DOES SOLAR LIGHT TRAP REDUCE THE COST OF PESTICIDES USED IN RICE FIELD?

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ABSTRACT

Pesticide application against insect pest infestation is environmentally unsafe and costly. An attempt was taken to evaluate the solar light trap as ecofriendly and cost-effective approach in Transplanted Aman rice (BRRI dhan32) field at Barhatta Upazila (Sub-district) in Netrokona district of Bangladesh. It was found that rice pest like rice yellow stem borer, rice leaf roller, green leaf hopper, brown plant hopper, rice leaf miner, rice gall midge, white leafhopper, rice bug, rice ear cutting caterpillar, white-backed planthopper, rice caseworm, grasshopper, rice skipper and rice beetle were the major insects that captured under the solar light traps. Some beneficial insects were also attracted by the trap these were ladybird beetle, water scavenger, giant water bug, ground beetle, rove beetle, damsel fly. All the harmful and the beneficial insects were belonging the order of Lepidoptera, Hemiptera, Orthoptera, Coleoptera, Diptera and Odonata. Though the mean yield of rice was statistically insignificant in both fields, the light trap installed fields required the less frequency of pesticides than the control fields which ultimately rendered the low pesticides cost in a great extent. On an average 1,034 BDT was reduced in per hectare.

Keywords: Solar light trap, Ecofriendly, Cost effectiveness, Rice pests

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important crops in the world and grown in 177 countries. In Asia, around 2.7 billion people consume rice as a staple food (Kumar et al., 2009). In Bangladesh rice (*Oryza sativa* L.) dominates the cropping pattern throughout the country as almost 90 percent of populations depend on rice. Bangladesh ranked fourth concerning rice production among the rice-producing countries (FAO, 2019). It is the staple food of about 160 million people in Bangladesh. It provides caloric intake to over 63% of urban consumers and over 71

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Received: 17.03.2022

Accepted: 14.06.2022
% for the rural population (Alam, 2013). It generates half of the agricultural GDP and one-sixth of Bangladesh’s national revenue. Moreover, the rice sector provides nearly 48% of rural employment. About 11.39 million hectares of land are used for rice cultivation to produce 35.05 million metric tons of rice (BBS, 2018). Around 18% of the national rice production was covered by the haor (bowl shaped swallow depression which is flooded during the monsoon) areas (Huq et al., 2012). Netrakona was one of the seven haor districts consisted of 52 haors. As the area was prone to frequent flooding, the farmers preferred to cultivate rice than vegetable crops (BHWDB, 2012). Different rice varieties have been developed by Bangladesh Rice Research Institute (BRRI) over the years including high yielding and modern variety to increase the yield of the crop as well as to reduce the cost of production of rice.

As most of our farmers mainly rely on rice cultivation for their livelihood, from the expectation of higher yields, farmers are now being encouraged to cultivate hybrid variety rather than local variety (Sivagnanam and Murugan, 2020). But the main concern regarding rice cultivation in Bangladesh is the harmful insect pests that cause enormous yield loss (Mackill, 2018). Bangladesh has a tropical monsoon climate characterized by wide seasonal variations in rainfall, temperature and humidity. The infestation of pests in the rice ecosystem is rising day by day due to the climate change (Alam, 2013). Around 800 insect species associated with the rice ecosystem have been reported throughout the world. Out of these, 100 insect species are considered as harmful for the rice ecosystem and the rest of them are considered as friendly species (Pathak, 1970). About 20 species were identified as the most harmful insects that causes around 15-90% yield loss in rice (Pathak and Khan, 1994). Brown plant hopper, yellow stem borer, Rice bug etc. are considered as the major insects in the rice ecosystem (Moses et al., 2019). To reduce insect infestation in the rice field, farmers are practicing different insect management technologies. Different types of methods are used for insect management viz. cultural, mechanical, physical, chemical and biological method (Alam, 2013). In Bangladesh, most of the farmer prefers chemical method for insect pest management. This irrational use of chemical pesticides in the rice ecosystem increases the cost of production and has a long-term residual impact on the environment and biodiversity (Yaqub et al., 2017; Sun et al., 2018). Rice is cultivated around the haor area in Boro season, using chemical pesticides is so dangerous for the aquatic biodiversity of haor areas. There are plenty evidences that represents the harmfulness of chemical insecticides and their residues to fish (Salam et al., 2015; Rahman et al., 2020).

Every year thousand tons of chemical insecticides are being used in Bangladesh. Pesticide use has increased 400% per acre and the cost increased by 600% during the couple of decades. The sales of pesticides were doubled between 1985 and 1990. Currently, 84 pesticides have been registered in Bangladesh which belonging to 242 trade names. In rice fields, over 80% of total pesticides are used (Parveen and Nakagoshi, 2001). In 2017, the farmers of Bangladesh used around 37,258 metric tons of chemical pesticides in their crop fields (DAE, 2018). To fulfill this enormous
demand, the government has to import a huge amount of pesticide from other countries. Moreover, this tremendous and indiscriminate use of pesticides is increasing the cost of production of rice. According to Bangladesh Crop Protection Association (BCPA), the annual import cost stands nearly 200 million USD (Khandker and Hossain, 2017). Considering the economic conditions of the farmers and the alarming effects of chemical pesticides on the environment, alternate pest management tools should be reconsidered. Recently light trap is used for pest control in many agroecosystems (Lee et al., 2017; Yee, 2017; Abd Rahman et al., 2018; Sunitha, 2018; Patidar et al., 2019). The light trap is an ecofriendly management tool that manages the pest by conserving the insect species at a minimum level (Sunitha, 2018). This trap mainly captured the nocturnal harmful insects (Abd Rahman et al., 2018). However, the conventional light trap has some limitations (Kunz, 1988; Gavhande et al., 2019). It cannot be used in some rural areas. This problem is solved by the solar light trap which can be set up in any place (Meshram et al., 2018). This solar light trap is being used in many parts of the world (Kadel et al., 2018; Band et al., 2019). Generally, the solar light trap is used for monitoring and forecasting of pest (Kammar et al., 2020). However, very few researches have been done on the cost reduction of pesticides by using the solar light trap. Therefore, our research was aimed to investigate the cost reduction of pesticides in rice field by using the solar light trap.

MATERIALS AND METHODS

Study site
The study was conducted in Barhatta Upazila (Sub-district) (24°51 to 25°00 North latitude and 90°46 to 91°00 East longitude) of Netrokona district of Bangladesh (Figure 1) Seven blocks (Agricultural unit area mapped by Department of Agriculture Extension, DAE) i.e., Ramvodrapur, Shalpudoshal, Otitpur, Chotokoilati, Roymadov, Singhdha and Fokirer Barzar blocks of seven unions (unit area of Sub-district) in Barhatta Upazila were considered for the experimental site. Insects especially rice yellow stem borer, Rice leaf roller, rice bug, green leaf hopper prone area were selected during the block selection.

Experimental design
Rice field were categorized into control (without light trap) and experimental field (with installation of light trap) Each block has one control field and one experimental field. Transplanted Aman rice variety (BRRI dhan32) was selected to conduct the research.
Land preparation
Each control and experimental field size were 1 ha composed of several small plots. Ploughing was done by power tiller. During puddling, manure and chemical fertilizer were used as basal dose. The fertilizers doses were used in the field as Urea 195 kg, TSP 60 kg, MoP 105 kg and Gypsums 68 kg, Zinc Sulphate 12 kg per hectare, respectively. TSP, MoP, Gypsum and Zinc fertilizers were used during land preparation. Urea was used into three splits, first split was in 15 to 20 days after transplanting, second split was in 35 to 40 days and third or final split was done 55 to 60 days after transplanting of the seedlings.

Seedlings raising and transplanting
Seedlings were raised in an ideal seedbed. Around 30 days seedlings were transplanted during mid-August 2019. Seedlings were transplanted by following the line sowing method.

Intercultural operations
Frequent weeding i.e. three times weeding was done. Fertilizer application was done as per need based. Perching was practiced in both categorized of fields. Depending on the requirement, assessed by the presence of insects in the transplanted Aman rice field, different types of insecticides were applied both in control and experimental fields e.g. Sunfuran 5G (Carbofuran), Marshal 20EC (Carbosulfan), Imitaf 20SL (Imidaclorpri), Virtako 40WG (Thiamethoxam 20% + Chloraniliprole 20%), Suntap 50SP (Cartap), Diazinon 60EC (Diazinon), Dursban 20EC (Chlorpyrifos), Nitro 505EC (Chlorpyrifos 50% + Cypermethrin 5%), Regent 50 SC (Fipronil). Supplementary irrigation was also provided as per needed.
Solar Light Trap setting and insect collection

Seven solar light traps were set up in 1st week of September 2019 in seven locations of Barhatta Upazila of Netrokona (Figure 2 and Table 1). The bottom portion of the solar light trap was fixed in soil with cementing materials. A bulb with a holder was tightened with the straight frame to prevent it from the collapse. A bowl was set up under the frame to collect the insect samples. The bucket was filled with detergent mixed water to keep the insect samples. A solar panel was set up at the top of the frame which was charged in daytime and used after sunset around 6 pm through the bulb. Data on insect samples were collected on each Wednesday from the solar light trap for nine times during the whole season. Mainly nocturnal insects were trapped in the light traps. Insects were collected from the bowl in the morning at 10 am and the bowl was replaced with fresh detergent water in every Wednesday. The farmers of the consecutive field were involved in the insect collection. The trapped insects were washed after hand picking. After washing, the insects were preserved in a jar containing 70% formaldehyde solution and kept for further identification and analysis.

Figure 2. Experimental setup of solar light trap at T-Aman rice field in Barhatta Upazila of Netrokona district

Data analysis

The preserved collected insect samples were analyzed in the entomology laboratory of Sylhet Agricultural University. We classified the major insects according to their common name and orders. Data on pesticides use frequency were recorded. The yield of transplanted Aman rice (BRRI dhan32) was assessed both in control and in experimental plot. The independent t-test was performed to compare the means of yield by using IBM SPSS 26 software. Finally, we compared the cost of pesticides in both the control and experimental plots to assess the cost-effectiveness of the solar light trap in the transplanted Aman rice fields.
Table 1. Details of the solar light trap used in the T-Aman rice field of Barhatta Upazila of Netrokona district in 2019

| Description of the product                        | Specification                                                                 |
|--------------------------------------------------|-------------------------------------------------------------------------------|
| Solar Panel                                      | 20Wp (Approved Brand)                                                        |
| Battery                                          | (Sealed lead Acid Battery)                                                    |
| Volts = 12.0 (6x2), AH = 4.5, time 4 hours       |                                                                               |
| Controller with box (Micro Controller based)     | Load Cable, panel cable, etc.                                                 |
| Rated Voltage: Input Voltage-20volt Dc           |                                                                               |
| Output Voltage: 12 Volt Dc                       |                                                                               |
| Rated charging Current: HVD :14.2                 |                                                                               |
| LED Display:                                     |                                                                               |
| Box Dimension: 7.5x8.5x5.5” Digital print        |                                                                               |
| Inside the wooden box for battery                |                                                                               |
| Bulb                                             | Pest attractive bulb, Rated voltage: 12 V                                    |
| Rated power: 3W UV LED                           |                                                                               |
| Light Trap Frame/ stand with light shade         | (As per BRRI specification 50 cm diameter)                                   |
| Accessories                                      | (Holder, wire for connection and hanging)                                    |
| Plastic bowl capacity                            | 20 L                                                                           |

RESULTS AND DISCUSSION

Results showed that many insects from different Orders were captured under the solar light trap (Figure 3). Light trap mainly attracts the nocturnal insects. Nocturnal insects have the affinity to the light wavelength during night. Park and Lee, (2017); Sridhar and Kumaran, (2018), reported that insects showed different levels of affinity to the different wavelength of the light trap.

Figure 3. Insects captured under the solar light trap at T. Aman rice field in Barhatta Upazila of Netrokona district
After identification of the preserved sample, it was found that insects belonging to the order of Lepidoptera, Hemiptera, Orthoptera, Coleoptera, Diptera and Odonata were mainly captured under the trap. Most common insects trapped in the solar light trap were rice yellow stem borer, rice leaf roller, green leaf hopper, brown plant hopper, rice leaf miner, rice gall midge, white leafhopper, rice bug, rice ear cutting caterpillar, white-backed planthopper, rice caseworm, grasshopper, rice skipper and rice beetle (Table 2). Meena et al., (2018) reported that 40 insect species of the Order Lepidoptera were caught when they had installed a light trap in the rice field. Light trap also showed positive effects on capturing the pest of other crops. Sridhar and Kumaran, (2018) found that light trap can be utilized as an effective component for the management of *Tuta absoluta* (Lepidoptera: Gelechiidae) on Tomato.

Table 2. Insect pest captured under the solar light trap in the Transplanted Aman rice field of Barhatta Upazila of Netrokona district in 2019

| Insects                  | Scientific name                        | Family      | Order   |
|--------------------------|----------------------------------------|-------------|---------|
| Rice yellow stem borer   | *Scirpophaga incertulas* (Walker)      | Crambidae   | Lepidoptera |
| Rice leaf roller         | *Cnaphalocrocis medinalis* (Guenee)    | Pyralidae   | Lepidoptera |
| Green leaf hopper        | *Nephotettix virescens* (Distant)      | Cicadellidae| Hemiptera |
| Brown planthopper        | *Nilaparvata lugens* (Stal)            | Delphacidae | Hemiptera |
| Rice leaf miner          | *Hydrellia philippina*                 | Ephydridae  | Diptera  |
| Rice gall midge          | *Orseolia oryzae* (Wood-Mason)         | Cecidomyiidae| Diptera |
| White leafhopper         | *Cofana spectra*                       | Cicadellidae| Hemiptera |
| Rice bug                 | *Leptocorisa acuta* (Thunberg)         | Alydidae    | Hemiptera |
| Rice ear cutting caterpillar| *Mythimna separate* (Walker)       | Noctuidae   | Lepidoptera |
| White-backed planthopper | *Sogatella furcifera*                  | Delphacidae | Hemiptera |
| Rice caseworm            | *Nymphula depunctalis* (Guenee)        | Crambidae   | Lepidoptera |
| Grasshopper              | *Oxya* sp.                             | Acrididae   | Orthoptera |
| Rice skipper             | *Pelopidas mathias*                    | Hesperiidae | Lepidoptera |
| Rice beetle              | *Dyscinetus morator*                   | Scarabaeidae| Coleoptera |

Some of beneficial insects were also attracted by light such as ladybird beetle, water scavenger, giant water bug, ground beetle, rove beetle, damselfly. Our research revealed that solar light trap captured both the beneficial and harmful insect species (Table 3). This refers those nocturnal insects can be beneficial as well as harmful. Singh et al., (2018); Kammar et al., (2020) reported the capture of both beneficial and harmful insects under the light trap.
Table 3. Beneficial Insect captured under the solar light trap in the Transplanted Aman rice field of Barhatta upazila of Netrokona district in 2019

| Insects          | Scientific name                | Family       | Order     |
|------------------|--------------------------------|--------------|-----------|
| Ladybird beetle  | *Coccinella septempunctata*    | Coccinellidae| Coleoptera|
| Water scavenger  | *Hydrophilus triangularis* (Say) | Hydrophilidae| Coleoptera|
| Giant water bug  | *Lethocerus americanus*        | Belostomatidae| Hemiptera|
| Ground beetle    | *Calleida decora*              | Carabidae    | Coleoptera|
| Rove beetle      | *Paederus sp.*                 | Staphylinidae| Coleoptera|
| Damsel fly       | *Nehalennia gracilis*          | Coenagrionidae| Odonata |

Due to regular light trapping, farmers decided to use pesticide based on insect’s presence. Pesticides application in the rice field is very common practice in Bangladesh (Islam et al., 2016; Sumon et al., 2016; Rahaman et al., 2018). Farmers used comparatively less pesticides in experimental plot area than control plot. All of the control plots required 3 times of pesticide application while experimental plots required only 1 or 2 times of pesticide application. The average frequency of pesticide application in control and experimental plots were 3 and 1.6 respectively. This indicated that almost half of the pesticide usage could be reduced by setting up the solar light trap in rice field.

Harvesting of rice was done during mid-November 2019. Average yield of BRRI dhan32 was estimated as 2.92±0.036 MT and 2.9±0.03 MT per hectare in control and experimental field respectively. It was found that there was no statistical significance ($p$ value=0.501) between the mean yield of rice in control and experimental field (Figure 4).

![Figure 4](image-url)
Though the yield of rice was statistically insignificant, the solar light trap contributed to the reduction of pesticide load in the rice field. The solar light trap served here as an eco-friendly management tool against the harmful insect of the experimental fields. Alam, (2013) used light trap as an insect management technology in rice ecosystem at the area of Chittagong, Rajshahi, Gaibandha, Tangail, and Jalukathi district. When we calculated the cost on the use of pesticides, it was found that solar light trap installed fields required less amount of pesticides (Table 4).

Table 4. Pesticide costing in T. Aman rice (BRRI dhan32) in different locations of Barhattaupazila of Netrokona district in 2019

| Location       | Frequency of pesticide application in control field | Frequency of pesticide application in experimental field | Cost in Control field (BDT ha⁻¹) | Cost in Experimental field (BDT ha⁻¹) | Reduction of Cost (BDT ha⁻¹) | Reduction (%) |
|---------------|-------------------------------------------------|-------------------------------------------------|---------------------------------|---------------------------------|-------------------------------|---------------|
| Ramvodrapur   | 03                                              | 01                                              | 3262                            | 1950                            | 1312                          | 40.2           |
| Sholpadhoshal | 03                                              | 02                                              | 3375                            | 2400                            | 975                           | 28.9           |
| Otipur        | 03                                              | 01                                              | 2775                            | 1875                            | 900                           | 32.4           |
| ChotoKoilati  | 03                                              | 02                                              | 3337                            | 2325                            | 1012                          | 30.3           |
| Raimadov      | 03                                              | 02                                              | 3225                            | 2250                            | 975                           | 30.2           |
| Fokirer Bazar | 03                                              | 02                                              | 3525                            | 2625                            | 900                           | 25.5           |
| Singhdha      | 03                                              | 01                                              | 3262                            | 2100                            | 1162                          | 35.6           |
| Average       | 03                                              | 1.6                                             | 3252                            | 2218                            | 1034                          | 31.8           |

Therefore, it reduced the cost of pesticide per hectare. The maximum reduction percentage of pesticide cost was found in Ramvodrapur which was 40.2% and minimum reduction percentage of pesticide cost was found in Fokirer Bazar which was 25.5%. Finally, it saved around 1034 BDT in an experimental plot area (1 ha) which is equivalent to 31.8% of the cost of pesticides. Siddiquee et al. (2019) reported that the pesticide cost from total cost of production ranges from 12.8-13.6%. Solar light trap reduced the cost of production through the less frequency of application of pesticides against different harmful pest of rice.

CONCLUSION

The solar light trap was found to be effective to capture different insect species in the rice field. This trap was able to reduce the pesticide load to manage harmful insects while sustaining the yield of rice. The reduction of pesticide use resulted in lower
cost of pesticides in rice field. Therefore, the solar light trap can be a sustainable management tool to reduce both the harmful insects and cost of pesticides used in rice fields.

ACKNOWLEDGEMENT

The authors are grateful to the SAAOs and Upazila Agriculture Office, Department of Agriculture Extension, Ministry of Agriculture and farmers of Barhatta Upazila, Netrokona district for their cordial cooperation.

REFERENCES

Abd Rahman, N.A., Dujali, S.N., Rahim, H.A., Yaakop, S., Ng Y.F., Jin, S.T., Bakri, A. and Ahmad, Z.A. (2017). An assessment of the nocturnal insect diversity and abundance between an agricultural and suburban landscape in Peninsular Malaysia. *Serangga*, 22(1): 1-21.

Alam, M.Z. (2013). Survey and assessment of insect management technologies and environmental impact on rice ecosystem of Bangladesh. *International Journal of Applied Research and Studies*, 2(4): 1-6.

Band, S.S., Sanjay, V., Patidar, S. and Matcha, N. (2019). Comparative efficiency of ultra violet black light lamp and mercury vapour lamp as a light source in light trap against major insect pest of Kharif crops. *Journal of Entomology and Zoology Studies*, 7(1): 532-537.

Barhatta Upazila Map (2011). https://bdmaps.blogspot.com/2011/11/barhatta-upazila.html. Accessed on 11th February, 2022.

BBS (2018). Statistical Year Book of Bangladesh, Statistics Division, Ministry of Planning, Dhaka.

BHWDB (2012). Master Plan of Haor Areas, Vol. II. Main Report. Ministry of Water Resources, Government of Bangladesh, Dhaka.

DAE (2018). http://dae.portal.gov.bd/site/page/4ea467f4-d8d1-4396-908e-9c3c661d0de4. Accessed on 6th February, 2022.

FAO (2019). Crops and livestock products, Statistical Division, Food and Agriculture Organization, UN. https://www.fao.org/faostat/en/#data/QCL/visualize. Accessed on 7th April, 2020.

Gavhande, A.M., Kalbande, S.R. and Kambalkar, V.P. (2019). Development of eco-friendly solar photovoltaic insect light trap for pest control. *International Journal of Current Microbiology and Applied Science*, 8(07): 95-101.

Huq, S., Rahman, A.K.M.A., Ali, S.M.I., Moeller, P. and Gnoyke, P. (2012). Community based adaptation to climate change in Bangladesh. *Proceedings of 1st National Conference on Community Based Adaptation to Climate Change in Bangladesh* held at Dhaka, Bangladesh. Pp. 21-22.
Islam, M.S., Alam, M.S., Uddin, M.N., Zabir, A.A., Islam, M.S., Haque, K.A., Islam, M.A. and Hossain, S.A. (2016). Farm level pesticides use in Patuakhali and Comilla region of Bangladesh and associated health risk. *Journal of Health and Environmental Research, 2*(4): 20-26.

Kadel, J., Sah, L.P., Devkota, M., Colavito, L.A., Norton, G., Rajotte, E.G. and Muniappan, R. (2018). Effectiveness of different types of traps for management of *Tuta absoluta* in Nepal. *Journal of the Plant Protection Society, 5*: 166-174.

Kammar, V., Rani, A.T., Kumar, K.P. and Chakravarthy, A.K. (2020). Light trap: a dynamic tool for data analysis, documenting, and monitoring insect populations and diversity. In: Chakravarthy, A.K. (Editor). Innovative Pest Management Approaches for the 21st Century. Springer, Singapore. Pp. 137-163.

Kamruzzaman, M. and Shaw, R. (2018). Flood and sustainable agriculture in the Haor basin of Bangladesh: A review paper. *Universal Journal of Agricultural Research, 6*(1): 40-49.

Khandker, S. and Hossain, M.L. (2017). Use of chemical pesticides in agriculture. http://m.theindependentbd.com/printversion/details/130161. Accessed on 6th February, 2022.

Khatun, S., Mondal, M.M., Khalil, M.I., Roknuzzaman, M. and Mollah, M.M. (2020). Growth and yield performance of six Aman rice varieties of Bangladesh. *Asian Research Journal of Agriculture, 12*(2): 1-7.

Kurta, A. and Kunz, T.H. (1988). Capture methods and holding devices. In: Kunz, T.H. (Editor). Ecological and Behavioral Methods for the Study of Bats. Smithsonian Institution Press, Washington, DC. Pp. 1-30.

Lee, J.S., Lee, J.H., Park, K.S., Yeo, K.H., Kim, J.H. and Kweon, J.K. (2017). Efficiency of yellow and white light traps on controlling tobacco whitefly in tomato greenhouse. *Protected Horticulture and Plant Factory, 26*(4): 432-437.

Mackill, D.J. (2018). Iconic rice varieties. *Rice, 11*(1): 1-2.

Meena, S.K., Sharma, A.K. and Aarwe, R. (2018). Total insect fauna of order lepidoptera collected through light trap installed in paddy field. *Journal of Entomology and Zoology Studies, 6*(3): 1362-1367.

Meshram, S.A., Kapade, S.A., Chaudhari, A.D. and Nagane, K.B. (2018). Design a solar light trap for control of field crop insects. *International Research Journal of Engineering and Technology, 5*.

Moses, S., Kishor, D.R., Misra, A.K. and Ahmad, M.A. (2019). Identification and quantification of major insect pests of rice and their natural enemies. *Current Journal of Applied Science and Technology, 32*(2): 1-10.

Park, J.H. and Lee, H.S. (2017). Phototactic behavioral response of agricultural insects and stored-product insects to light-emitting diodes (LEDs). *Applied Biological Chemistry, 60*(2): 137-144.

Parveen, S. and Nakagoshi, N. (2001). An analysis of pesticide uses for rice pest management in Bangladesh. *Journal of International Development and Cooperation, 8*(1): 107-126.
Pathak, M.D. (1970). Insect Pests of Rice and Their Control. Rice Production Manual. Los Baños: University of the Philippines, College of Agriculture in cooperation with the International Rice Research Institute. Pp.171-198.

Pathak, M.D. and Khan, Z.R. (1994). Insect Pests of Rice. International Rice Research Institute, Los Banos, Manila, Pp.21-22.

Patidar, S., Vaishampayan, S., Band, S.S. and Sahu, B. (2019). To study the seasonal activities of major insect pest species of paddy collected in light traps. *Journal of Pharmacognosy and Phytochemistry*, 8(3): 4278-4282.

Rahaman, M.M., Islam, K.S. and Jahan, M. (2018). Rice farmers' knowledge of the risks of pesticide use in Bangladesh. *Journal of Health and Pollution*, 8(20).

Rahman, M.S., Islam, S.M., Haque, A. and Shahjahan, M. (2020). Toxicity of the organophosphate insecticide sumithion to embryo and larvae of zebrafish. *Toxicology reports*, 7: 317-323.

Salam, M.A., Shahjahan, M., Sharmin, S., Haque, F. and Rahman, M.K. (2015). Effects of sub-lethal doses of an organophosphorus insecticide sumithion on some hematological parameters in common carp, *Cyprinus carpio*. *Pakistan Journal of Zoology*, 47(5): 1487-1491.

Siddiquee, A.H., Sammy, H.M. and Hasan, M.R. (2019). Assessing profitability, marketing activities and problems in modern rice production in two northern Districts of Bangladesh. *The Agriculturists*, 17(1-2): 31-40.

Singh, S., Sharma, A.K., Saxena, A.K., Panday, A.K. and Kakade, S.H. (2018). Taxonomic analysis of phototactic beneficial insects as biocontrol agents (Predators and parasites) collected in light trap in rice ecosystem at Jabalpur. *Journal of Entomology and Zoology Studies*, 6(3): 850-853.

Sivagnanam, K.J. and Murugan, K. (2020). Impact of hybrid rice cultivation on farmers’ livelihood in Tamil Nadu. *Journal of Land and Rural Studies*, 8(1): 22-36.

Sridhar, V. and Kumaran, G.S. (2018). Light trap, an effective component of integrated management of *Tuta absoluta* (Lepidoptera: Gelechiidae) on Tomato. *Journal of Horticultural Sciences*, 13(1):126-128.

Sudhikumar, A.V., Jocque, R. and Sebastian, P.A. (2009). A new species of the ant spider genus *Suffasia* (Araneae: Zodariidae) from the Western Ghats, India, with a key to the species of the genus. *Zootaxa*, 2203(1): 59-64.

Sumon, K.A., Rico, A., Ter Horst, M.M., Van den Brink, P.J., Haque, M.M. and Rashid, H. (2016). Risk assessment of pesticides used in rice-prawn concurrent systems in Bangladesh. *Science of the Total Environment*, 568: 498-506.

Sun, C., Zeng, L., Xu, J., Zhong, L., Han, X., Chen, L., Zhang, Y. and Hu, D. (2018). Residual level of dimethachlon in rice-paddy field system and cooked rice determined by gas chromatography with electron capture detector. *Biomedical Chromatography*, 32(7).

Sunitha, N.D. (2018). Ecofriendly management of thrips in capsicum under protected condition. *Journal of Entomology and Zoology Studies*, 6(1): 617-621.
Yaqub, G., Iqbal, K., Sadiq, Z. and Hamid, A. (2017). Rapid determination of residual pesticides and polyaromatic hydrocarbons in different environmental samples by HPLC. *Pakistan Journal of Agricultural Sciences,* 54(2).

Yee, W.L. (2017). Attraction of *Rhagoletis indifferens* (Diptera: Tephritidae) to white light in the presence and absence of ammonia. *Florida Entomologist,* 21-28.