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Ecological IPM strategies for management of pests of rice

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Abstract
Rice is most important staple food and diet for large part of world's population. It is the foundation of national stability and economic growth in many developing countries. Rice harbours many species of insect pests and outbreaks of pest occurs due to misuse of insecticides which cause threatening to entire rice ecosystem. Recently, rice yield losses increased due to outbreaks of brown plant hopper, leaf folder, rice hispa, yellow stem borer and white backed plant hopper. In contrast, improved management of rice ecosystem through intensive IPM practices can enhance natural control of pest populations through cultural, mechanical, use of biocontrol agents, natural enemies and judicious application of pesticides. So, carefully planned IPM practices should be followed for promoting biodiversity, health, environmental risks, economic stability and structural complexity of rice ecosystem.

Keywords: IPM, rice, biological practices, observations, management

1. Introduction

India is the world's second-largest producer of rice and the largest exporter of rice in the world. Total production of Rice during 2020-21 is estimated at record 121.46 million tonnes. It is higher by 9.01 million tonnes than the last five years' average production of 112.44 million tonnes. In 2020, world production of paddy rice was 756.7 million metric tons (834.1 million short tons), led by China and India with a combined 52% of this total. Other major producers were Bangladesh, Indonesia and Vietnam. The five major producers accounted for 72% of total production (FAOSTAT, 2020) [12]. Rice is the staple food of an estimated 3.5 billion people worldwide and the daily diet of nearly half the world's population. It is also the primary source of income and employment for more than 200 million households across countries in the developing world (Muthayya *et al.*, 2014) [20].

In almost all rice -producing countries it is considered as an ideal host for many insect pests, since it's grown in warm and humid environments which aid their survival and proliferation (Dale, 1994) [10]. Outbreaks of rice-feeding insect pests are thus a serious threat to food security. Rice yield losses increased due to widespread outbreaks of the brown plant hopper (*Nilaparvata lugens*), rice leafolder (*Cnaphalocrocis medinalis* Güenée), small brown planthopper (*Laodelphax striatellus* Fallen), rice hispa (*Dicladispa armigera* Oliver), yellow stem borer (*Scirpophaga incertulas* L.) and white-backed planthopper (*Sogatella furcifera* Horvath). These pests cause hundreds of millions of dollars of losses every year and threaten food security in regions where rice is the staple food (Ali *et al.*, 2019) [1].

Increased reliance on pesticides for the pest control in rice production is unsustainable and cost-ineffective due to the development of pesticide-resistant pest, pesticide-induced outbreaks of insect pests, and rising in the cost of pesticide use (Berg, 2002) [7]. Increase in usage pesticides for crop protection is associated with sustained harmful effects on health and the environment, toxic to natural enemies, beneficial insects and causes pollution. This problem has led to another way of controlling pest that is "Integrated Pest Management (IPM)" (Dhakal and Poudel, 2020) [11].

Indiscriminate use of pesticides can easily disrupt the natural balance between insect pests and their natural enemies. Conservation of bio-control agents is prime important and can be achieved by limiting broad spectrum insecticides use, or by applying insecticides which are selectively toxic to pests but not to predators (Shepard *et al.*, 1995) [34]. Hence, reducing pesticide applications and adopting Integrated Pest Management (IPM) strategies through cultural, mechanical, biological practices have to be taken into consideration by farmers for managing pests.

2. Objective
The objective of the study is to discuss about adoption of modern and intensive agricultural practices through IPM in rice field and its future aspects.

3. Methodology
This review is collected and prepared based on secondary sources of information. Pieces of literature were collected from different journal articles, research papers, books, other sources like governmental bodies websites and relevant reports were studied and major findings were summarized.

4. Discussion
4.1 History of IPM
Since 1970s, Integrated Pest Management (IPM) is in practice and it relies on ecologically based management that aims to suppression of the pests through a combination of techniques such as modification of agronomic practices, mechanical and physical methods, use of resistant varieties, biological control and need based insecticide application. However, IPM was not proved successful as it was thought to be at the beginning due to low adoption and unawareness about its usefulness of management technologies and their application in real farm situation. **(**Bentley and Andrews, 1996, Savary *et al.*, 2012) [5, 30].

Historically, AWPM (Areawide Pest Management) had been practised since the late 1800s which focused mainly on orchestrated and coordinated assault techniques rather than the field-by-field strategy (Faust *et al*., 2008) [13]. It can be compared with the modern-day IPM (Integrated Pest Management). Iskandar (1980) [15] reported the use of insectivorous wild birds like brown throated sunbird (*Anthreptes malacensis*) and little spider hunter sunbird (*Arachnothera longirostra*) for the management of insect pests like caterpillars in some parts of Indonesia. Similarly, ducks have been used in the Javan rice fields to control the insect population.

However, integrated control as originally formulated had a relatively slight center of attention. However, the challenging thought of 'pest management' gained support in some quarters of 1960s, it was wider and included large numbers of suppressive strategies such as host plant resistance, cultural control and semio-chemicals. Though, integrated control and pest management steadily became synonymous, even if each remained largely insect oriented. Early 1970s until the incorporation of all classes of pests, modern concept of IPM was born (Kogan, 1998, Prokopy and Kogan, 2003) [16, 27]. Overall Integrated pest management has been a valuable model for organizing research and extension efforts worldwide over the past 30 years.

4.2. Pest Monitoring and Surveillance
Pest monitoring is the most important and integral part of Insect pest management programme. It helps to know the occurrence of insect pest, developmental stage and infestation level at certain intervals. We can monitor the initial development of pests in endemic areas and observe survey routes based upon the endemic areas which are required to be identified to undertake roving surveys. Farmers should be mobilised to observe the insect pest and disease occurrence at the regular intervals for field scouting. Therefore, for field scouting plant protection measures are required to be taken only when insect pests and diseases cross Economic Threshold Level (ETL) **(**Prakash *et al.*, 2014) [25].

1. **Roving survey:** For every 10 km distance at 7-10 days intervals (depending upon pest population) roving survey is done. At least 20 spots should be observed in s day.
2. **Field scouting:** Field scouting for pests and bio-control fauna by extension agencies and farmers once in 3-5 days should be undertaken to workout ETL.

b. Pest monitoring through pheromones and light traps

Certain pests require positioning of various kind of traps like pheromones, light traps to monitor pest build up and also useful for early warning of farmers by ascertain the magnitude, route and environmental factors that favour those movements.

1. **Pheromone traps:** For monitoring of yellow stem borer and moth population 5 traps per ha may be used.
2. **Light trap:** For observing photo-tropic insect pests, chinsurah light trap or any other light trap can be operated for two hours in the evening.
3. **Sweep-nets-water pans:** For assessing the population of insect pests through visual observations sweep-nets and water pans may be used and for biocontrol agents to determine the type of pesticides to be recommended or used.

Table 1: Pests of Rice and their Economic Threshold Level (ETL)

S. No	Common name	Scientific name	ETL
1.	Yellow stem borer	*Scirpophaga incertulas*	10% dead hearts or 1 egg mass or 1moth/m^2
2.	Brown planthopper	*Nilaparvata lugens*	10 insects per hill at veg. 20 insects/hill at a later stage
3.	Gall midge	*Orseolia oryzae*	1 gall/m^2 or 10% silver shoot
4.	Gundhi bug	*Leptocorisa oratorius*	1 nymph/adult per hill
5.	Leaf folder	*Cnaphalocrocis medinalis*	2-3 damaged leaves/ hill post active tillering stage
6.	White backed planthopper	*Sogatella furcifera*	10 insects per hill at veg. 20 insects/hill at a later stage
7.	Green leafhopper	*Nephotettix nigropictus* *Nephotettix virescencs*	2 insects/ hill in tungro endemic areas. 20-30 insects/hill in other areas
8.	Army worm	*Mythimna separata*	1 leaf/ hill stray incidence prior to harvesting
9.	Rice hispa	*Dicladispa armigera*	2 adults or 2 dead leaf/hill

(Pasalu *et al.*, 2004, Prakash *et al.*, 2014) [23, 25]

4.3 Different IPM practices for rice insect pests
4.3.1 Cultural practices
Cultural practices are followed to increase the productivity of crops and are useful in the suppression of pests at the same time (Reddy *et al.*, 1979) [29]. It involves primary and secondary practices. Primary cultural practices are those done specifically to control insects such as draining a field to control the aquatic caseworm larva or planting a trap crop for

stem borers. Secondary practices are those that are specifically done for crop husbandry, such as land preparation and weeding, but which also happen to minimize pest build up.

Several practices like crop rotation, intercropping, tillage, use of cover crops and mulches, management of irrigation, drainage, maintenance of correct spacing, seasonal planting etc. are important cultural practices adopted for insect pest management (Chandola *et al.*, 2011, Faust, 2008) [8, 13]. Crop rotation with other non-host crop is important to break continuity in insect pest life cycle and population build up. Tillage, an important cultural practice, destroys the natural habitat of egg, larva and pupae of soil-borne insects. Water management like intermittent draining of water from the fields is helpful when planthopper population become abundant (Behera *et al.*, 2013) [4]. Draining rice fields can be effective in reducing initial infestation levels. The field should be drained for 3 - 4 days when heavy infestations occur. Early and synchronous rice planting often less attack by various insect pests like yellow stem borer, gall midge, BPH, WBPH and GLH particularly in wet season and produce more yield. Application of optimum dosage of nitrogen in 2-3 splits avoids build-up of insects such as stem borer, gall midge, leaf folder, BPH and WBPH. Stubble destruction by ploughing, irrigation or machine after harvesting is helpful to check the carryover of the stem borer and gall midge insects (Pasalu *et al.*, 2004, Misra and Jena, 2007) [23, 19].

4.3.2 Mechanical practices

Removal and destruction (burn) of diseased/pest infested plant parts. Clipping of rice seedlings tips at the time of transplanting to minimize carryover of rice hispa, case worm and stem borer infestation from seed bed to the transplanted fields. Use of coir rope in rice crop for dislodging case worm, cut worm and swarming caterpillar and leaf folder larvae etc., on to kerosinized water (1 L of kerosene mixed on 25 kg soil and broadcast in 1ha). Collection of egg masses and larvae of pest to be placed in bamboo cages for conservation of biocontrol agents.

4.3.3 Biological practices

The biological management of insect pests involves the use of natural enemies, hormones, antimetabolites, feeding deterrents, repellents, pheromones and so on. Besides these, genetically modified host resistance cultivars are developed to control the damage of insect pests**.** In a broad sense, the biological approach of pest control also includes the use pheromones for monitoring pest population and to interrupt their mating, making the releases of insects sterile, the use of bio-pesticides which are made from living organisms or the product of living organisms and use of parasitoids and predators (Baker *et al.*, 2020) [2].

Natural enemies are among the most preferred tools for biological control since insect predators are found in almost all agricultural and natural environments. Some natural biological agents include Spiders, aphids, Damsels flies, Water bugs, Dragonflies, Mirid bugs, Meadow grasshoppers, Carabids, Staphylinid beetles, Coccinellids, Platygaster, and Bracon **(**Basana and Patil, 2019) [3]. Ex. Chinese ladybird (*Harmonia axyridis*), is one of the insects used as a predator of aphids, wolf spider feeds on both hopper nymphs and adults and is considered to be a major regulator of brown planthopper populations. Mass trapping of yellow stem borer male moths by installing pheromone traps @ 20 traps/ha with lures containing 10-15 mg pheromone at 20 days after transplanting.

In comparison to other crops, use of biocontrol agents through inundative or inoculative releases in rice ecosystem has provided sporadic success (Pathak *et al.*, 1996) [24]. *Trichogramma japonicum* and *T. chilonis* may be released @ 1 lakh/ha on appearance of egg masses / moth of yellow stem borer and leaf folder in the field. *Metarhizium anisopliae* commonly attacks rice planthoppers, leafhoppers and rice black bugs, *Scotinophara* sp. A dead black bug, covered by white mycelia of *M. anisopliae.* A number of rice cultivars, resistant to certain insect pests, have been released. Among these, Ratna and Sasysree are resistant to Stem borers. Varieties such as Sneha and Pothana can tolerate Gall midge. Chaitanya, Krishanaveni are effective against Brown planthopper. HKR 120 is resistant against white-backed planthoppers. Similarly, Vikramaraya and Nidhi are resistant against green leafhoppers (Pasalu *et al.*, 2004) [23]. Some biological pesticides like Neem seed kernel extract (Azadirachta indica A. Juss), Vitex negundo L. leaf extract, and Bacillus thuringiensis which are used in rice affect the larval growth, feeding, and performance of rice leaf folder (Nathan *et al.*, 2005) [21]. Unlike synthetic pesticides, botanicals do not kill the insect pests in field condition but reduce their activity by repellency, feeding deterrency, reproductive inhibition and oviposition deterrence.

4.3.4 Chemical practices

Chemical control is one of the quickest and reliable tools of decreasing insect pest populations in rice, particularly in emergency situations where there is no suitable alternative. Need based, judicious and safe application of pesticides are most vital segments of chemical control measures under IPM. It involves developing IPM skills to play safe with environment by proper crop health monitoring, observing ETL and conserving natural biocontrol potential before deciding in favour of use of chemical pesticides as a last option.

Carbofuran or Phorate granules are broadcasted in the wet nursery, 10 days after sowing, to prevent stem borers and gall midges in rice. Soaking of seedling roots with 0.2% Chlorpyriphos for 12 hours is suggested to manage stem borer and gall midges at early growth stages of rice (Yadav *et al.*, 2021) [36]. Granular formulations of chlorantraniliprole 0.4 GR @ 10 kg/ha, and fipronil 0.3 GR @ 12 kg/ha are effective against stem borer and leaf folder. Among spray chemicals, in situations where leaf folder and stem borer cause problem then cartap hydrochloride 50 SP @ 750 g/ ha, fipronil 5 SC @ 1500 ml/ha and rynaxypyr 20 SC@ 150 ml/ha are useful (Seni and Naik, 2020) [32]. Multiple tests in India have reported insecticides such as Carbofuran, Phorate, Cartap and Isazophos being safer to natural enemies than other spray formulations such as Monocrotophos and Chlorpyriphos. A recent study revealed rynaxypyr 20 SC @ 30 g a.i/ha to be the best chemical treatment for rice with least effect on natural enemies. Thiamethoxam 25 WG @ 37.50 g a.i /ha, Buprofezin 25 SC @ 250 g a.i /ha and Dinotefuran 20 SG @ 40 g a.i /ha were found to be most effective against planthoppers. Fipronil 5 SC @ 75 g a.i/ha was found to be the best against gall midge. (Seni and Naik, 2017) [31]. Triazophos and Acephate (spray formulations) were found to be safer to egg parasites of stem borer and predatory mirids and spiders (Lakshmi *et al.*, 1998) [18].

4.3.5 Future aspects of control
Now a days more research and trails are conducting on genetic engineering. Host plant resistance is the most effective, economical and reliable means for plant protection. The selection of resistance genes needs to be done with a better knowledge of the virulence composition of the insect pest populations in the target area and the genetics of plant resistance. Several trails are going on to improve the durability of resistant genes through gene rotation and gene pyramiding but due to rapid gene flow among migratory insects like plant and leafhoppers which leads to genetic diversity and causes difficulty to manage them. To overcome this problem, QTL are helpful. It involves identifying the effective resistance genes/QTL (quantitative trait loci) from various sources, characterize them genetically and make reliable tightly linked molecular markers for their introgression through marker assisted backcross breeding (MABB) into popular rice varieties (Chen *et al.*, 2012, Seni, 2021) [9, 33]. Site-specific pest management is another promising approach which aids in decision making and emphasizing the area with economically high pest density. Spatial knowledge about pest distribution is used for this control approach (Park *et al.*, 2007) [22]. RNAi technology for crop pest control holds a great promise for effective management of pests. It is defined as sequence specific silencing of target gene by affecting mRNA synthesis at the cellular level triggered by dsRNA and responsible for gene regulation and defence against pathogens. It is observed that by successful delivery of dsRNA molecules into insects by ingestion causes the target gene silencing (Price and Gatehouse, 2008, Bentur *et al.*, 2021) [26, 6], resulting the detrimental effect on physiology and ultimately causes the mortality of the target insect. Kola *et al.*, (2016) observed that by feeding YSB larvae with dsRNA of cytochrome P450 derivative (CYP6) and amino peptidase N (APN) treated cut stems resulted in increased mortality of the insect. Nanotechnology involves the formulations of pesticides and insecticides based on nano-materials, use of nanoparticle-mediated genes or DNA transfer to produce insect-resistant cultivars, preparation of biosensors that assist in remote sensing and so on. It has been promoted as an effective and harmless alternative for insect pest management (Rai & Ingle, 2012) [28]. Vani and Brindhaa (2013) [35] reported 100% mortality of rice moth, *Corcyra cephalonica* when silica nanoparticle was tested against them.

5. Conclusion
In recent years there is a great reduction in usage of chemical pesticides is seen and use of biological control methods is increasing which results in increasing abundance of some beneficial insects and improving the natural control of specific pests. IPM in combination with new modern techniques have to be done for the management of pests in rice. Now a days farmers are following IPM practices but there are many farmers left without having knowledge and idea about IPM practices. Knowledge about IPM provides ways that minimizes economic, health and environmental risks. So, studies should be focused on involving extension functionaries, researchers, government and non-government organizations including participation of farmers for successful implementation of IPM.

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