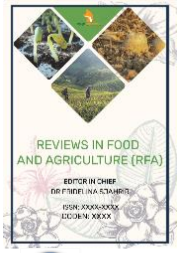
Reviews In Food And Agriculture (RFNA)

DOI: http://doi.org/10.26480/rfna.02.2020.54.58

ZIBELINE INTERNATIONAL PUBLISHING

ISSN: 2735-0312 (Online)
CODEN: RFAEAW



CrossMark

REVIEW ARTICLE

INTEGRATED PEST MANAGEMENT (IPM) AND ITS APPLICATION IN RICE – A REVIEW

Avish Dhakal*, Suraj Poudel

Institute of Agriculture and Animal Science, Tribhuvan University, Nepal.
****Corresponding author Email: avishdhakal4321@gmail.com***

ARTICLE DETAILS

Article History:

Received 23 August 2020
Accepted 30 September 2020
Available online 06 October 2020

ABSTRACT

Rice is the staple food crop for more than half of the world's population though it's cultivation is done in only 11% of the world's cultivable land. Several pests attack rice in different ways at different stages. Increased reliance on pesticides for pest control is found to be unsustainable and cost-ineffective. So, Integrated Pest Management (IPM) has been introduced as the best alternative for pest management in rice. IPM in rice helps to minimize risks to the environment and human health. Rice IPM uses the combination of cultural, use of resistant varieties, biological, physical, and chemical practices for pest control. Farmers Field School has been the most effective way to increase IPM knowledge among rice farmers. Such training helps to facilitate the farmers to apply ecologically informed farming practices. There are several challenges regarding the implementation of rice IPM. To increase IPM implementation in rice emphasis should be given on farmers' training and education. The role of government is also vital for the successful implementation of IPM. This review article provides an overview of various IPM practices being performed in rice fields at present.

KEYWORDS

Farmers, Chemical, Pesticides, Control.

1. INTRODUCTION

Rice is the most important food crop in the world and it accounts for the world's largest populations of consumers and farmers in the world (Zeigler and Barclay, 2008). India, China, and Japan are the countries with the largest area of cultivation, the largest production, and the largest productivity (4.9 t/ha) of rice in the world respectively (Gadal et al., 2019). Each geographical region with a different climatic feature is characterized by different insect pest complexes and management practices. Plant disease and insects are found more in tropical climate while in temperate region fewer insects and disease problem is found as compared to tropics (Chauhan et al., 2017). There are over 100 species of insects that attack rice in different ways (Pathak and Khan, 1994). These pests harm the productivity of rice. So, it is very necessary to manage those harmful pests by using various suitable pest control techniques. Various major insects that occur in rice are Armyworm, Green leafhopper, Rice bug, Rice leaf folder, Stem borer, Ant, Black bug, Field cricket, Cutworm, Green semi-looper, Green horned caterpillar, Rice caseworm, Rice gall midge, Rice hispa, Rice skipper, Rice thrips, Rice whorl maggot, Grasshopper and Locust, Mealybug, Mole cricket, Root aphid, Zigzag leafhopper, and Root grub. Similarly, Blast, Sheath blight, Sheath-rot, Bacterial blight of rice, and Rice-tungro disease are the major diseases that occur in rice. It has been proved that the 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). High use of chemical pesticides for crop protection is associated with sustained harmful effects on health and the environment (Barzman et al., 2015). This problem has led to another way of controlling pest that is "Integrated Pest Management (IPM)".

IPM has been an important measure for crop protection since the 1960s (Horgan, 2017). IPM has emerged as the most recognized and very strong concept in modern agricultural science (Kogan, 1998). Theoretically, the farmer who practices IPM will make knowledge-oriented economically justified decisions about pest management that minimizes risk to human health as well as the environment. IPM deals with the management of multiple pests simultaneously, regular monitoring of pests as well as their natural enemies, application of treatment and economic threshold when using pesticides, and the use of multiple and suppressive tactics in an integrated manner (Duke and Powles, 2008). According to FAO, IPM makes careful consideration for the least possible disruption to the agroecosystem and encourages natural pest mechanisms. IPM helps to increase the profitability of farmers by taking consideration of the cost of input and consequences to the environment. Since a large number of human populations in the world are involved in rice cultivation, the pest control practices by using IPM strategies certainly benefit a large number of the human population by reducing losses and increasing yield.

1.1 Objective of The Study

The objective of this study is to provide information about various integrated pest management practices performed in rice, including the

Quick Response Code	Access this article online	
	Website: www.rfna.com.my	**DOI:** 10.26480/rfna.02.2020.54.58

difficulties and suggestions for the adoption of IPM practices in rice fields.

2. Methodology

This review is 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.

3. Discussion

3.1 History of IPM In Rice

The history of IPM in rice parallels with the introduction of high yielding semi-dwarf varieties of rice in tropical agricultural systems along with chemical fertilizers and pesticides (Cohen et al., 1997). This increased the yield of rice in developing countries substantially. However, the negative side effect was also resulted due to this. One of the major side effects was a change in the Brown planthopper's status from an infrequent pest to a persistent outbreak pest that caused the huge loss in the rice field throughout tropical Asia (Settle et al., 1996). The major cause of the outbreak of Brown planthoppers was the overuse of chemical insecticide which was even toxic to the biological enemy of Brown planthoppers and it also stimulated the reproduction of Brown planthoppers when applied at a sub-lethal dose (Kenmore, 1991). So, the FAO Rice IPM Program was implemented to educate the farmer about IPM (Matteson et al., 1994). This approach recognized the need for the non-formal education process of learning by discovery and experimenting and it also gave emphasized the necessity for the farmers to understand the rice ecosystem. Hence, the rice field became the learning place for the farmers participating in Farmers Field School (FFS) (Ooi, 1996).

3.2 Ecology Based IPM

The practices of the farmers in the field depend on what they understand. To control or prevent the pest in the rice, a farmer must understand rice pest ecology. A well-informed concept of the rice ecosystem provides a better way to understand the way for insect pests' management in rice. A better understanding of agricultural insect ecology is very necessary to control the pest (Settle et al., 1996). This ecology-based view about IPM explains that the majority of beneficial insects or spiders are found in a healthy ecosystem. Let's take an example that in the tropical wet rice ecosystem of Indonesia, the percentage of neutrals (insects, plankton feeders) of the total species identified was 19%, predator and parasitoids was 64% and that of rice pest was 7% (Mangan and Mangan, 1998; Settle et al., 1996). Beneficial insects are very effective in controlling the pest. They occur in the tropical wet rice ecosystem before the pests and feed on neutral insects and detritivores that already exist in the rice field. Therefore, beneficial insects are effective in controlling the pest at the early stage (Settle et al., 1996). Similarly, chemical pesticides are destructive and they interrupt the balance of the wet rice ecosystem. Usually, they can induce the pest outbreak by killing the natural enemies of pests or by making the pest-resistant or making them physically invulnerable to pesticides. For example, high insecticide applications caused the outbreak of Brown planthoppers in Indonesia and its survival capacity also increased by more than ten times (Kenmore, 1991). So, the farmers need to understand the importance of beneficial insects and reduce the uses of insecticides which destroy them.

3.3 Farmers Field School (FFS)

To implement the Ecology-Based IPM, the Farmers Field School (FFS) model of training was designed to train the farmers (Kenmore et al.,1991). This model of training farmers was first adopted by Indonesia in 1989 for the implementation of IPM in rice. In Nepal, it was adopted in 1998 for the first time (Peshin et al., 2014). Farmers Field School (FFS) is an efficient method of managing pest stress that strengthens the farmers' understanding and their role as researchers and the use of ecological science and technology. It is a session long educational courses conducted in the field in a small group of farmers (Kenmore, 1991). In FFS, farmers observe and analyze their agroecosystems from planting to harvest regularly. Here, farmers observe the predatory behaviors of the species collected from the field and reared in insect zoos, and their ecology is studied. Similarly, the members of the group collect the data and analyze them and they are encouraged to make the decision based on the result of analysis of the collected data (Peshin et al., 2014). Farmers decide whether the crop has reached the critical stage and if there is any need for the pesticidal spray in the paddy field. This type of learning practice increases the farmers' knowledge and confidence in IPM as compared to conventional top-down delivery of technical suggestions. It also facilitates the farmers to apply ecologically informed farming practices. FFS is such a model that gives the farmers chance to do experiment with IPM and find the logically-relevant management options of the pest (Mancini et al., 2008).

3.4 Economic Threshold IPM

The other model of IPM application, Economic Threshold IPM, is such a model that depends on pesticides rather than beneficial insects/spiders for the pest control. The economic threshold is reached when the cost of control is exceeded by the benefit of pest control so that there is no economic loss (Mangan and Mangan, 1998). It is different from the FFS model that in the Economic Threshold Model, farmers are taught in the classroom with some field time to identify some major pests while in FFS, farmers are taught in the field. In Economic Threshold Model, the decision of crop protection is made based on "scouting" of the pest at the four most critical stages and the pesticides are sprayed when the pest reaches the Economic Threshold Level (Mangan and Mangan, 1998). The economic threshold of IPM does not take concern about the whole agroecosystem but only takes account of the pest-plant relationship. This method focuses to identify and control the three or four pests with the right chemicals. Farmers learn the correct formulas and chemicals to control the pest which is taught by the experts. In this model of IPM, the decision of treatment is based on the economically derived decision rules and the control strategies are applied based on rules when the Economic Threshold level is reached (Fernandez-Cornejo, 1996).

3.5 Pesticide Use

Pesticides are common tools for pest management. In Asia, the stem borer damages the rice crop up to 5 to 10% annually but occasionally in the condition of the outbreak it may reach up to 60% (Pathak and Khan, 1994). To reduce the loss of yield due to such pests, farmers haphazardly use the chemical pesticides in higher rates than those recommended by the experts and extension agents because they believe that higher application of pesticides than the recommended dose is more effective (Abdollahzadeh et al., 2015). Such indiscriminate use of chemical pesticide can lead to the problems like harmful health effects, contamination of ground-water through seepage runoff, transmittal of pesticide residues to the farm family and the consumers by the means of the food chain, enhancing the pest resistance to pesticides thereby causing pest outbreaks, destroy the beneficial insects, reduce the population of microorganisms in the soil. Various health disorders like nausea, blurred vision, and respiratory disorders are found more in farmers who use pesticides than those who don't use (Sankoh et al., 2016). Severe health and environmental hazards due to pesticide use in the developing countries occur mainly due to the lack of information among the farmers about the demerits of indiscriminate use of pesticides in a dangerous way (Dasgupta et al., 2005). So, it is necessary to make integrated management to overcome the problems of pesticide use before getting worst in the future. The losses due to the indiscriminate use of pesticides can be controlled by educating farmers and changing the farmer's behaviors on pesticide use (Dasgupta et al., 2005). It has been found that the farmers who are trained in FFS about IPM use less pesticide than those who are not trained at FFS (Supriatna, 2003). However, for the successful implementation of rice IPM, the integration of insecticide uses with biological control methods, use of resistant varieties, and cultural method, is very important (Lim and Heong, 1984).

3.6 Different Practices in Rice IPM

IPM is an approach that combines physical, cultural, biological, and chemical control methods for pest management (Munyua, 2003). The various methods of pest control that are practiced in rice IPM are:

3.6.1 Cultural methods

Cultural methods of pest control include the crop production method that is used consciously or unconsciously by the farmers. The measurement of the effectiveness of the cultural practices is often difficult because the same practice which causes the reduction of one pest may increase another (Reissig, 1985). Several cultural practices like field geometry, mixed cropping, planting method, planting density, planting time, tillage operation, weeding, and burning of straw influence the abundance of different pests in rice. For example, the larger and square field is more beneficial as the larger and square fields have less perimeter to area ratio and hence they suffer less from water weevils which occur in the field along the borders (Gigarick, 1984). In a study, dryland rice intercropping with cotton or pigeon pea resulted in a decreased population of white-backed planthoppers (Satpathy, 1977). Transplanting rice is found to have more stem borer than direct-seeded crops (Koyama et al., 1968). Similarly, the population of leaf folders increases with the density of planting (Kushwaha and Sharma, 1981).

3.6.2 Use of resistant varieties

Use of resistant varieties is one of the important methods of IPM as they do not increase the cost of farmers, require less pesticide than that of susceptible varieties and they reduce the damage of pest population at all levels throughout the season (Reissig, 1985). The use of resistant varieties can be considered as a safe alternative to pesticide use in rice production. Various techniques are used to produce insect-resistant rice crop varieties like mutagenesis, the introduction of foreign genes (Single-gene and gene pyramiding), transplastomic approaches, genetically engineered/modified Bt Toxins, oligonucleotide-directed mutagenesis, engineered nucleases, engineered plant membrane transporters, and antisense technologies. Even though the number of insect-resistant rice varieties has been developed in the world but to date, no country approved those varieties of rice (Rasool et al., 2020).

3.6.3 Physical methods

Physical control of the pest can be defined as "the manipulation of physical factors to eliminate pests or reduce their population to tolerable level" (Fields, 1994). The implementation of physical control technologies for pest control in pre-harvest conditions is affected by various factors like technical obstacles in implementing the strategy, cost of physical control relative to competing technologies, and dependence of farmers on chemicals (Panneton, 2001). It is a labor-intensive method. So, the adoption of this method decreases with the increase in the labor cost and when the less expensive alternative method becomes available. The physical methods of pest control in rice include different practices like removal of the plant which is infested with the pest, cleaning of bunds, use of light traps, and use of oil on the paddy water. For example, kerosene oil is used against root weevils by pouring into the flooded field (Kuwayama, 1963). The light trap is considered to control seed bugs (Sen and Chaudhuri, 1959). Root aphid is claimed to have been controlled by roughing (Tanaka, 1961).

3.6.4 Biological methods

The biological method of pest control is the key element of IPM. Biological control of pest can be defined as "ecologically based pest management that uses one kind of organism (the natural enemies) to control another (the pest species) (Hoddle and Van Driesche, 2009). Natural biological agents include Spiders, Damsels flies, Water bugs, Dragonflies, Mirid bugs, Meadow grasshoppers, Carabids, Staphylinid beetles, Coccinellids, Platygaster, and Bracon (Basana Gowda and Patil, 2019). 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, and the use of bio-pesticides which are made from living organisms or the product of living organisms (Baker et al., 2020). 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). These studies show that the application of natural plant products with bacterial toxins causes growth inhibition, antifeedant effect and may also possess some toxic effects on harmful insects.

3.6.5 Chemical methods

The chemical method is the last resort in IPM practice. It includes the use of chemical pesticides for pest control. Pesticides suppress the pests to prevent the loss of crop. But high use of pesticides cannot lead to the sustained long-term production of rice. So, the use of pesticides must be based on ecological principles and the farmers must be able to take advantage of the diversity of the ecosystem and its productivity (Norton et al., 2010). For this awareness among the farmers about the ways to gain optimum long-term productivity of the rice field ecosystem is very necessary. In rice IPM, the chemical method of the pest control can be integrated with biological, cultural, and use of resistant varieties practices for controlling the pest. The judicious use of pesticides helps to control pests in rice. Selective use of pesticides helps to avoid or reduce the effect on non-target species. While using the chemical pesticides, the socio-economic aspects of the pesticide should be considered and they should be applied at the correct timing and in minimum doses only to avoid predictable economic losses (Lim and Heong, 1984).

3.7 Difficulties in The Adoption of IPM

The implementation of IPM in the last decade seems to be weakened and the use of pesticides causing the pest outbreak seems to be increased (Wiyono, 2020). Because of this plant health are getting more complicated due to the attack of pest and disease. One of the most important obstacles in the implementation of IPM is that it requires the combined effort of the farmers within the farming community (Parsa et al., 2014). The combined effort may be important because pest can move easily from one field to another that are small and separated by a short distance. Another major problem is its complexity and it is difficult to integrate new pest control practices to make it acceptable to the farmers (Fenmore and Norton, 1985). Other challenges regarding the implementation of IPM may be lack of training among the farmers about IPM, lack of knowledge among the farmers about the implementation of IPM and it is labor-intensive (Rahman, 2012). Farmers find difficulty in adopting the IPM because the cost of the IPM is more than the apparent benefit, it is less oriented to the need of farmers and it is difficult to implement than conventional management with pesticides (Parsa et al., 2014). IPM practices were not adopted by some farmers in Thailand because of its unsuitability for large farms, difficulties in the implementation of IPM and the farmers had strong confidence in the potential of chemical insecticide for the control of pest (Timprasert et al., 2014).

3.8 Suggestions to Increase the Adoption of IPM

To increase the implementation of IPM, it is very necessary to emphasize education and training to the farmers. It is necessary to focus on the educational and motivational programs by the implementing agencies to increase the IPM practice for farmers (Rahman, 2012). Well educated farmers are more aware of the effects of using pesticides and they have a better understanding of the importance of alternative pest control methods (van Eeden and Korsten, 2013). Education and training were found to be the main factors responsible for environmentally sound pest control practices in Pakistan (Khan and Damalas, 2015). Extension services can also play an important role in the implementation of IPM. It is found that the farmer who interacts more with the extension agents are more likely to use alternative pest control methods like IPM (Timprasert et al., 2014). Similarly, a study in Uganda shows that women have greater knowledge about IPM than men and they are more aware of the potentially harmful effect of pesticides (Erbaugh et al., 2003). Thus, IPM implementation programs focusing the women's participation may increase the IPM adoption. Moreover, the supportive policy of the government is also very important for the successful implementation of IPM (Munyua, 2003). Government policies and actions like reducing the pesticide subsidies and providing monetary support to strengthen extension, research, and technical services can be helpful for the successful implementation of IPM (Teng, 1994). IPM programs should be developed in more countries. Emphasis should be given to teaching the farmers about IPM through FFS rather than any other method. The transmission of knowledge about IPM through training and visit extension system has been failed and the "Farmers first" approach which involves transferring of knowledge about IPM through participatory non-formal education in the farmer's field which is followed by community IPM practices that focus on farmer-training-farmer and research by farmers is getting success in IPM implementation (Matteson et al., 1994).

4. Conclusion

This study shows that indiscriminate use of pesticides has a harmful effect on human health and the environment. Excessive pesticide use causes the destruction of beneficial insects and the outbreak of the pest. So, Integrated Pest Management is the best alternative of pesticide use for pest management in the paddy field. FFS has been the most effective way to increase knowledge among the farmers about IPM tools and techniques. In IPM, different practices like physical, biological, cultural, use of resistant varieties, and chemical practices are combined for the pest management in the paddy field. Although the economic and ecosystem benefit of the IPM has been realized by some farmers in the world but yet there are many rice farmers left who are still left to be taught about IPM. Development of the IPM program is required in more countries and such a program should ensure such type of education systems that helps to reduce the agricultural practices that cause negative impacts on the environment. The implementation of programs like Farmers Field School should be given more emphasis. There is a need for different studies to be made in the different regions of the world to discover the various eco-friendly integrated pest control means. Studies must be primarily focused on the implementation of integrated pest control means that involve the participation of farmers in pest control activities.

Authors' Contribution

Both authors have equally contributed to the preparation of this manuscript.

References

Abdollahzadeh, G., Sharifzadeh, M.S., Damalas, C.A., 2015. Perceptions of the beneficial and harmful effects of pesticides among Iranian rice farmers influence the adoption of biological control. Crop Protection, 75, Pp. 124–131. https://doi.org/10.1016/j.cropro.2015.05.018

Baker, B.P., Green, T.A., Loker, A.J., 2020. Biological control and integrated pest management in organic and conventional systems. Biological Control, 140, Pp. 104095. https://doi.org/10.1016/j.biocontrol.2019.104095

Barzman, M., Bàrberi, P., Birch, A.N.E., Boonekamp, P., Dachbrodt-Saaydeh, S., Graf, B., Hommel, B., Jensen, J.E., Kiss, J., Kudsk, P., Lamichhane, J.R., Messéan, A., Moonen, A. C., Ratnadass, A., Ricci, P., Sarah, J.L., Sattin, M., 2015. Eight principles of integrated pest management. Agronomy for Sustainable Development, 35 (4), Pp. 1199–1215. https://doi.org/10.1007/s13593-015-0327-9

Basana, G.G., Patil, N.K.B., 2019. Integrated Pest Management (IPM) in Rice under Changing Climate. Climate Resilient Agricultural Technologies for Future. Training Manual, Model Training Course on Climate Resilient Agricultural Technologies for Future, ICAR-National Rice Research Institute, Cuttack, 3, Pp. 15.

Berg, H., 2002. Rice monoculture and integrated rice-fish farming in the Mekong Delta, Vietnam - Economic and ecological considerations. Ecological Economics, 41 (1), Pp. 95–107. https://doi.org/10.1016/S0921-8009(02)00027-7

Chauhan, B.S., Jabran, K., Mahajan, G., 2017. Rice Production Worldwide. In Rice Production Worldwide, Pp. 1–563. https://doi.org/10.1007/978-3-319-47516-5

Cohen, M.B., Alam, S.N., Medina, E.B., Bernal, C.C., 1997. Brown planthopper, Nilaparvata lugens, resistance in rice cultivar IR64: Mechanism and role in successful N. lugens management in Central Luzon, Philippines. Entomologia Experimentalis et Applicata, 85 (3), Pp. 221–229.

Dasgupta, S., Meisner, C., Huq, M., 2005. Health effects and pesticide perception as determinants of pesticide use: evidence from Bangladesh. The World Bank. https://doi.org/10.1596/1813-9450-3776

Duke, S., Powles, S., 2008. Perspective Integrated pest management (IPM): definition, historical development and implementation, and the other IPM Lester. Pest Management Science, 63 (11), Pp. 1100–1106.

Erbaugh, M., Donnermeyer, J., Amujal, M., Kyamanywa, S., 2003. The Role of Women in Pest Management Decision Making in Eastern Uganda. Journal of International Agricultural and Extension Education, 10 (3), Pp. 71–81. https://doi.org/10.5191/jiaee.2003.10309

Fenmore, P.G., Norton, G.A., 1985. Problems of implementing improvements in pest control: a case study of apples in the UK, 4 (1), Pp. 51–70. https://doi.org/10.1016/0261-2194(85)90005-5

Fernandez-Cornejo, J., 1996. The Microeconomic Impact of IPM Adoption: Theory and Application. Agricultural and Resource Economics Review, 25 (2), Pp. 149–160. https://doi.org/10.1017/s1068280500007814

Fields, P., 1994. Physical methods for insect control in stored-grain ecosystems. Stored-grain ecosystems, 39, Pp. 353.

Gadal, N., Shrestha, J., Poudel, M.N., Pokharel, B., 2019. A review on production status and growing environments of rice in Nepal and in the world. Archives of Agriculture and Environmental Science, 4 (1), Pp. 83–87. https://doi.org/10.26832/24566632.2019.0401013

Grigarick, A.A., 1984. General problems with rice invertebrate pests and their control in the United States. Protection ecology, 7 (2/3), Pp. 105-114.

Hoddle, M.S., Van Driesche, R.G., 2009. Biological Control of Insect Pests. In Encyclopedia of Insects (Second Edi). Elsevier Inc. https://doi.org/10.1016/B978-0-12-374144-8.00033-3

Horgan, F.G., 2017. Integrated pest management for sustainable rice cultivation: a holistic approach, Pp. 309–342. https://doi.org/10.19103/as.2016.0003.23

Kenmore, P.E., 1991. How Rice Farmers Clean up the Environment Conserve Biodiversity, Raise More Food, Make Higher Profits.

Khan, M., Damalas, C.A., 2015. Factors preventing the adoption of alternatives to chemical pest control among Pakistani cotton farmers. International Journal of Pest Management, 61 (1), Pp. 9–16. https://doi.org/10.1080/09670874.2014.984257

Kogan, M., 1998. Integrated pest management: Historical perspectives and contemporary developments. Annual Review of Entomology, 43, Pp. 243–270. https://doi.org/10.1146/annurev.ento.43.1.243

Koyama, T., Kikuchi, M., Hirao, J., 1968. On the injuries caused by insect pests and the development of the rice stem borer in the rice plants sowed directly on the submerged field. Bulletin of the Tohoku National Agricultural Experiment Station, (36), Pp. 43-51.

Kushwaha, K.S., Sharma, S.K., 1981. Relationship of date of transplanting, spacings and levels of nitrogen on the incidence of rice leaf folder in Haryana. Indian Journal of Entomology, 43 (3), Pp. 338-339.

Kuwayama, S., 1963. Notes on two curculionid beetles attacking the rice plant in Japan. Plant Prot. Bull., 5, Pp. 156-161.

Lim, G.S., Heong, K.L., 1984. The role of insecticides in rice integrated pest management. judicious and Efficient Use of Insecticides on Rice, Pp. 19-40.

Mancini, F., Termorshuizen, A.J., Jiggins, J.L.S., van Bruggen, A.H.C., 2008. Increasing the environmental and social sustainability of cotton farming through farmer education in Andhra Pradesh, India. Agricultural Systems, 96 (1–3), Pp. 16–25.

Mangan, J., Mangan, M.S., 1998. A comparison of two IPM training strategies in China: The importance of concepts of the rice ecosystem for sustainable insect pest management. Agriculture and Human Values, 15 (3), Pp. 209–221.

Matteson, P.C., Gallagher, K.D., Kenmore, P.E., 1994. Extension of Integrated Pest Management for Planthoppers in Asian Irrigated Rice: Empowering the User. In Planthoppers, Pp. 656–685. https://doi.org/10.1007/978-1-4615-2395-6_21

Munyua, C.N., 2003. Challenges in Implementing Integrated Pest Management (IPM) Practices: Implications for Agricultural Extension. Proceedings of the 19th Annual Conference, Pp. 469–479.

Nathan, S.S., Chung, P.G., Murugan, K., 2005. Effect of biopesticides applied separately or together on nutritional indices of the rice leaffolder Cnaphalocrocis medinalis. Phytoparasitica, 33 (2), Pp. 187–195.

Norton, G.W., Heong, K.L., Johnson, D., Savary, S., 2010. Rice pest management: issues and opportunities. Rice in the global economy: Strategic research and policy issues for food security, Pp. 297-332.

Ooi, P.A.C., 1996. Experiences in educating rice farmers to understand biological control. Entomophaga, 41 (3-4), Pp. 375-385. https://doi.org/10.1007/BF02765791

Panneton, B., Vincent, C., Fleurat-Lessard, F., 2001. Current status and prospects for the use of physical control in crop protection. In Physical Control Methods in Plant Protection, Pp. 303-309. Springer, Berlin, Heidelberg.

Parsa, S., Morse, S., Bonifacio, A., Chancellor, T.C.B., Condori, B., Crespo-Pérez, V., Hobbs, S.L.A., Kroschel, J., Ba, M.N., Rebaudo, F., Sherwood, S.G., Vanek, S.J., Faye, E., Herrera, M.A., Dangles, O., 2014. Obstacles to integrated pest management adoption in developing countries. Proceedings of the National Academy of Sciences of the United States of America, 111 (10), Pp. 3889–3894. https://doi.org/10.1073/pnas.1312693111

Pathak, M.D., Khan, Z.R., 1994. Insect pests. In International Rice Research Institute and International Centre of Insect Physiology and Ecology.

Peshin, R., Jayaratne, K.S.U., Sharma, R., 2014. IPM Extension: A Global Overview. In Integrated Pest Management: Current Concepts and Ecological Perspective. https://doi.org/10.1016/B978-0-12-398529-3.00026-9

Rahman, M.M., 2012. Problems and suggestions for farmers adoption of IPM practices in rice (Oryza sativa L) cultivation. Bangladesh Journal of Agricultural Research, 37 (1), Pp. 121-128. https://doi.org/10.3329/bjar.v37i1.11183

Rasool, A., Akbar, F., Rehman, A., Jabeen, H., 2020. Genetic Engineering of Rice for Resistance to Insect Pests. In Rice Research for Quality Improvement: Genomics and Genetic Engineering, Pp. 129-148. Springer, Singapore. https://doi.org/10.1007/978-981-15-5337-0_7

Reissig, W.H., 1985. Illustrated guide to integrated pest management in rice in tropical Asia. Int. Rice Res. Inst...

Sankoh, A.I., Whittle, R., Semple, K.T., Jones, K.C., Sweetman, A.J., 2016. An assessment of the impacts of pesticide use on the environment and health of rice farmers in Sierra Leone. Environment International, 94, Pp. 458–466. https://doi.org/10.1016/j.envint.2016.05.034

Satpathy, J.M., Das, M.S., Naik, K., 1977. Effect of multiple and mixed cropping on the incidence of some important pests. Journal of Entomological Research, 1 (1), Pp. 78-85.

Sen, A.C., Chaudhuri, D.P., 1959. Incidence of rice gundhy bug and steps for its control. Indian J. Entomol, 21 (4), Pp. 287-288.

Settle, W.H., Ariawan, H., Astuti, E.T., Cahyana, W., Hakim, A.L., Hindayana, D., Lestari, A. S., Pajarningsih, Sartanto., 1996. Managing tropical rice pests through conservation of generalist natural enemies and alternative prey. Ecology, 77 (7), Pp. 1975–1988. https://doi.org/10.2307/2265694

Supriatna, A., 2003. Integrated pest management and its implementation by rice farmer in Java. Jurnal Litbang Pertanian, 22 (3), Pp. 109.

Tanaka, T., 1961. The rice root aphids, their ecology and control. Spec. Bull. Coll. Agric. Utsunomiya, 10, Pp. 1-83.

Teng, P.S., 1994. Integrated pest management in rice. Experimental Agriculture, 30 (2), Pp. 115-137. https://doi.org/10.1017/S001447970002408X

Timprasert, S., Datta, A., Ranamukhaarachchi, S.L., 2014. Factors determining adoption of integrated pest management by vegetable growers in Nakhon Ratchasima Province, Thailand. Crop Protection, 62, Pp. 32–39. https://doi.org/10.1016/j.cropro.2014.04.008

van Eeden, M., Korsten, L., 2013. Factors determining use of biological disease control measures by the avocado industry in South Africa. Crop Protection, 51, Pp. 7–13. https://doi.org/10.1016/j.cropro.2013.03.011

Wiyono, S., 2020. Building new phase of IPM in Indonesia. IOP Conference Series: Earth and Environmental Science, 468 (1). https://doi.org/10.1088/1755-1315/468/1/011003

Zeigler, R.S., Barclay, A., 2008. The Relevance of Rice. Rice, 1 (1), Pp. 3–10. https://doi.org/10.1007/s12284-008-9001-z.