvath) and *Tagosodes pusanus* (Distant). Moreover, the tungro disease vectored by the green leafhoppers is significantly reduced too.

In crop rotation, the planting of unsprayed cowpea or bush sitao before and after rice promotes the build-up of predators, such as the meadow grasshopper, *Conocephalus longipennis* (de Haan) and predatory crickets, *Metioche* spp. and *Anaxipha* spp. The massive aphid populations generated from the legumes supported the nutritional requirements and boosted the reproductive potential of the meadow grasshoppers and predatory gryllids. Hence, a high population of predators is “mass-reared” in the field in the natural way. These predators will eventua-lly migrate to nearby rice fields and devour egg masses of stem borers and leaf-and planthoppers.

Planting older seedlings reduces rice whorl maggot (RWM) and golden apple snail infestations. Similarly, draining water from the field controls whorl maggot attack because rice fields without water at 20-30 days after transplanting (DT) encourage natural biological control or predation against rice whorl maggot, *Hydrellia philippina* Ferino. The gray-colored ephydrid fly, *Ochthera sauteri* Cresson is an efficient hunter of RWM adults in drained fields and can consume 20-40 RWM adults in a day.

Modern rice varieties have compensatory properties from insect damages. Complete plant loss from armyworm damage at the vegetative stage is no longer shocking. Water and fertilizer regimen can restore the lost crop in time with the yield still comparable to undamaged rice field.

Chemical Control

The benefits derived from the use of synthetic organic pesticides since they were first introduced 50 years ago have been well documented. However, just like many things in modern life, excessive use and abuse of these products have brought many undesirable side effects. These include poisoning and adverse health effects on humans, contamination of the environment and loss of biodiversity.

History of pest management in rice suggests that some of the modern agricultural techniques induce secondary pest problems. The brown planthopper, *Nilaparvata lugens* (Stal) for instance, is often enhanced by the use of broad spectrum insecticides intended for the control of other rice insect pests (Kenmore, 1980; Heong *et al*., 1991).

Despite a growing body of scientific and empirical evidence showing that insecticides in tropical rice were a mistaken and counter-productive input, that fact remains that since the 1960s and 70s and until today, insecticides have been and are still the dominant control tactic. Tens of millions of farmers throughout Asia have become habituated to using insecticides. Worldwide, rice now accounts for more insecticides than any other crop, with about 80% of this amount used in Asia (Woodburn, 1990). In the Philippines, rice constitutes 44% of the total market for insecticides (Cuyson, 1999). The question is no longer whether insecticide use should be drastically reduced, but rather, what is the best mechanism of bringing about this reduction and getting farmers "off the habit"? Unfortunately, the misunderstanding among farmers (and, indeed many government workers) concerning the use of insecticides is not related to just a single concept, but rather to a suite of related concepts. Farmers commonly believe:

(1) that all insects in their fields have the potential to do damage to their crop;
(2) that any amount of loss to the plant leaves and stems will cause a concomitant loss in yield; and
(3) that insecticides are a kind of "medicine" that helps the plant be healthy in the same way that immunizations protect humans.

Ignorance engenders fear, and an uneducated, fearful, and passive farmer population will continue to rely on insecticides. To turn this around is difficult. The mechanism of insecticide-induced resurgence is not obvious as it involves indirect effects and an inherent delay of almost one month between the cause (insecticides) and effect (outbreak).

What is the recent development in chemical control of rice insect pests?

Risks of pesticides are continuously regulated by legislative control. According to Villanueva (1999), regulatory activities are still considered to be most feasible and practical option for ensuring a balance between the benefits and risks associated with pesticide use. Revised policies could only be meaningful with the following conditions: (1) appropriate organizational structure for effective regulation; (2) responsible pesticide industry (registrants); and (3) educated populace.

In furtherance of the policy on the judicious use of pesticides, the following five-point agenda should be adopted to maximize benefits and minimize social costs: (1) efficient registration process for less toxic/less hazardous pesticides, and of biorationals which include biochemical and microbial pest control agents (PCAs) and other natural enemies of insect pests; (2) reasonable licensing requirements; (3) more responsible product stewardship; (4) well structured monitoring and evaluation of post-registration and post-licensing activities; and (5) stringent penalties for violations of pesticide rules and regulations.

A decentralized, participatory educational approach, such as that embodied in IPM Farmer Field School ongoing in many countries in Asia, has succeeded in helping farmers overcome the old misconceptions by helping them demonstrate for themselves the ecological cause-and-effect relationship associated with insecticide use. The four fundamental principles of IPM within this program are:

(1) Grow a healthy crop;
(2) Observe the field weekly;
(3) Conserve the natural enemies; and
(4) Farmers must become experts

A food web approach to evaluating the effect of insecticide spraying on insect pest population dynamics in a Philippine irrigated rice ecosystem was initiated by Cohen *et al.* (1994). Data from a 645-taxa Philippine-wide food web and multiple regression models showed that spraying insecticide (Deltamethrin) disorganized the population dynamics of insect species feeding in the rice field. Multiple regression models were less able to forecast the population fluctuations of pest species in the sprayed fields than in the unsprayed fields on the basis of various numbers and combinations of independent variables. Researches looking into the safer and more efficient methods of applying insecticides are going on.

On top of all these, the outstanding development in chemical control is the birth of novel insecticides. These are new products that have selective properties, specific to target insect pests and compatible with biological control.

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