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PHEROMONE USE FOR INSECT CONTROL: PRESENT STATUS AND PROSPECT IN BANGLADESH

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Abstract

The insect's world is filled with many odors. Insects use these odors to cue them in a variety of complex social behaviors, including courtship, mating, and egg laying. Scientists and pest control specialists have known about these complex communication systems for decades. The main aim of this study was to visualize the availability, trends and differences in the sources of pheromone control in agricultural growth of Bangladesh. It also concerned on constrains and present use of pheromone and their possible recommendation on behalf of Bangladesh agriculture. It concentrated on the data during last three decades (1980-2010), comprising status of pheromone use in Bangladesh agriculture and its future. Review revealed that Bangladesh has been enormously successful in increasing pheromone use in agricultural production (especially for vegetables). Understanding of the nature of pheromones and their potential for pest control along with the future prospective of pheromone technique in agriculture were stated. Since the pheromone, technologies for control of major crop pests in Bangladesh are still limited. So that this review emphasized on more attention to the authority to increase the research works and project facilities related to develop and promote pheromone techniques. It is highly recommended to increase availability of pheromone in market, more investment in research and development, introduction of newly identified pheromone for specific pest, to assist government and non-government organizations to work with farmers to reduce harmful insecticide use and promote pheromone tactics as one part of integrated crop management (ICM).

Keywords: Sex pheromone, Integrated Crop Management, Monitoring, Trapping, Mating disruption

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Introduction

Bangladesh, one of the smallest countries (area 57 K sq. miles) in South-East Asia, has a predominantly farming-based economy. A delta, historically originated through the sedimentation of the Bay of Bengal, the country is blessed with highly fertile agricultural lands. However, due to very high population, the nation has always been struggling against poverty and starvation. Bangladesh economy draws its main strength from agriculture sector. The sector contributes 19.10% (at current prices) and employs about 51% of the labor force (Mondal, 2010). Despite increase in the shares of fisheries, livestock, and forestry, crop sub-sector alone accounts for 60.83% share of agricultural GDP (BBS, 2011). Agricultural land per capita is decreasing over the years in Bangladesh. Agriculture and environment are closely interlinked. Agricultural production system depends on the environment for utilization of land, rainfall, daylight duration, insect pests and diseases. Pest problem is one of the major constraints for achieving higher production in agriculture crops. Bangladesh loses about 30% of its crops due to pests and diseases each year (BBS, 2011). So how do farmers control their insect pest problems? Farmers in Bangladesh depend on synthetic insecticides because they are readily available, highly promoted, inexpensive, easy to apply and quick acting. However, applied insecticides also kill non-target arthropods, typically insects involved in pollination and predators such as spiders and ground beetles. Insecticide residues find their way into watercourses, particularly in rice cultivation, and affect the water we drink and food we eat (Cork *et al.* 2003, 2005). Furthermore, quite often the indiscriminate and unscientific use of pesticides has led to many problems, such as pests developing resistance, resurgence of once minor pest into a major problem besides environmental and food safety hazards.

There are many alternative approaches to control insect pests. Cultural practices, including crop sanitation, use of resistant varieties and methods to promote the activities of natural enemies and predators all act to reduce the threat from potential insect pests. Thus keeping insect pests below damage thresholds, does not aim reduce populations to a level where genetic change is induced, leading to the development of resistant biotypes. Such biorational pesticides include insecticides such as neem kernel seed extract, different extracts of plant parts, fungi (*Beaveria, Metarhizium*), viruses (nuclear polyhedrosis virus), bacteria (*Bacillus thuringiensis*) and semiochemicals (Akhtar and Mandal, 2008; Islam *et al.*, 2008a; Mamun *et al.,* 2008; Islam, 2009; Islam and Becerra, 2011; Islam and Begum, 2011). Country needs to adopt the total integrated pest management system as the insecticide-based management system has failed to control many pests. The pests are becoming resistant to almost all chemical pesticides as the frequency of spraying is gradually increasing while their efficacy is gradually decreasing. Biological control involves use of a specially chosen organism to control a specific pest. This chosen organism might be a predator or a parasitoid, which attacks harmful insects. Field demonstration results prove that the use of biological agents has no adverse effect on human health and the cost effectiveness of bio-control measures is very attractive, safe and sustainable. Insects communicate by means of scents–pheromones, chemicals used for 'signaling'. With these, they both locate and identify their mates. They are natural chemicals emitted in micro quantities in the form of a vapor by virtually all known insects. Each insect species has its own unique signature scent. In fact, sex provides us with a powerful means of surveillance and control in the insect world. A female insect typically puffs out a thousand millionth of a gram of her signature several times a minute. Males of her species follow this scent to mate with the female. It follows that if you can identify and then duplicate that scent, you have the means of controlling the males of that species. This is the mysterious incidence of pheromone technology.

The existence of pheromones has been known for centuries, apparently originating in observations of mass bee stinging in response to a chemical released by the sting of a single bee. The first isolation and identification of an insect pheromone (silkworm moth) occurred in 1959 by German scientists. Since then, hundreds, perhaps thousands of insect pheromones have been identified by increasingly sophisticated equipment. Today we have a much clearer view of the limitations and possibilities associated with insect pheromones in IPM programs. The two primary uses of insect pheromones are for detection and monitoring of populations and for mating disruption. These uses take advantage of sex pheromones on which a vast majority of insect pests relies to mediate reproduction.

To date, the research works on pheromone in pest management in Bangladesh still limited. There are few scientists involved in trapping of moths using pheromone (Alam *et al.*, 2003; Cork *et al.*, 2001, 2003, 2004a, 2004b, 2005; Uddin, 2008; Mazumder and Khalequzzaman, 2010) in Bangladesh but no one works on the identification of pheromone from Bangladeshi insect species. The survey report on pheromone practice in Bangladesh agriculture is also limited (Islam, 2012). Major objective of this review article is to discuss the pheromone technology in pest management, present status of pheromone use in Bangladesh agriculture and suggest possible opportunities to address the topic that may assist the government and non-government policy makers to develop national economy.

Uses of Pheromones in Pest Management

The use of pheromone for controlling pest insects requires three items: a pheromone chemical, a trap, and a support to hang the trap in the field. Technically sex pheromones can be used in three principal ways:

Detection and Monitoring: The principle use of insect pheromones is to attract insects to traps for detection and determination of temporal distribution. In most instances, the males are responders to female-produced pheromones. Trap baits, therefore, are designed to closely reproduce the ratio of chemical components and emission rate of calling females. Trap baits of many designs have been tested over the years. Trap design is also critical to effective use of traps for monitoring insect populations. Traps vary in design and size dependent on the behavior of the target insects. The information from trap catches can be very useful for decision making on insecticide applications or other control measures. For example, trap catches may indicate a loss of effect of pheromone on mating disruption and the need to reapply a pheromone treatment. Careful monitoring and experience in interpreting collected data are important for success. Traps may also be placed with the objective of destroying males for population control.

Examples of the use of pheromones in pest management programmes for detection, monitoring and timing of pesticide spray programmes are sesiid moth, *Macroscelesia japona* , in orchards of Ibaraki prefecture, Japan (Islam *et al.,* 2007), codling moth, *Cydia pomonella,* in apple and pear orchards in

Australia (Williams, 1989), citrus leaf miner (*Phyllocnistic citrella*) in orchards in Ogasawara (Bonin) Islands and Ehime Prefecture, Japan (Vang *et al.*, 2008), *Heliothis spp.* in USA (Lopez *et al.,* 1990), nettle moth, *Parasa lepida lepida* (Limacodidae) in orchards in Gifu prefecture in Japan (Islam *et al.*, 2009), apple leaf roller, *Bonagota cranaodes* in Brazil (Kovaleski *et al.*, 1998), *Spodoptera litura* in India (Ranga Rao *et al.,* 1991), *Leucinodes orbonalis* in Bangladesh (Alam *et al.*, 2003, Uddin *et al.*, 2008, Mazumder and Khalequzzaman, 2010).

Mass trapping: Sex pheromone baited traps can capture male moths continuously, thus preventing mating and multiplication of the pest. This approach has proven to be particularly efficient and economical. *Rhynchophorus palmarum* is the primary pest of oil, coconut and palm in Central and South America. By 1994 the number of trees needing to be felled was reduced to less than 3,000 per annual demonstrating that mass trapping can be highly effective in controlling palm weevil populations (Alpizar *et al.*, 2002, Hallett *et al.*, 1999, Oehlschlager *et al.*, 2002). Highest mass trapping of males of *Macroscelesia japona* reported by lure baited with *E*2,*Z*13-18: Ald and *E*2,*Z*13-18:OH (Islam *et al.,* 2007). Examples of mass trapping are lures baited by *Z*7,9-10:OH were examined on nettle moth*, P. lepida lepida* (Islam *et al.*, 2009), cotton weevil (*Anthonomus grandis*) successfully baited with its aggregation pheromone (Cork *et al.,* 2003), Japanese strain of *Phyllocnistic citrella* trapped only the lure containing *Z*7,*Z*11-16:Ald (Vang *et al.,* 2008).

Brinjal (*Solanum melongena* L.) is an economically important crop throughout South and South East Asia. Fruit losses in excess of 50% are commonly reported due to the boring activity of larvae of the brinjal shoot and fruit borer, *Leucinodes orbonalis* (Cork *et al.*, 2005). Zhu *et al.* (1987) reported (*E*)-11-hexadecenyl acetate as the pheromone of *L. orbonalis* and traps baited with up to 500 µg attracted more male moths than six virgin females. Subsequently Attygalle *et al.* (1988) identified (*E*)-11-hexadecen-1-ol in addition to the related acetate using insects obtained from Sri Lanka. In field trails conducted in India where blends containing between 1 and 10% *E*11-16: OH caught even more male *L. orbonalis* than *E*11-16: Ac alone. At the 1000 µg dose, addition of 1% *E*11-16: OH to *E*11-16: Ac was found to be significantly more attractive to male *L. orbonalis* than either 0.1 or 10% *E*11-16:OH. Trap catch was found to be positively correlated with pheromone release rate, with the highest dose tested, 3000 µg, catching significantly more male moths than lower doses (Cork *et al.*, 2001). In order to reduce the cost of pheromone based technologies for control of *S. incertulas*, a programme of research to develop an effective mass trapping system. This proved to be highly effective using indigenous traps and lures at a density of 20 traps ha^{-1} (Cork and Krishnaiah, 2000).

Mating disruption: Sex pheromone can be used for disruption of mating, which is achieved by placing high concentrations of pheromone at regular intervals throughout the field. The high concentration of pheromone saturates the area resulting in males failing to find females, which produce very minute quantities of these chemicals, thus preventing mating and multiplication of the pest. The major pest of cotton in Egypt in the early 1980's was the pink bollworm (PBW), *Pectinophora gossypiella*. The female sex pheromone was identified by workers in the USA (Bierl *et al.*, 1974). The diversity of mating communication system in lepidopteran insects was also reported (Islam *et al.,* 2008b). The economic importance of *P. gossypiella* and the fact that its pheromone is relatively cheap and chemically stable, the decision was made to try to control it using mating disruption. It has also been identified as a pest control method in which the insect does not become resistant.

Pheromone traps

Various types of traps are available commercially, while others can be made by farmers inexpensively at home. A pheromone-baited lure inside the trap will bring male moths inside the trap. Proper trap design is critical to kill the pest once it enters the trap. The type of trap to be used depends on the behaviour of the target insect. Various research works showed the most effective traps in pest control are delta traps, winged traps and funnel traps. Different available and relatively low cost traps are shown in Fig. 1**.** Pheromone traps are very sensitive, meaning they attract insects present at very low densities. They are often used to detect presence of exotic pests, or for sampling, monitoring, or to determine the first appearance of a pest in an area.

Present Status on Pheromone use in Bangladesh

There is significant evidence that insecticide use in Bangladesh is increasing dramatically (Fig. 2). The country imports pesticides worth 24000 crore taka every year a huge business. Farmers are applying pesticides where they are not actually necessary, at high cost to themselves and the environment. These pesticides are becoming redundant because of the development of resistance to them and more importantly affect environmental pollution. Governments are becoming aware of the negative environmental and health aspects associated with the use of these compounds, so now there is an urgent need for the development of alternative control technologies.

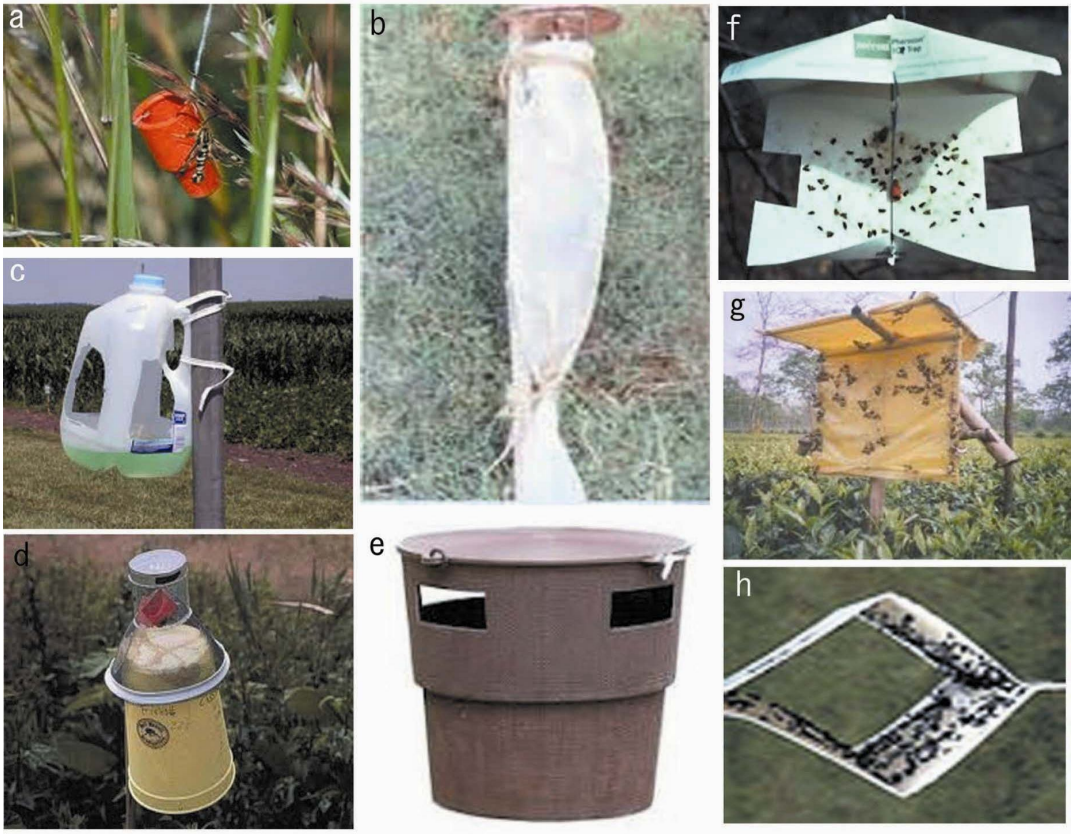

Fig. 1. Different types of pheromone traps used in field; traps used in crop field (a-e), traps with trapped pest insects (f-h). **a.** one lure septum hanged with crop plant, **b.** net trap, **c.** water trap, **d.** bucket trap, **e.** bucket with window trap, **f.** delta trap, **g.** Yellow sticky trap, **h.** wing trap

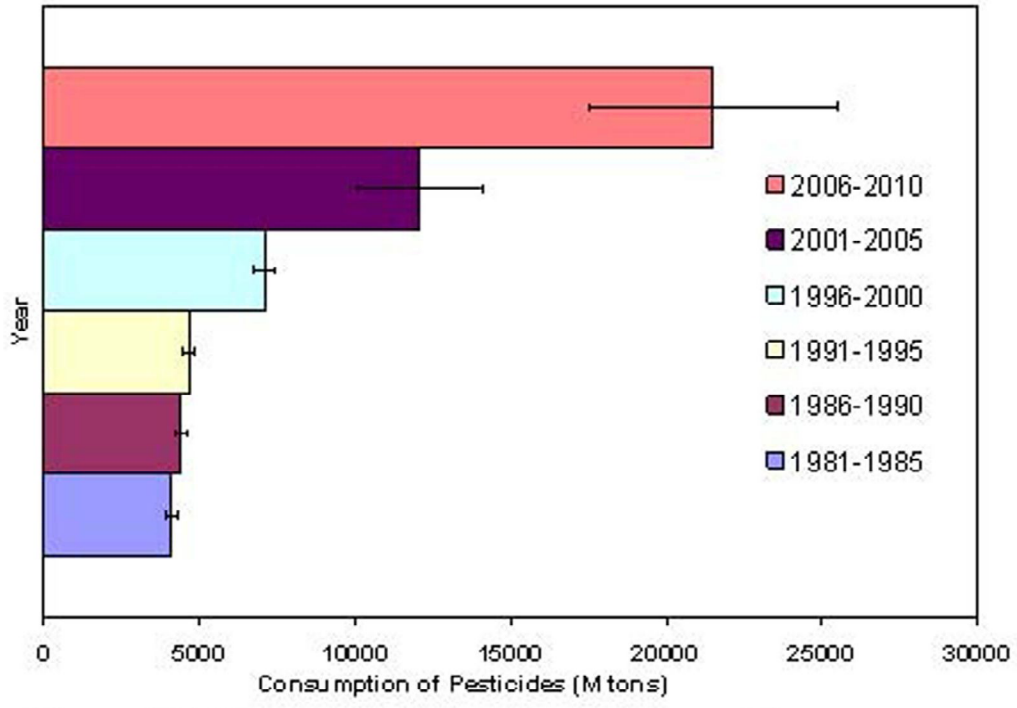

Fig. 2. Pesticide consumption in Bangladesh over 30 years (Source, BBS 2011).

In Bangladesh, about more than 100 major crops are cultivated over a year. There are more than 1000 harmful insects' causes of economic loss on the major cultivated crop. However, the availability of pheromone components of very few insects is reported and available in market. Presently, most of the pheromone components either imported from abroad or synthesized in Bangladesh. However, those chemicals are not confirmed by proper research work for the insects available in Bangladesh. The regional variation in chemical communication reported among the same insect species occurred due to their races differences (Vang *et al.*, 2008). So it should be noted that identified pheromone of an insect from another country may not match with the Bangladeshi strain. This review also emphasized one note that there are extreme limited reports available about the identification of insects' pheromone in Bangladesh.

Bangladesh Agriculture Research Institute (BARI) and Department of Agriculture Extension (DAE) provided synthetic sex pheromones and beneficial insects to a number of farmers in vegetable growing districts like Jessore, Narsingdi, Comilla, Bogra, Pabna and other 244 Upazilas experiment and find out if these inputs could replace harmful pesticides to reduce damage to public health as well as harmful pests can be controlled by using sex pheromone traps, locally known as magic trap. The magic traps are popular among farmers of limited area in Bangladesh that demand for those has increased very quickly. However, ironically the supply is so little that, farmers face problems in expanding this new device for controlling pests in a natural, environment-friendly, safe and secured way to boost crop production. The knowledge and availabilities of pheromone in Bangladesh related similar information reported by Islam (2012).

Limited organizations got permission to import pheromones from abroad. Those organizations got special permission to import several sex pheromones item from plant protection wing of DAE, MOA, GOB. There is a remarkable gap between different research institute and such company or organization engaged in commercialization of pheromones. Limited reports available about the economical benefit achieved after using pheromone technologies in Bangladesh. For example, few farmers in Sikandarpur village in Jessore are being doubly benefited. They are earning more money by producing vegetables at lesser costs while protecting the environment also. They use pheromone trap to kill insects instead of applying insecticides. Alam *et al.* (2003) reported on sex pheromone trap technology for the control of shoot and fruit borer in brinjal and cucurbits in that region of Bangladesh. As above, adult female yellow stem borers (*Scirpophaga incertulas*) attract their mates with a pheromone and this can be exploited in a pest management strategy by developing a synthetic pheromone blend and a lure and trapping system, which attract and trap male moths in Bangladesh. Uddin *et al.* (2008) also reported on such male moth trap, where emphasize on trap types and height to find effective trapping.

Building on work conducted by scientists in India, Syngenta has been collaborating with BRRI and NRI to adapt mass trapping technology for use in Bangladesh (Cork *et al.*, 2004a). According to scientists from three organizations (Natural Resources Institute, NRI; Bangladesh Rice Research Institute, BRRI and the multinational agrochemical company Syngenta) worked in collaboration to find sustainable control method, sleeve traps with a pheromone lure are both effective and cost-efficient in controlling the insect which is responsible for 70-80% of pest damage to rice crops (Anonymous, 2003). Mazumder and Khalequzzaman (2010) reported that the sex pheromones which have been extensively studied and already are in management programmes to improve their efficacy in totality in an Integrated Pest Management Programme on the basis of feedback from the extension workers, and farmers. They studied mainly on the efficiency of male moth catch of eggplant shoot and fruit borer, *Leucinodes orbonalis*.

The previous research reports supported that a wide range of trap designs, pheromone blends and concentrations were tested with farmers in their fields in Comilla and Mymensingh districts in 2001-03, along side a socio-economic study of farmer's resources, constraints and perceptions to ensure the resulting technology was appropriate for adoption (Cork *et al.*, 2004b). On farm, large-scale mass trapping trials demonstrated that 20 traps ha^{-1} were sufficient to reduce male yellow stem borer populations significantly. The trials provided good evidence that mass trapping could significantly reduce the level of mating, with consequent reductions in larval progeny (Cork *et al.*, 2004b).

It is also good news for us that the pheromone of fruit and shoot borer moth is now synthesized and produced in the factory. It is available in the market and to use the sex pheromone in the field, one needs two items: the chemical (or the pheromone) lure and a suitable trap, which are available in Bangladesh with much cost effective price. Thus pheromonal control as an IPM strategy may control eggplant shoot and fruit borer with minimal use of pesticides (Prosad *et al.*, 2005; Uddin et al., 2008; Mazumder and Khalequzzaman, 2010).

Disseminating the idea to farmers is already done in many areas of the country though it is limited. Some of the participating farmers are working in their fields to demonstrate how pheromone/lures worked in their field. It is also important that neighbouring farmers will get preparation to work together in the technology worked. Although most of the farmers in Bangladesh are illiterate but they can still learn the benefits of using the lures around the traps through demonstrations. They already known about the natural enemy of harmful insects are saved, that the danger of insecticide use is avoided, their environment is safe and that they can have a good crop. Recently, Islam (2012) reported on the knowledge and practices on pheromone used by Bangladeshi farmers, where found the present knowledge on pheromone technology and some important suggestions. Farmers now understood the money that they save in reducing their use of pesticides can be spend instead on herbicides which are less toxic and give a more effective return.

Besides, the above discussion on present status of pheromone technology in Bangladesh agriculture few broad problems are pointed out, such as:

1. Insufficient investment in pheromone research in Bangladesh,
2. Use of IPM technology is limited to rice and few vegetables.
3. Lack of proper knowledge on identification and synthesis of pheromones.
4. Lack of scopes for promotion and training of potential scientists on pheromone research.
5. Limited commercial manufacture of pheromone technology for control of insects of rice and brinjal developed.
6. Training programmes for pesticide dealers, farmers on pheromone and ICM technologies are still limited.
7. Insufficiency of materials required for pheromone technology.

Recommendations

In view of the several disadvantages /limitations associated with the unscientific use of pesticides in agriculture, there is an urgent need for minimizing the use of chemical pesticides in the management of insect pests. Growing public concern ever potential health hazards of synthetic pesticides and steep increase in cost of cultivation/low profit making by farmers has led to the exploration of eco-friendly pest management tactics such as Integrated Crop Management (ICM). Admitting the scarcity of sex pheromones and beneficial insects, researchers commented by using huge dozes of pesticides destroyed our biodiversity. The government is yet to consent to bulk import and mass use of insect pheromones. We expect the government and the private sector entrepreneurs to set up more laboratories to identify and synthesize pheromone components of the harmful insects for developing a sustainable pest management system.

To overcome the limitations related to pheromone technology for crop protection; the government, NGOs and personnel engaged in agro-research/works should be concern about the following suggested recommendations:

1. Establishment of a new institution/ foundation is recommended to meet the need for pheromone techniques and adaptation in Bangladesh agriculture.
2. Investment should be raised in pheromone research works collaborated with different agro-based research institutes and agricultural universities.
3. The fund should be raised to help generate pheromone-based technologies with climate change hazards and disseminate such technologies at farmers' level.
4. Government might encourage establishment of farmer's cooperatives to ensure the availability of the pheromones on time.
5. Researcher should be conduct to test the adoptability of identified pheromone for pest insects available in Bangladesh.
6. Researcher should be take similar attention on harmful pests of other major crops like rice and vegetables.
7. More specific pheromone component(s) for the harmful insect(s) should be developed to control the pest(s).
8. Contribution of private sector and NGOs has to be encouraged to quality pheromone production.
9. It is also necessary to expand IPM practice to other economic crops (e.g. Fruits, Pulses etc.).
10. Attempts on pheromone technologies should now be made to transfer at the field level.
11. Farmers should as well be motivated to reduce their dependence on the use of chemical pesticides to control harmful pest insects.
12. Conduction of appropriate training programs on pheromone technologies with farmers, field level agricultural officers, researchers/scientists are necessary.

It is essential to review the present activities on pheromone tactics to pest control with the relevant experts, professionals, and farmer's representatives and update it based on their comments and suggestions. Author would like to illustrate the high attention on status of pheromone use in Bangladesh agriculture and future activities is addressed by the government to ensure sustainable agriculture and food

security. This issue needs to be spelled out in the present National Agricultural Policy (NAP).

Conclusion

Bangladesh has been enormously successful in increasing its agricultural production in an effort to attain self-sufficiency. This has been largely achieved through new technologies in agriculture. The farmers were immensely benefited by using a combination of pheromones and beneficial insects when they could no longer control harmful pests even after spraying insecticides. Damage to production was 40 to 50 per cent even after spraying cocktail insecticides but after using pheromones and beneficial insects, the rate of damage diminished to 10 per cent. The identification and uses of insect pheromones is an active area of research and new developments continue to be made. Potentially, pheromones may be used to trap out certain Bangladeshi harmful insects and to attract insects to insecticide or chemosterilant baits, reduce the number of insecticide applications, or to confuse insects and disrupt mating. Use of traps as a sampling tool to determine need for and timing of control measures can provide the basis of an ICM/IPM strategy for these pests.

Pheromone programs have been used for several decades around the globe and to date (2012) there is no documented public health evidence to suggest that agricultural use of synthetic pheromones is harmful to humans or to any other non-target species. However, continuing research is being conducted. In order to reduce the pesticidal load in the environment and with sustainability, certain behavioral chemicals could be harnessed. Such an endeavor is the use of sex pheromones. This dynamic and paradigm shift in management strategies satisfies all the bio-safety concern as well as playing a pivotal role in combating insect pests of high-value and damage sensitive crops. The research from socio-economists will help to guide the strategy for promotion of the pheromone technology in Bangladesh successfully. This review facilitates technical ways for identification/confirmation, understanding of the nature of pheromones, their potential for pest control and overview in respect of Bangladesh.

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