EXTENT AND POTENTIAL USE OF BIO-PESTICIDES FOR CROP PROTECTION IN SAARC COUNTRIES

SAARC

SAARC Agriculture Centre (SAC)

Trigonella graecum *Sitophilus granarius* *Rhyzopertha dominica* *1901* *Pogostemon heyneanus,*
Mentha arvensis or *Artemisia vulgaris* (aqueous extract) *Azadirachtin* decoction *Peganum harmala* *Skimia laureola,*
SNPV- (Single-embedded Nuclear polyhedrosis virus) *Justicia adhatoda* *Ocimum basilicum* Nimboli *Trichoderma*
Chrysanthemum flower paste **BIOPESTICIDES** *Spedoptera litura* pheromone
Vitex negundo Spinosad Tobacco aqueous decoction *Acorus calamus* *Mentha arvensis* (aqueous extract)
Abamectin Pheromone bait trap *Sausarea lappa,* Nimbokil *Lantana camera,*
Eucalyptus Bt Methyl Euginol (pheromone) for oriental fruit fly (1 product) Neem fruits (Aqueous solution)
Lime *Xanthoxyllum alatum* Roxb.
HNPV-(Helicoverpa nuclear polyhedrosis virus for *Helicoverpa armigera*)
Cuelure (pheromone) for cucurbit fruit fly (3 products) Brinjal shoot & fruit borer pheromone *Carum copticum L.*
Elderberry decoction **Adhatoda vasica** *Tribolium castaneum,*

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Editors

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Foreword

The demand for increased crop yield and production is often attained by use of higher yielding crop varieties and increased use of chemical fertilizer and pesticides. Although the toxic effects of chemicals used in agriculture are known facts, there are always instances of chemical abuse leading to health and environmental hazards. The poisoning of food and ground water is prevalent in most countries now. Despite the drive for organic farming, the use of chemical pesticides is still on the rise.

The enormous wealth of botanicals with pesticidal properties in the SAARC region and the century old traditions of use of aromatic and medical plants as medicines and insect repellents, we have plethora of knowledge and resources to learn and adapt. The advances made in bio-pesticides in the region particularly India, Pakistan and Bangladesh there lies enormous technical knowhow that can be consolidated for sharing and promoting to farming population in the region. This will also help in popularizing the bio-pesticide products commercially produced in the region.

This compilation emanating from expert inputs from the national scientists, who has devoted on entomology/pathology and bio-pesticide research, provides a regional perspective on the use and extent of bio-pesticide and suggests way forward to share best practices among the SAARC Member countries to enhance agricultural production and food security.

I personally hope that this compilation and recommendations from the consultation meeting will be useful to apply and adapt best practices for reclamation of saline soils and enhance the agricultural productivity.

I would appreciate receiving feedbacks, comments and suggestions from readers which would help us to improve our program.

Dr. Abul Kalam Azad
Director, SAARC Agriculture Centre

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Executive Summary

The agriculture land in SAARC region extends to more than 345 million hectares which is spread across diverse agro-ecological zones. The diversity of crops grown in the region and pest and disease prevalent in the region poses enormous challenges to the farmer to save their crops from the pest and diseases. The challenge to produce more food to fulfill the need of rapidly growing population has forced growers to use pesticides to protect crops and secure higher production. The indiscriminate use of pesticides has raised the concern and lead to enactment of global declaration "International Code of Conduct on the Distribution and Use of Pesticides - Guidance on Pest and Pesticide Management Policy Development" in 2010. The inappropriate use of pesticides in public health, industries, and household sanitation can pose risk to public health and environment.

As an alternative, use of bio-pesticides (botanical and microbial) are widely promoted as safe and environmentally friendly means to counter the pest and diseases at the same time contain the harmful effects of the chemical pesticides. Many of these bio-pesticides are within the range of farmers' reach in terms of cost and many of these formulations can be prepared by farmers too.

The use of nicotine extract to control plum beetles as early as 17th century may have been triggered by the need to protect crop due to damage by insect pest. The earliest recorded work of Agostine Bassi during 1835 who demonstrated that *Beauveria bassiana* (white-muscadine fungus) could be used to cause an infectious disease in silkworm. The breakthrough research in identifying bacteria *Bacillus thuringiensis* (Bt) as the cause of disease in silkworm by Japanese biologist Shigetane Ishiwata in 1901 gave way to several other researches on microbial solution to pest control. In 1911, Bt was classified and remains most widely used bio-pesticides to this day. Bio-pesticides are used to control pests, pathogens, and weeds by a variety of means.

The prospect for use of bio-pesticides in SAARC region is enormous. At the same time the technological innovation in developing bio-pesticides also exist in the region. Aligning to the food safety needs, application of environmentally safe bio-pesticide vis-à-vis the integrated pest management approach is fast becoming a popular approach in agriculture. With the range of bio-pesticides available in the market with varying efficacies it is important to have adequate knowledge about the bio-pesticides before applying it. As bio-pesticides are narrowly selective and pose few problems to non-target organisms including natural enemies. However, specific mode of action, slow acting, safer than chemicals, limited field persistence, high unit cost can make it more expensive. Considering that most countries are promoting organic products and food safety measures, the common knowledge of bio-pesticides used in the region and their efficacy can enhance the potential use of bio-pesticides.

SAARC Region poses wealth of botanicals which can be effectively used in different formulations of bio-pesticides. According to Talukder (2006) there are 43 plant species as insect repellents, 21 plants as insect feeding deterrents, 47 plants as insect toxicants, 37 plants as grain protectants, 27 plants as insect reproduction inhibitors, and 7 plants as insect growth and development inhibitors. In view of the wealth on resources and knowledge in the region, SAARC Agriculture centre organized a program to (i) prepare an inventory of bio-pesticides and its extent of use in agriculture, (ii) document best practices in use of bio-pesticides, (iii) prepare directory of bio-pesticides producers in the region, and (iv) prepare a synopsis of bio-pesticide in crop protection in SAARC Region and the way forward. Six countries (Afghanistan, Bangladesh, Bhutan, Nepal, Pakistan, and Sri Lanka) participate in the program by contributing comprehensive country status report and partake in the regional consultation meeting.

All countries have enacted Pesticide Acts and Ordinance to regulate import and use of chemical pesticide in agriculture and other uses. The concern of environmental hazards by abuse of chemical pesticides and other chemicals are well covered under the purview of the environmental policies of each country.

Country	**Act and Policy**
Afghanistan	No policy
	The Pesticide Ordinance, 1971
	Pesticide Rules, 1985
Bangladesh	The Pesticide Ordinance, Amended 2007
	The Pesticide Act of Bhutan, 2000
Bhutan	Economic Development Policy, 2010
	Pesticide Act 1991; Pesticide Regulation (1994); IPM in 1996
Nepal	Environment Protection Act and Environmental Protection Regulation (1997); April 2003 (Banned import of 12 pesticides), 2 in 1007, and 1 in 2012
Pakistan	West Pakistan Agriculture Pest Ordinance 1959, WP Agriculture Pest Rules, 1960, Environmental Protection Ordinance 1983, Environmental Protection Council Procedure Rules 1993, Environmental Protection Act 1997, National Environmental Policy 2016, Agricultural Pesticide Ordinance 1971
Sri Lanka	Control of Pesticides Act No.33 of 1980 and its amendment No.6 enacted in 1994

In every country there is well established institutional set up to regulate the pesticide use as shown below:

Country	Regulatory agency
Afghanistan	Ministry of Agriculture, Irrigation and livestock
Bangladesh	Plant Protection Wing (PPW) of Department of Agricultural Extension (DAE)
	National Plant Protection Centre (NPPC)- Quality Control of Pesticides
Bhutan	BAFRA - Registration of Pesticide Products and Manufacturers
Nepal	Pesticide Registration and Management Division, Plant Protection Directorate
Pakistan	Department of Plant Protection
Sri Lanka	Registrar of Pesticides, Department of Agriculture

The predominant bio-pesticide products in the region are neem-based formulations and trichoderma. In specific, there are 45 different formulations in Nepal followed by Sri Lanka with 34 products and Pakistan 16. In Bangladesh, Bhutan and Afghanistan there are 13, 10 and 3 bio-pesticides currently in use by farmers respectively. Most of these formulations are produced in respective countries, except in Afghanistan and Bhutan how depend on imported products. There are 19 agencies in Bangladesh, 10 in Nepal, 7 in Sri Lanka and 1 in Pakistan engaged in bio-pesticide production. They also have very strong support from public institutions to produce bio-pesticides.

The country study and the regional consultation identified following issues in promotion and adoption of bio-pesticides:

Policy

- Inadequate policy /varying national policy of member states.
- No clear lead agency
- Registration system is time consuming and tedious for the chemical pesticides
- Inconsistent labeling of harmful inputs

Research

- Several Indigenous knowledge and practices are in the region but due to lack of documentation, decreased availability of botanicals is limiting their adoption.
- Lack of standardized technologies in extraction, formulation and mass production
- Collaborative research

Extension and Development

- Field level efficacy of bio-pesticides/up-scaling
- Lack of education/awareness on the advantages and disadvantages of use of bio-pesticides

- Farm level accessibility of effective bio-pesticides
- Quality control and monitoring
- Networking in the private-public institutes in the SAARC countries
- Capacity development
- Limited production facilities

Some of the actions proposed by the consultation meeting are as follows:

Policy

- Legal framework for commercialization of bio-pesticide needs to be done by respective government
- Promote and support private sector to manufacture/formulate bio-pesticides within the country.
- Facilitate trade among the member countries (conducive trading policies/regulations, tax exemption, tariffs, subsidies, etc)
- Identification/establishment of referral lab in the SAARC region which is accredited to carry out testing and revalidation of bio-pesticides.
- Adopt FAO guided fast track registration system for bio-pesticides.
- Labeling of hazardous materials to be made mandatory in member countries
- Harmonization of bio-pesticide promotion policies of SAARC member states

Research

- Initiate collaborative research on testing and promotion of most promising bio-pesticide
- Testing the bio-efficacy of botanicals and other bio-agents; development methods/mass production of bio-agents and extraction methods for botanicals; cultivation methods to be developed for important botanicals (domestication of wild plants e.g. sweet flag)
- Lead agency and laboratory identified for research and development on bio-pesticides in all the member countries
- Several Indigenous knowledge and practices are in the region but due to lack of documentation, decreased availability of botanicals is limiting their adoption.
- Conservation technologies (in situ and ex situ) to be developed for the effective biological agents and botanicals (e.g. establishment or incorporation within existing botanical gardens or gene bank or herbarium)

- SAC can initiate development of a centre of excellence for product development, toxicity testing of botanical pesticides and taxonomic identification of bio-agents.

Extension and Development

- Organize training on bio-pesticide formulation and product development
- Awareness building- Publicity and advocacy (News and awareness in print and electronic media, radio, poster programmes, curriculum at School and college level)
- Establish networking among the SAARC countries for knowledge and technology sharing
- Documentation, promotion and sharing of traditional knowledge on pest management at local level with proper acknowledgement and keeping in mind the international treaties
- Assist private sector in exclusive bio-pesticide business

CHAPTER 1

Extent and potential use of bio-pesticides for crop protection in Afghanistan

Dr. M.Z. Sharifi[1]

Introduction

Raising crop productivity and production are becoming increasingly important to meet growing food requirements imposed by the incessantly increasing the world population (Yildirm and Guvence, 2005), which is expected to reach 8 billion by 2020, that higher population necessities greater food production (Sharifi *et al*., 2009, Sharifi *et al*., 2011, Sharifi and Matsumura, 2012). Over the next 20 years, crop production will have to increase significantly to meet the needs of a rising human population. This has to be done without damaging the other public goods—environment and society. (Bastiaans *et al*., 2008 and David *et al*., 2010). Afghanistan is an agricultural country and more than 80 % of the population relies on agriculture for their livelihoods. Therefore, agriculture is a major industry in Afghanistan, involving a large portion of the population. Approximately one-third of the population is food insecure and will require agricultural assistance. The total annual cereal requirement for Afghanistan is estimated at 6.5 million tones. There is still a cereal deficit of 753,000 tones, almost all of which is for wheat, which is the staple crop of the Afghan population. The leading cereal production in Afghanistan is shown in (Table 1). After 25 years of war, agricultural production and rural infrastructure were left with devastating damages. Agricultural production has been considered is the key sector for revival of the economy and well-being of the people in the country. But it is not enough level to achieve the food self-sufficiency for the people (Kawasaki *et al*., 2012). The total land area in Afghanistan is 65,223,000 hectares that is divided to temporary land 47%, forest and woodland 18%, irrigated crops areas 23% and cultivated rainfed areas 12% (Figure 1).

Bio-pesticides become an integral part of modern Afghan agriculture and their use is one of the most significant factors contributing to the high levels of agricultural productivity observed in many provinces of the country where most cultivated crops receive at least one, and usually many more, pesticide applications per year. The development and widespread use of pesticides in Afghanistan has largely taken place over the last 20 years with a succession of more sophisticated and effective pesticide products being introduced. However, in Afghanistan there is no pesticide company.

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One way to increase food availability is to improve the management of pests. There are estimated 67000 different crop pest species—including plant pathogens, weeds, invertebrates and some vertebrate species—and together they cause about 40 per cent reduction in the world's crop yield (Oerke *et al*., 1994). Crop losses caused by pests undermine food security alongside other constraints, such as inclement weather, poor soils and farmers' limited access to technical knowledge (Speranza *et al*., 2008).

Bio-pesticides are used to control pests, pathogens, and weeds by a variety of means. Microbial bio-pesticides may include a pathogen or parasite that infects the target. Biochemical bio-pesticides can also act through a variety of mechanisms. Some act by inhibiting the growth, feeding, development or reproduction of a pest or pathogen. Plant extracts were likely the earliest agricultural bio-pesticides, as history records that nicotine was used to control plum beetles as early as the 17th century (Pretty, 2008 and Heinz, 2004).

The most commonly used bio-pesticides are: bio-fungicides (*Trichoderma*), bio-herbicides (*Phytopthora*), and bio-insecticides (*Bacillus thuringiensis*) in the world but in Afghanistan, currently the bio-fungicide of (*Trichoderma*) is used. The interest on bio-pesticides is based on the advantages associated with such products which are: (i) inherently less harmful and less environmental load, (ii) designed to affect only are specific, pest or, in some cases, a few target organism, (iii) often effective in very small quantities and often decompose quickly, thereby resulting in lower exposure and largely avoiding the pollution problem and (iv) when used as a component of Integrated Pest Management (IPM) programs, bio-pesticides can contribute greatly (Gupta, 2010).

The objective of this study is to determine and prepared an inventory of bio-pesticides and their usage in agricultural areas of Afghanistan.

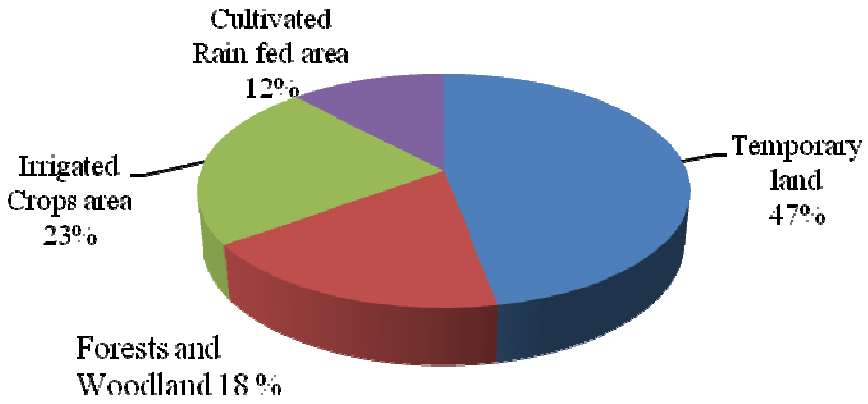

Figure 1. Total land areas of Afghanistan.

Table 1. Leading Cereal Crop Production in Afghanistan (2005-2012) ('000 ton)

Crop	Harvest Years							
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Irrigated Wheat	2,728	2,902	2,818	2,406	3,433	3,082	3,069	3,460
Rainfed Wheat	1,537	1,606	1,606	217	1,682	1,450	321	1,590
All Wheat	4,265	4,508	4,424	2,623	5,115	4,532	3,390	5,050
Milled Rice	325	361	425	410	432	450	450	471
Maize	315	357	366	280	300	301	301	310
Barely	337	364	370	333	486	305	305	505
Total Cereals	977	1,082	1,161	1,023	1,218	1,056	1,056	1,286

Policy and institutions regulating pesticides use

Despite the advantage of some existing policies, the direct controls used today to regulate pesticides leave much to be desired. A major challenge facing our profession is to expose the inefficiency and wastes associated with some existing regulations and propose alternatives. Not all of the alternatives would involve financial incentives and market mechanisms, but these might prove to be less costly and more efficient regulations (David, 1997).

As we have argued, the responses to pesticide regulation depend on technologies available to farmers. Thus, optimal resource allocation and pesticide management policies should change over time as new technologies are introduced. This suggests that, in spite of the desirability of stable and constant regulations, it is optimal to modify regulations as new technologies are developed. Actually, the relationship between regulations and technology is more complex since changes in policy may induce the development of new technologies. Policy should consider not only current technological options but also the capacity to introduce new innovations and the potential of policies to encourage innovations. This suggests that policies based on the concept of adaptive management will become increasingly important (David, 1997).

Current bio-pesticide regulations in Afghanistan are significantly efficient, even acknowledging the difficulties associated with determining pesticide policies. They can be greatly improved by incorporating economic considerations into the policy process. Moving from bans toward financial incentives and flexible policies that will allow chemical use where the benefit cost ratios are high will improve resource allocation.

Inventory of bio-pesticides used in Agriculture sector

Various types of bio-pesticides such as bio-insecticide, bio-fungicide, bio-herbicide, bio-nematicides, etc. are used for different applications like seed treatment on farm application and others in the world. Worldwide there are about 1400 bio-pesticide products being sold. At present, there are 68 bio-pesticide active substances registered in the EU and 202 in the USA (David *et al*., 2010). Growth in bio-pesticides market is rising with increasing organic products consumption which is driven by important factors such as increasing consumer awareness towards organic benefits. Governments in different countries have already started encouraging for the development of bio-pesticides due to their low toxicity, safety, and high efficacy in pest control (Globule Bio-pesticides Market, 2012-2017).

Bio-pesticides fall into three major classes: Microbial bio- pesticides , Plant bio-pesticides and Biochemical bio-pesticides

Microbial bio-pesticides consist of a microorganism (e.g., a bacterium, fungus, virus, or protozoan) as the active ingredient.

- **Bacteria:** Bio-pesticides based on bacteria have been used to control plant diseases, nematodes, insects, and weeds. Bacteria are present in all soils and are the most abundant micro-organisms in soil samples. Many spore forming and non-spore forming bacteria are known to be effective against a wide spectrum of insects and diseases. The most well-known and widely used of all bio-pesticides are insecticides based on *Bacillus thuringiensis*, has been in continuous commercial use for over 50 years, a record not exceeded by any other insecticide active ingredient (Gupta, 2010 and Rosa, 2008).
- **Fungi:** Two of the most common commercial fungal bio-pesticides are *Trichoderma* spp. and *Beauveria bassiana*. Each are frequently used in the nursery, ornamental, vegetable, field crop, and forestry industries to control a variety of pests. *Trichoderma* spp. is some of the most common fungi in nature. Many beneficial *Trichoderma* have the ability to readily colonize plant roots, without harming the plant (Gupta, 2010 and Rosa, 2008).
- **Protozoa:** Protozoa are single-celled eukaryotic organisms that exist in both water and soil. While most protozoa feed on bacteria and decaying organic matter. For example, the protozan *Nosema locustae* is known to be a natural bio-control agent of many grasshopper species. Grasshoppers cause millions of dollars of damage to forage crops each year (Gupta, 2010 and Rosa, 2008).
- **Viruses:** Microbial bio-pesticides known as baculoviruses are a family of naturally-occurring viruses known to infect only insects and some related arthropods. Most are so specific in their action that they infect and kill only one or a few species of *Lepidoptera* larvae (caterpillars), making those good

candidates for management of crop pests with minimal off-target effects (Gupta, 2010 and Rosa, 2008).

- **Yeast:** A variety of yeasts have been investigated for their usefulness in controlling plant diseases.

Plant bio- pesticides are pesticides substances that plants produce from genetic material that has been added to the plant.

Biochemical bio-pesticides are naturally occurring substances that control pests by non-toxic mechanisms. Conventional pesticides, by contrast, are generally synthetic materials that directly kill or inactivate the pest (Gupta, 2010 and Rosa, 2008).

In Afghanistan there are just three bio-pesticides introduced by some company during 2- 3 years because of so many reasons like lack of extension, knowledge of farmer about bio-pesticide usage.

Table 2. Number of bio-pesticides used in Afghanistan.

Bio-pesticide product	Target crop	Target Pest/disease	Application mode	Application rate	Remarks
Trichoderma	Vegetables	Fungal diseases & Soil fertilizer	Ground application equipment	2 table spoon per litter	Used in Takhar and Badakhshan Provinces
Madex plus	Apple	Codling Moth	Ground application equipment	100 ml per ha	Used in 15 provinces
Dipel 150 Dust	Vegetables Cabbage	cabbage loppers, imported cabbage worms and grape leaf folder	Powdering by hand equipment	14 Kg/ha	Kabul province

Table 3. Quantity and Extant use of bio-pesticides in Afghanistan.

Bio- pesticide products	Quantity used	Area coverage (Hectare)
Trichoderma	20 kg	20
Madex plus	20 L	200
Dipel 150 Dust	1 Ton	71.5

Best practices in bio-pesticide application in Afghanistan

Because of insufficient existence of bio-pesticides in Afghanistan, there is no practice widely available in many agricultural areas of the country as well as farmers have not completely knowledge about bio-pesticides and their usage. In my opinion the bio-pesticides practice must be learned for farmer around the country. It is the responsibility of Ministry of Agriculture, Irrigation and livestock of Afghanistan to import the useful bio-pesticides for a short time and for a long time bio-pesticides should produce in Afghanistan and the application method expanded around the country.

Success stories on bio-pesticide use in Afghanistan

As mentioned, above the history of bio-pesticides is not so many in Afghanistan because of the number of bio-pesticides usage are limited. It is mentioned for responsible organizations (Government of Afghanistan and donor countries) to attend the currently agriculture situation of Afghanistan. During 2-3 years just the following bio-pesticides were imported and used in some regions of Afghanistan.

Trichoderma: It is used on vegetables to control fungal diseases in Takhar and Badakhshan provinces in the north part of Afghanistan.

Madex plus: It is used on apple to control Codling Moth in different 15 provinces in the northern parts of Afghanistan.

Dipel 150 Dust: this biological insecticide is used to control cabbage loopers, cabbage worms and grape leaf folder in the farm of faculty of agriculture, Kabul University.

Therefore, stories have not been found so long in the country however, the effects of mentioned bio-pesticides used in Afghanistan are successful in crop protection.

Future prospects

Government is likely to continue imposing strict safety criteria on conventional chemical pesticides, and this will result the import of bio-pesticides from outside the country. Perhaps the biggest advances in bio-pesticide development will come through exploiting knowledge of the genomes of pests and their natural enemies. This information will give us new insights into the ecological interactions of pests and bio-pesticides and lead to new possibilities for improving bio-pesticide efficacy. Situation of Afghanistan is very suitable for product the bio-pesticides because of it’s an agricultural country. On the other hand, organic resources are available in many provinces of Afghanistan.

Conclusions and recommendations

Considering the importance of bio-pesticide in agriculture, it has been the subject of much research, largely directed towards the discovery of method for their development. Worldwide efforts have been taken to address two main important problems: the high cost of pesticides and to prevent environmental pollution (Sharifi, 2013).

According to the situation of Afghanistan, it indicates that there is huge scope for growth of the bio-pesticide sector in Afghanistan. At the same time increasing population can be fed by organic farming. In the last decade the usage of bio-pesticides has increased in all over the world therefore, our recommendations are as follow.

- Worldwide efforts must be taken to produce the most efficient bio-pesticides and introduced to developing countries with subsidies.
- The education and extension of bio-pesticides needs to be expanded in many developed and under developed countries.
- According to Afghanistan, it is recommended to the Ministry of Agriculture, Irrigation and livestock to provide opportunities to import useful bio-pesticides from abroad.

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CHAPTER 2

Extent and potential use of bio-pesticides for crop protection in Bangladesh

Dr. Syed Nurul Alam[2]

Introduction

Bangladesh lies in the north-eastern part of South Asia with a total land of 147,570 sq. km. The country has a population of 152.5 million and its average population density of 1015 person per sq km is one of the highest in the world. Except the hilly regions in the north-east and the south-east and some highlands in north and north-western part, the country consists of low, flat and alluvial fertile lands. Bangladesh generally enjoys a subtropical monsoon climate. Temperature ranges from 7.2^0C – 12.8^0C to a maximum of 23.9^0C – 36.7^0C. Monsoon starts in June and continues till October. The annual rainfall ranges from 1,200 mm to 3,450 mm which makes it possible to grow a variety of agricultural crops throughout the year. Bangladesh grows a variety of crops and rice is the predominate one that accounts for about 78% of the cropped areas. Rice, the staple food of the country, is cultivated throughout the country in three different seasons. The second most important cereal crop is wheat that accounts for about 2.52 of the cropped areas, which followed by maize (1.12%). Jute (4.80), potato (3.10), vegetables (2.40) also occupies considerable amount of acreage. Other crops such as pulses, oil seeds, spices, fruits, sugarcane, cotton, tea, and tobacco account for the remaining 8.26% (Figure 2).

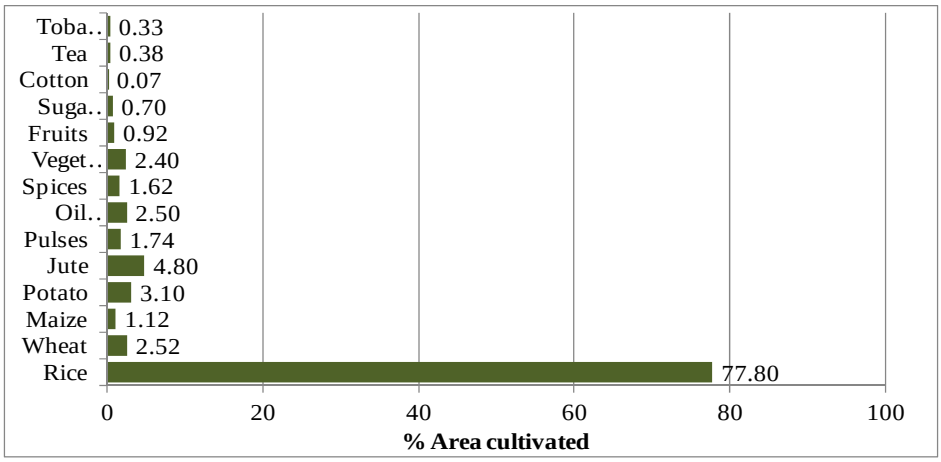

Figure 1. Area coverage of major crops in Bangladesh (BBS 2011)

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The economy of Bangladesh is primarily dependent on agriculture. With about 84 percent of the total population living in rural areas and directly or indirectly engaged in a wide range of agricultural activities, the agricultural sector plays a critical role in the national economy, accounting for 19.29 percent of total gross domestic products in 2011-12 (BBS, 2011). The agricultural sector is the single largest contributor to income and employment generation and a vital element in the country's challenge to achieve self-sufficiency in food production reduce rural poverty and foster sustainable economic development. Agriculture of Bangladesh is now in the process of transformation from subsistence to commercial farming. Meanwhile, Bangladesh has already entered into the European market, exporting vegetables and other high value crops to EU Member States. This process has opened a vista for private sector investment in the areas of production of high value crops, production of seeds (especially hybrid seeds), of environmental safe pesticides and blended fertilizers, agro-processing enterprises, etc. The policy reforms that have taken place offer greater scope and opportunities for private sector participation and an enabling environment towards promoting agribusiness and investment.

However, continuous application of synthetic fertilizers and indiscriminate use of toxic chemical pesticides has already created resistant pest population and adverse effects on soil properties. As a consequence yield stagnation or even yield declines have been observed. The reduction or non-use of synthetic chemicals with in organic farming systems can ensure sustainable crop protection; reduce environmental hazards and possible adverse effects on human and wildlife. In contrast to synthetic fertilizers, organic fertilizers improve the physical, chemical and biological properties of soil, and its use is important in sustaining soil productivity in the long term. The most common organic materials currently used throughout the world are bio-fertilizers and bio-pesticides.

The worst scenario is now prevailing in the pest management arenas of the country. Like other countries, pest attacks are one of the most important limiting factors to different crop production in Bangladesh. Due to pest infestation more or less about 20-52% of crop loss happens every year. Till today farmers of our country are mostly depending on the toxic synthetic pesticides to combat with those pests attack, in spite of the developments in organic agriculture and pesticide-restricted crop cultivation. Indiscriminate and excessive uses of toxic synthetic pesticides are common scenario in many areas to combat with destructive pests and diseases. However, in Bangladesh, the frequency and amount of pesticide applications per unit area is highest in the high valued crops. Among the various vegetable, fruits and spices crops, profitable crops like brinjal, country bean, cabbage, cauliflower, cucurbits, summer tomatoes, okra, string beans, mango, litchi, chili etc. receive excessive amounts of pesticides as they suffer serious pest damage (Alam *et al.,* 2004). On brinjal alone, commercial

producers apply toxic chemical pesticides to produce marketable fruits at a cost of more than US$ 560 (Tk. 50,000) per ha (40% of total production costs) (Rashid *et al*., 2002). According to Bangladesh Crop Protection Association (2006), pesticide use for growing vegetables was six times higher than the rice (1.12 kg/ha for vegetables, while it was only 0.20 kg/ha in rice). Due to development of resistance by different insect pests to different chemical pesticides, it was reported that for vegetables in general, an increasing trend was observed in use of pesticides by farmers in combating the pests throughout the country (Sabur and Mollah, 2000). However, in spite of everyday application of toxic pesticides, farmers could harvest 40-50% fruits free of insect infestations (Alam, 2004). Since majority of the farmers do not maintain any waiting period before crop harvest, the consumers become inevitably exposed to high levels of pesticide residues in their diets. The situation is compounded by the fact that, unlike cereals, vegetables or fruits are often consumed soon after harvest and there is little time for the chemicals to degrade. Different crops especially vegetables and fruits are harvested and marketed without knowing any residue status. This is most likely to cause serious health hazard to the consumers. Crops with thin skins or those eaten whole are the most risky for consumers. Moreover, the repeated applications have induced multiple resistances of different pests against various pesticides. It is also suspected that in Bangladesh the fish populations in the open water bodies as well as in the rice fields have been reduced due to the adverse effects of the pesticide use. Not only that, frequent use of toxic pesticides have boost up the population of many minor pests like whitefly, jassid, fruit borers, prodenia caterpillar, red pumpkin beetle, cut worm, red mite, aphids, mango twig galls, mango fruit weevil, mango fruit borer, jack fruit borer, litchi mite, litchi borer, guava spiraling whitefly, guava fruit borer, different viruses etc. Just before one decade none of those pests were considered as the major pests of vegetables or fruits.

One of the ways to avoid this measurable pest management system may be to develop eco-friendly, sustainable, socio-economic acceptable integrated pest management (IPM) strategies. IPM is one of a number of integrated approaches that are gaining credence for use in sustainable agriculture development. It involves the integration by farmer of the most appropriate management strategies for pest control where sole dependency on pesticides can be avoided. IPM packages are mainly dependent on ‘Bio-pesticides’. Bio-pesticides refer to products from natural sources such as animals, plants, and microorganisms, including “natural ingredient pesticide,” “microorganism pesticides” and “biochemical pesticides.” Bio-pesticides offer several advantages over convertional synthetic chemical pesticides. They are safer and less toxic to human and animals than chemical ones. Moreover, bio-pesticides will not endanger birds or other non-target animal, which make them safer to the habitat and environment.

Bio-pesticides can offer much more targeted activity against a desired pest, as opposed to conventional pesticides, which can affect a broad spectrum of pests and non-target arthropods including beneficial. Bio-pesticides often are effective in very small quantities, thereby offering lower exposure. Furthermore, they decompose more quickly than the conventional synthetic pesticides. Due to those reasons, bio-pesticides are supplementing the synthetic pesticides in the IPM programs, which offer potentially higher crop yields and can dramatically reducing the use of chemical pesticides.

The potentiality of bio-pesticides has increased substantially throughout the world including Bangladesh. Extensive and systematic research and development works on mass production, storage, transport and application of bio-pesticides, augmentation and application of bio-control agents have improved both in public and private sector in recent years with the ultimate objective of improving its commercial production and use. With the increased environmental awareness, increase activities of IPM, widening of organic farming, more R&D of bio-pesticides etc., use of synthetic pesticides especially in case of insecticides are showing a declining trend, whereas the bio-pesticide market is growing.

Policy and Institutions regulating pesticide use

Pesticide Use Pattern in Bangladesh

Pesticide use in Bangladesh started from mid fifties and gained momentum in early 1970's with the introduction of green revolution through the use of HYV rice. Through the import of 3 metric tons (mt) of insecticides in 1956, Bangladesh entered into the era of the synthetic chemical pesticides for pest control. During that time pesticides were procured by the government and supplied to the farmers free of cost (100% subsidy). Subsidies were halved in 1974 and withdrawn entirely in 1979. In 1979, pesticide subsidy was totally withdrawn and sale of pesticides were left to the private sector. After withdrawal of the subsidies the use of pesticides declined. However, the consumption began to rise again as agriculture activities expanded. Sales of pesticides doubled in the period 1982-89 and tripled in the last decade. During the last 10 years starting from 1997 to 2007, the consumption of pesticides in the agricultural sector of the country has increased by 328% (during 2008 sale volume of pesticide was, 48,690.19 t and sale value was around US$ 1,558,450 (Tk. 12 crore), where insecticides being the dominant item (57%) (Figure 3), including fungicide, rodenticide and herbicide. In Bangladesh during 1996-97 to 2007-08, pesticide consumption increased 328.4% and per ha pesticide use increased 598.8%. In 2008-09, 2009-10 the use rate was almost static and in 2010-11 for the first time a decline trend of pesticide use was observed (3190 mt less used than previous year, PPW 2011) (Figure 4).

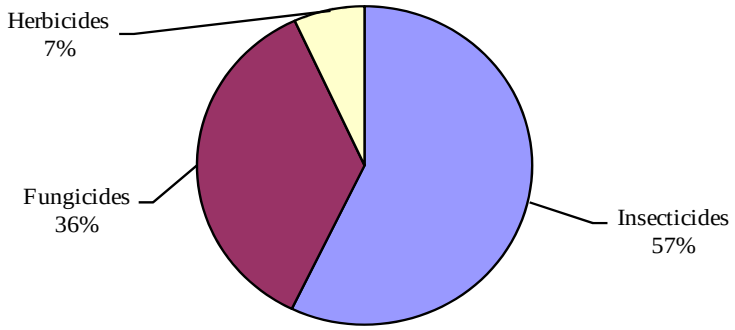


Figure 2. Share of pesticide market (sale volume) by type

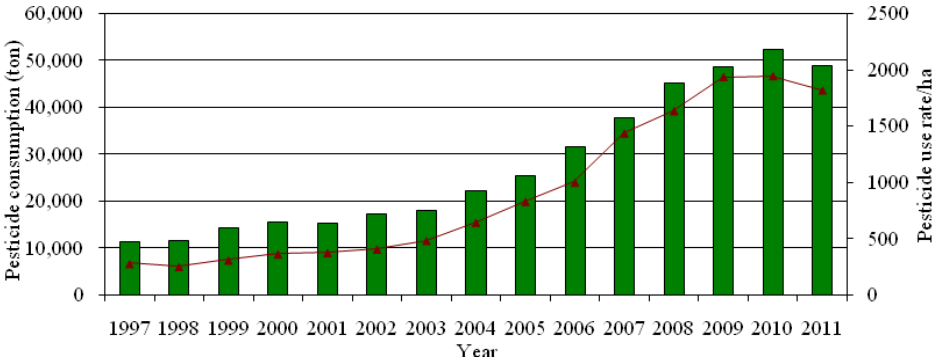


Figure 3. Year wise insecticide use pattern in Bangladesh (1997-2011)

Regulation for pesticide registration

In Bangladesh registration is compulsory before any pesticide can be imported (except for research purpose), manufactured, sold, stocked or advertised. Pesticide Ordinance to regulate the import, manufacture, formulation, distribution and sale was promulgated in January, 1971 and implemented in 1979. However, specific rules were drafted at July, 1985. “The Pesticide Ordinance, 1971” was revised during 2007 and its name was changed to “The Pesticide Ordinance (Amended), 2007”. The Pesticide Rules, 1985 was amended with the incorporation of the provisions of bio-pesticide registration along with few other changes during 2010. There is a Pesticide Technical Advisory Committee (PTAC), a Pesticide Technical Advisory Sub-Committee (Sub-PTAC), a laboratory, government analysts, inspectors and a licensing requirement for all aspects of pesticide handling, production, import/export, and rules relating to packaging, labeling, storage and safety. The ordinance is administrated by the Ministry of Agriculture through the Plant Protection Wing (PPW) of Department of Agricultural Extension (DAE). The ordinance conforms to the guidelines of the Food and Agriculture Organization (FAO).

Pesticide registration procedure

At first an application in triplicate for registration of a brand of pesticide shall be made to the Registration Authority (Plant Protection Wing of DAE). There are three different forms

Form 1(a) for Chemical pesticides,

Form 1(b) for Biochemical pesticides and

Form 1(c) for Microbial pesticides. (According to Amendment 2010)

- Application shall be done by using the appropriate form.
- On receipt of an application for registration of a brand of pesticide, the Registration Authority sends the application together with a sample of pesticide to the laboratory for test or analysis.
- On receipt of the successful result of the test or analysis, the Registration Authority forward the same to the Advisory Sub-Committee for approval & after getting approval send to the respective specialized institutes or organization authorized by the Pesticide Technical Advisory Committee (PTAC) to conduct biological test and trial for both the new molecule and Mee-too product under field condition.
- Two different locations & two crop season field trials are required and after trial report should be available within one month.
- The specialized institute (National Agricultural Research Institutes) shall conduct the field trials following Bio-efficacy Test Protocols.
- After getting the field efficacy results from the specialized institute, Registration Authority send the report to the next meeting of Sub-PTAC.
- After approval from the Sub-PTAC the both the result of chemical and field trial test send to PTAC meeting for final approval.
- On receipt of a report from the Advisory Committee, the Registration Authority, if he is of the opinion that the brand of pesticide conforms to the requirements of the Ordinance and these rules, give registration to the brand of pesticide on such conditions as may be specified in the certificate and assign to the certificate a registration. A certificate of registration granted shall apply only to the pesticide described in the application to which the certificate relates.
- Pesticides registered, as aforesaid, shall be published by the Registration Authority in the official Gazette within thirty days from the date of granting registration certificate.

Registered pesticides in Bangladesh

Till December 2012, 175 different products (2894 trade name products) are being registered for agricultural purposes (insecticide 78, miticide 6, bio-pesticide 3, fungicide 52, stored grain pest 4, rodenticide 2, and herbicide 30) (PPW, 2013) (Table 4). However, the government has already banned extremely hazardous (Ia) and highly hazardous pesticides (Ib). Till 2012, government has banned 195 trade name products, that include all "dirty dozen" product along with extremely and highly hazardous pesticides.

Table 1. List of registered pesticides in Bangladesh (approved up to 65 PTAC meeting, held on 20 December 2012) (PPW 2013)

Sl. No.	Types of pesticides	Total registered pesticides		Remarks
		Common name	Trade name	
01.	Insecticides	76	1659	Registrations of bio-pesticides have been started from 20 December 2012. Before that several bio-pesticides were registered as insecticides
02.	Miticides	06	153	
03.	Bio-pesticides	05	55	
04.	Fungicides	52	633	
05.	Stored grain pesticides	04	66	
06.	Herbicides	30	315	
07.	Rodenticides	02	13	
Total		175	2894	

Inventory of bio-pesticides used in agricultural sector

With food security issues on the front burner across the globe, Bangladesh Government has also highly prioritized the issue and been adopting state-of-the-art technologies to boost up the crop production with environment friendly condition through different wings of Ministry of Agriculture. In Bangladesh the bio-pesticide marketing is very much in an initial stage. However, few research and development works on bio-pesticide based pest management have been done in several public research institutes especially at Bangladesh Agricultural Research Institute (BARI) and universities. Some of the developed technologies on bio-pesticide based pest management especially pheromone based insect pest management approaches also get credential and became very much popular among the farm community of the country. Government of Bangladesh has also been encouraging the farmers to reduce their sole dependency on pesticides for controlling insect pest through the easy availability of the bio-control agents and other IPM materials and thereby minimizing their economic loss. The main

weakness of this bio-pesticide based pest management is the easy availability of the inputs to the end user, farm community. In our country pest management inputs are being marketed entirely by the private sector. Unfortunately till 2005 no private entrepreneurs were interested to do business in this sector. Although during this period the bio-pesticide related commercial organizations couldn't flourish well due to legislative hindrance. Bangladesh doesn't have any registration policy for commercial use of bio-pesticide. Due to that reason none of private bio-pesticide company could sell their product directly to the farmers. During 2010, the Pesticide Rules, 1985 was amended with the incorporation of the provisions of bio-pesticide registration and from 2012 registration of bio-pesticides have been opened.

In Bangladesh, bio-pesticides mean a form of pesticide based on micro-organisms or natural products. That can be microbial, which consist of bacteria, entomopathogenic fungi or viruses or entomopathogenic nematodes, natural products like Azadirachtrin, Biochemical pesticides, viz. insect pheromone, para-pheromone and other chemicals. Fermentation products such as Spinosad (a macro-cyclic lactone) or Abamectin (a natural fermentation product of soil bacterium *Streptomyces avermitilis*) are also considered as bio-pesticides. Natural plant-derived products, which includes alkaloids, terpenoids, phenolics and other secondary chemicals and products based on extract of plants like garlic, allamanda have now been registered as bio-pesticides. In Bangladesh bio-pesticides are mainly used in pest management of agricultural crops. The descriptions of different bio-pesticides (registered/applied for registered) are as shown in Table 5 and Table 6:

Table 2. Bio-pesticides in agriculture

Bio-pesticide products	Target crops	Target pest/diseases	Application mode	Application rate	Remarks
Insect pests					
Cuelure (pheromone) (3 products)*	Cucurbit (sweet gourd, bitter gourd, ash gourd, teasel gourd, pointed gourd, melon, cucumber etc.)	Fruit fly (*Bactrocera cucurbitae*)	Set in water trap within one month of seed sowing.	70 lures (traps)/ ha	
Methyl Euginol (pheromone) (1 product)*	Mango	Fruit fly (*Bactrocera dorsalis*)	Set in water trap before one & half month of harvesting	80 lures (traps)/ ha	

Bio-pesticide products	Target crops	Target pest/diseases	Application mode	Application rate	Remarks
Spedoptera pheromone (1 product)*	Cabbage, cauliflower, mustard, aroids, chili, tomato bitter gourd etc.	Prodenia caterpillar, *Spodoptera litura*	Set in water trap within three weeks of seed sowing.	40 lures (traps)/ ha	
Brinjal shoot & fruit borer pheromone (2 products)*	Brinjal	Brinjal shoot and fruit borer, *Leucinodes orbonalis*	Set in water trap within two weeks of seedling transplanting.	100 lures (traps)/ ha	Lures should be changed after two months with a new one.
Abamectin1.8 EC (natural fermentation product) (39 products)*	Brinjal, tea, rice, cotton, litchi	Red spider mite, aphids, jassid, mosquito bug etc.	Foliar application	1.25 ml per liter of water	
Spinosad (natural fermentation product) (9 products)*	Rice, jute, brinjal, cotton	Shoot & fruit borer, aphids, jassids, bollworm, hairy caterpillar, leaf folder	Foliar application	0.4 ml per liter of water	
Azadirachtrin (neem based formulation) (3 products)	Vegetables, mustard, tea	Aphid, Jassid, red spider mite, thrips, mosquito bug	Foliar application	1 - 3 ml per liter water depending on formulation	Applied for registration
SNPV (Single-embedded Nuclear polyhedrosis virus for *Spodoptera litura*)	Cabbage, cauliflower, mustard, aroids, chili, tomato bitter gourd, cotton, tobacco etc.	Prodenia caterpillar, *Spodoptera litura*	Foliar application	0.2 gm per liter of water	Applied for registration
HNPV (Helocoverpa Nuclear polyhedrosis virus for	Cotton, tomato, chili	Bollworm, fruit borer, *Helicoverpa armigera*	Foliar application	0.1 gm per liter of water	Applied for registration

Bio-pesticide products	Target crops	Target pest/diseases	Application mode	Application rate	Remarks
Helicoverpa armigera)					
Bt formulation (*Bacillus thuringiensis*)	Vegetables, chili, cotton etc.	Lepidoptera pests	Foliar application	0.4 gm per liter of water	Applied for registration
Diseases					
Trichoderma (in pit soil)	Vegetables, spices (chili)	Soil borne diseases	Mixed with the top soil (6 inch) 1 week before planting.	1 kg per 4 decimal land, 5gm/ kg soil for nursery	
Trichoderma (as tricho-compost)	All vegetables and spices (chili)	Soil borne diseases	Mixed with the top soil (6 inch) 1 week before planting.	3 tons per ha.	
Trichoderma suspension	All vegetables and spices (chili)	Virus diseases	Foliar spray with water	100 ml solid suspension mixed with 10 liter water	
BAU tablet 1 (Garlic tablet)	Seed treatment for all vegetable crops	Seed borne diseases	Dissolve tablet in normal water (Tablet:water = 1:4 w/v), Dip seeds in the solution for 15 minutes	12 tablets/ha of seeds	
BAU tablet 2 (Allamanda tablet)	Seed treatment for all vegetable crops	Seed borne diseases	Dissolve tablet in normal water (Tablet:water = 1:4 w/v), Dip seeds in the solution for 15 minutes	12 tablets/ha of seeds	

* Register product

Table 3. Quantity and extent of use

Bio-pesticides products	Quantity used (2010-2012)	Area coverage (ha) (2010-12)
Cuelure (pheromone) for cucurbit fruit fly (3 products)	4,94,700 pcs. lures	7,067
Methyl Euginol (pheromone) for oriental fruit fly (1 product)	1,05,000 pcs. lures	1,310
Spedoptera litura pheromone (1 product)	40,250 pcs. Lures	1,005
Brinjal shoot & fruit borer pheromone (2 products)	2,83,800 pcs. lures	1,420
Abamectin 1.8 EC (natural fermentation product) (42 products)	32 tons	5,120
Spinosad (natural fermentation product) (11 products)	11 tons	5,500
Azadirachtin (neem based formulation) (3 products)	2 tons	400
SNPV (Single-embedded Nuclear polyhedrosis virus for *Spodoptera litura*) (2 products)	30 Kg	300
HNPV (Helicoverpa nuclear polyhedrosis virus for *Helicoverpa armigera*) (2 products)	8 Kg	160
Bt formulation (*Bacillus thurengiensis*)	100 kg	50
Trichoderma (in pit soil)	25 tons	425
Trichoderma (as tricho-compost)	1200 tons	400
Trichoderma suspension (for virus)	500 liters	10
BAU tablet 1 (Garlic tablet)	500 pcs.	40
BAU tablet 2 (Allamanda tablet)	450 pcs.	36

Best practices in bio-pesticide application

It has been observed that it is difficult to control a pest only by the application of a single tactics. In order to achieve sustainable result, it is necessary to develop complete and coherent packages of technologies that meet farmers' needs and completely replace the need for application of toxic chemical pesticides. It has been observed that effective management of *Spodoptera litura* can be ensured

with the mass trapping of *Spodoptera litura* by pheromone traps along with 2-3 application of SNPV (Alam *et al.*, 2012), inundative release of two parasitoids, *Tricogramma chilonis* and *Bracon habetor* can reduce the brinjal fruit damage to less than 10% along with the pheromone mass trapping and weekly removal of pest infested shoots and fruits from the field (Alam *et al.*, 2005). In Bangladesh, scientists of different public research institutes and universities, viz. Bangladesh Agricultural Research Institute (BARI), Bangladesh Agricultural University etc. have already developed bio-pesticide based pest management packages against several destructive insect pests and diseases of different crops. Best practices are discussed in brief as follows:

Cucurbit crops :

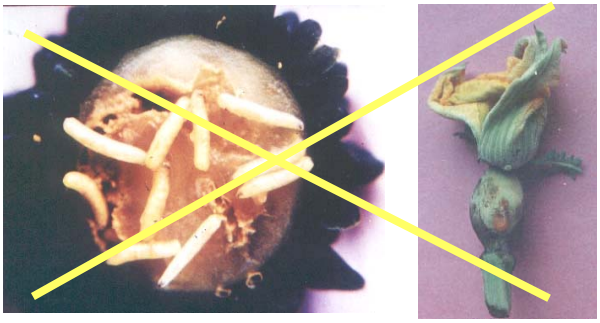
Cucurbit crops like bitter gourd, sweet gourd, cucumber, tassel gourd, ash gourds etc. are attacked by different insect pests but cucurbit fruit fly is considered as the major pest. It is a devastating pest of different cucurbit vegetables. In Bangladesh, this pest has been a major problem for the farmers as they invade the crops in high populations and devastate the cucurbit crops. Due to its nature of damage it is difficult to control this pest with insecticide. However, an effective and cheap management strategy against this pest has already been developed, which comprises of sanitation and use of sex pheromone mass trapping.

Bio-pesticide based Package (*Alam et al., 2005*) :

a. Sanitation: Weekly collection and destruction of infested fruits along with larvae.

b. Pheromone bait trap: The sex pheromone, ‘cuelure’, which mimics the scent of female flies, attracts the male flies and traps them in large numbers resulting in mating disruption. Simple plastic containers known as ‘BARI trap’ or ‘Magic trap’ were used for deployment of the pheromones. The rectangular plastic container had around 3-liter capacity and 20-22 cm tall. A triangular hole measuring 10-12 cm height and 10-12 cm base was cut in any two opposite sides. The base of the hole would be 3.0 cm above the bottom. Water containing two-three drops of detergent would be maintained inside the trap throughout the season. The pheromone soaked cotton was tied inside the trap with thin wire. Fruit fly adults enter the trap and fall into the water and die. Water inside the trap was replenished often to make sure the trap was not dry. The pheromone dispensers were continued throughout the cropping season. The pheromone bait traps should be in the cucurbit field at a distance of 12-15m^2 starting from 2-3 weeks of seed sowing and continued till last harvest.

c. Community approach: Community approach of the package should be practiced.



Weekly removal of infested fruits from the field

Pheromone mass trapping

Cabbage /Cauliflower

Leaf eating lepidopterous pests like prodenia caterpillar and diamond back moths are the main constraints for cabbage production. Bio-pesticide based pest management packages to control those pests are as follows:

Bio-pesticide based Package (*Alam et al., 2011*):

a. Mechanical control: Hand picking and destruction of *Spodoptera litura* or DBM egg/larvae during initial stage should be done in the cabbage and cauliflower fields.

b. Use of pheromone bait trap and application of SNPV & Bt: Sex pheromone for *Spodoptera litura* is now commercially available to trap the male moths before they mate. *Spodoptera litura* pheromone lures (in a plastic tube) baited in a suitable trap, 'BARI trap'. Male moths are attracted to the trap, captured and killed. The pheromone lure hung through the center of the lid inside the trap in such a way that the lure is 2-3 cm above the water level of trap. Trapping should be started from 2-3 weeks after transplanting and continued till last harvest. A distance of 30 m^2 should be maintained between the traps. If infestation starts even after pheromone trapping then 2-3 application of SNPV (@ 0.2 gm/liter of water) and Bt (@ 0.4 gm/liter of water) should be done.

Pheromone mass trapping

Release of larval parasitoids

c. Artificial release of bio-control agents: To promote the use of different bio-control agents, weekly release of two parasitoids should be done in the field. The parasitoids are i) egg parasitoid, *Tricogrammatidae bactri* (@ 1gm parasitized eggs/ha/week) and ii) larval parasitoid, *Bracon habetor* (@ 1 box containing 1000-1200 adult/ha/fortnight). Those bio-control agents would manage the fruit borer problem.

Brinjal

Brinjal is attacked by many insect pests. Among them brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guen. is considered as the major pest. The yield loss caused by this pest has been estimated more than 85% in Bangladesh. Despite its seriousness, farmers rely exclusively on the application of chemical insecticides to combat BSFB, which has resulted in a tremendous misuse of pesticides in an attempt to produce blemish-free marketable brinjal fruits. Unfortunately even after repeated insecticide spraying the farmers could not control the pest properly as the field population became resistance to the commonly used pesticides. BARI scientists have developed effective and economic bio-pesticide based package to combat the pest.

Bio-pesticide based package (*Alam et al., 2003*):

a. Sanitation: Weekly removal and destruction of pest-damaged shoots and fruits that harbor brinjal shoot and fruit borer (BSFB) larvae from the field.

b. Use of sex pheromone: Sex pheromone for BSFB (a combination of two chemicals) has been identified, synthesized, and is now commercially available to trap the male moths before they mate. BSFB pheromone lures (in a plastic tube) baited in a suitable trap, 'BARI trap'. Male moths are attracted to the trap, captured and killed. The pheromone lure hung through the center of the lid inside the trap in such a way that the lure is 2-3 cm above the water level of trap. The trap should be set just above the plant canopy. Bating should be started from 2-3 weeks after transplanting and continued till last harvest. A distance of 10 m^2 should be maintained between the traps. The pheromone plastic tubes (lures) should be changed at every 45-60 days.

c. Application of bio-pesticide Spinosad: During hot and humid period the population of BSFB increases very quickly. During that period Spinosad (Tracer 45 SC, @ 04 ml/liter of water) should be sprayed 3-4 times at 10-12 days interval.

d. Artificial release of bio-control agents: To promote the use of different bio-control agents, weekly release of two parasitoids should be done. The parasitoids are i) egg parasitoid, *Tricogramma chilonis* (@ 1gm parasitized eggs/ha/week) and ii) larval parasitoid, *Bracon habetor* (@ 1box containing 1000-1200 adult/ha/fortnight).

e. Community approach: Community approach of the IPM package should be followed.


Sanitation


Pheromone trapping


Minimum spray with Bio-con agent bio-pesticides


release

Tomato

The key constraints to tomato production relate to tomato leaf curl virus, particularly in summer production when total crop loss may happen because of the high efficiency of the vector, *Besimia tabaci*, transmission and susceptibility of currently available varieties. Other key constraints to tomato production relate to fruit borer, *Spodoptera litura* & *Helicoverpa armigera*. The recently developed bio-pesticide based management technologies against those pests are as follows:

Bio-pesticide based package (*Alam et al., 2011*):

a. Use of virus resistant germplasm: Resistant/tolerant lines against whitefly and leaf curl virus (containing the Ty-2 resistance gene) were developed. Those lines (TLB 182, TLB 111) were promoted among the farmers to resist whitefly and whitefly transmitted leaf curl virus disease.

d. Use of pheromone bait trap and application of SNPV & HNPV: Sex pheromone for *Spodoptera litura* is now commercially available to trap the male moths before they mate. *Spodoptera litura* pheromone lures (in a plastic tube) baited in a suitable trap, 'BARI trap'. Male moths are attracted to the trap, captured and killed. The pheromone lure hung through the center of the lid inside the trap in such a way that the lure is 2-3 cm above the water level of trap. Bating should be started from 2-3 weeks after transplanting and continued till last harvest. A distance of 30 m^2 should be maintained between the traps. If infestation starts even after pheromone trapping then 2-3 application of SNPV (@ 0.2 gm/liter of water) and HNPV (@ 0.1 gm/liter of water) should be done.

b. Artificial release of bio-control agents: To promote the use of different bio-control agents, weekly release of two parasitoids were done in the trial areas. The parasitoids are i) egg parasitoid, *Tricogramma evanescens* (@ 1gm parasitized eggs/ha/week) and ii) larval parasitoid, *Bracon habetor* (@ 1 bunker /ha/week). Those bio-control agents would manage the fruit borer problem.

Resistant line against TYLCV

Bio-pesticide based IPM trial

Country bean

Country bean is one of the most popular vegetables in Bangladesh. Now- a- days country bean became a year round crop instead of only growing during winter. So, due to year round availability infestation of different pod borers were also increased. Previously, pod borer, *Maruca vitrata* was considered as the single borer pest of country bean in Bangladesh. But recently it was observed *Helocovarpa armigera* infesting pods of country bean. On the other hand aphid's infestation is also considered as the limiting factor for country bean cultivation especially during cool and dry period. The following management approaches can effectively control the insect pests of country bean.

Bio-pesticide based package (*Alam et al., 2010*):

a. Mechanical control: Hand picking and destruction of *M. vitrata* and *H. armigera* infested flowers and pods should be done at alternate days in the country bean fields.

b. Artificial release of bio-control agents: To promote the use of different bio-control agents, weekly release of two parasitoids should be done in the field. The parasitoids are i) egg parasitoid, *Tricogramma chilonis* (@ 1gm parasitized eggs/ha/week) and ii) larval parasitoid, *Bracon habetor* (@ 1 bunker /ha/week). Bio-control agents should be released at least one day after Spinosad application.

c. Application of bio-pesticide Spinosad: During hot and humid period the population of the borers increases very quickly. During that period Spinosad (Tracer 45 SC, @ 04 ml/liter of water) should be sprayed 3-4 times at 10-12 days interval especially during the flower initiation period till harvesting.

d. Spraying of soap water: Spot application of powder soap (5 gm/liter of water) during initial aphid infestation can manage aphid population in a sustainable manner or spot application of Azadirachtin (neem based formulation) also control aphid population.

Chili

Prodenia caterpillar, *Spodoptera litura* and fruit borer, *Helicoverpa armigera* are two devastating pest of chili and key constraints to its production. However, the following management approaches can effectively control those insect pests:

Bio-pesticide based package (*Alam et al., 2013*):

a. Use of pheromone bait trap and application of SNPV & HNPV: Sex pheromone for *Spodoptera litura* is now commercially available to trap the male moths before they mate. *Spodoptera litura* pheromone lures (in a plastic tube) baited in a suitable trap, 'BARI trap'. Male moths are attracted to the trap, captured and killed. The pheromone lure hung through the center of the lid inside the trap in such a way that the lure is 2-3 cm above the water level of trap. Bating should be started from 2-3 weeks after transplanting and continued till last harvest. A distance of 30 m^2 should be maintained between the traps. If infestation starts even after pheromone trapping then 2-3 application of SNPV (@ 0.2 gm/liter of water) and HNPV (@ 0.1 gm/liter of water) should be done.
b. Artificial release of bio-control agents: To promote the use of different bio-control agents, weekly release of two parasitoids should be done in the trial areas. The parasitoids are i) egg parasitoid, *Tricogramma chilonis* (@ 1gm parasitized eggs/ha/week) and ii) larval parasitoid, *Bracon habetor* (@ 1 bunker /ha/week). Those bio-control agents would manage the fruit borer problem.

Chili infestation with fruit borer

Bio-pesticide based management

Mango, Guava, Orange

Fruit fly, *Bactrocera dorsalis*, is a devastating pest of different fruits viz. mango, guava and orange. In Bangladesh, this pest became a major problem for the fruit farmers, orchard owners as they invade the crops in high populations and devastate the fruits at the matured stage. Due to its nature of damage it is very much hard to control this pest with insecticide. However, an effective and cheap management strategy against this pest has already been developed, which comprises of sanitation and use of pheromone mass trapping.

Bio-pesticide based package (*Alam et al., 2007*):

a. Sanitation: Weekly collection and destruction of infested fruits along with larvae.

b. Pheromone bait trap: The pheromone, 'methyl euginol' attracts the male flies and traps them in large numbers. Simple plastic containers known as 'BARI trap' should be used for deployment of the pheromones. The pheromone soaked cotton tied inside the trap with thin wire. Fruit fly adults enter the trap and fall into the water of the trap and die. Water inside the trap should be replenished often to make sure the traps do not dry. The pheromone should set during the fruit maturity period (one & half month before fruit harvest) and continued till last harvest. The pheromone bait traps should be in the fruit orchard at a distance of 10-12 m^2.

c. Community approach: Community approach of the package should be practiced.

Fruit fly, *Bactrocera dorsalis* attacking Mango fruits

Mass trapping with Pheromone

Bio-pesticide based package against *Spodoptera litura*

Prodenia caterpillar or tobacco caterpillar, *Spidoptera litura* are becoming a destructive pests of several crops, viz. mustard, cabbage, cauliflower, tomato, aroids, several cucurbits, chili, cotton, tobacco etc. It is difficult to control this pest with any synthetic chemical insecticides. However, BARI scientists have developed an effective and cheap management strategy against this pest.

a. Use of pheromone bait trap: Sex pheromone for *Spodoptera litura* is now commercially available to trap the male moths. *Spodoptera litura* pheromone lures (in a plastic tube) baited in a suitable trap, 'BARI trap'. Male moths are attracted to the trap, captured and killed. The pheromone lure hung through the center of the lid inside the trap in such a way that the lure is 2-3 cm above the water level of trap. Bating should be started from 2-3 weeks after transplanting and continued till last harvest. A distance of 30 m^2 should be maintained between the traps.

b. Application of SNPV: If infestation starts even after pheromone trapping then 2-3 application of SNPV (@ 0.2 gm/liter of water) at 10 days interval should be done from the initial infestation period.

c. Artificial release of bio-control agents: For sustainable management of *S. litura* fortnightly release of larval parasitoid, *Bracon habetor* (@ 1 box containing 1000-1400 adult /ha/week) should be done in the infested areas.

Mass trapping of pheromone against *Spodoptera litura* in aroids and Mustard

Soil borne pathogens control by *Trichoderma sp.*

Different soil borne pathogens, viz. *Pythium* sp., *Sclerotium* sp., *Rhizoctonia* sp. etc are serious problems especially in nursery management. Due to lack of proper management 30-60% seedlings in the nursery and 20-40% crops in the field may be damaged due to the infestation of those pathogens. Those soil borne pathogens can be successfully control by parasitic fungus *Trichoderma sp*. In Bangladesh *T. harzianum* is being used as bio-pesticide against soil borne pathogen in three different forms. However, two types of *Trichoderma* sp. based bio-pesticides are becoming very popular in Bangladesh. They are tricho-compost, prepared with decomposed poultry liter, water-hyacinth, and molasses and *T. harzianum* and pit soil having *T. harzianum.*

Preparation of Tricho-compost at GKSS, Bogra

Success stories in bio-pesticide use

There are many success stories in pest management with bio-pesticide use in Bangladesh. Few of them are as follows:

1. Case studies

Case study Tarash, Sirajgonj: During 2008-09 a serious outbreak of prodenia caterpillar, *Spodoptera litura* occurred at Tarash, Sirajgonj areas (middle part of the country) in mustard crop. Around 200 ha of mustard cultivated land were severely infested with the pest. Farmers applied different insecticides at 2-3 times higher dose and even at alternate days but could not check the outbreak. Around 65% crop was damaged due to the attack of the pest. From next year (2009-10) Entomology Division, BARI in collaboration with the local Agricultural Office of DAE starts bio-pesticides based management of the pest through massive campaign. Total area was brought under pheromone trapping, release of larval parasitoid, *Bracon habetor* and two sprays of SNPV were done. Pheromone trapping helped to reduce infestation.

Outbreak of *S. litura* in mustard

Bio-pesticide based management

Case study Kamlakanda, Netrokona: During 2011-12 winters a serious outbreak of the same pest, prodenia caterpillar, *Spodoptera litura* happened at Kamlakanda, Netrokona areas (north-eastern part of the country) on cabbage. Around 40 ha of cabbage cultivated land was severely infested with the pest. Farmers applied different insecticides at 2-3 times higher dose and even at alternate days but could not check the outbreak. Around 100% crop was damaged due to the attack of the pest. During next year (2012-13) Entomology Division, BARI in collaboration with the local Agricultural Office of DAE starts bio-pesticides based management of the pest through massive campaign. Total area was brought under pheromone trapping, release of larval parasitoid, *Bracon habetor* and two sprays of SNPV were done and the infestation was totally checked.

Severe infestation of cabbage with *S. litura* Farmers are helpless

Protected crop with bio-pesticide

Case study Tunirhat, Panchgar: During 2011 late winter serious infestation of prodenia caterpillar, *Spodoptera litura* and fruit borer, *Helicoverpa armigera* occurred at Tunirhat, Panchgar areas (north-western part of the country) on tomato. Around 100 ha of tomato cultivated land was severely infested with the borer complex. Farmers applied different insecticides at 2-3 times higher dose and even at alternate days but effective control was not happened. Around 30-40% crops were damaged due to the attack of the pest. During next years (2012 and 2013) Entomology Division, BARI in collaboration with the local Agricultural Office of DAE starts bio-pesticides based management of those pests through massive campaign. Total area was brought under pheromone trapping, release of larval parasitoid, *Bracon habetor* and two sprays of SNPV and HNPV and there was no visible infestation happened.

Bio-pesticide based management

Bumper production of late winter tomato

Case study Bagarpara, Jessore: Fruit fly is a destructive pest of different cururbit crops. Especially in bitter gourd infestation of fruit fly can damage around 30-40% fruits. Farmers are spraying different insecticides at 2-3 days interval to control the pest without any effective results. However, area wide (community based) continuous mass trapping of fruit fly with pheromone ‘cuelure’ in ‘BARI trap’ effectively managed the pest problem. At Bagarpara, Jessore (south-western part of the country) continuous mass trapping with ‘cuelure’ was started during 2004 cropping season and continued till 2010. During 2004, a total of 15.5 ha of bitter gourd cultivable land were brought under mass trapping, which increased to around 120 ha during 2010. The pheromone bait traps were set in the bitter gourd fields at a distance of 12-15 m^2 starting from 2-3 weeks of seed sowing and continued till last harvest. During 2004, fruit fly catch per trap per week was 258 and the fruit infestation was 20.5%. However, both the catch as well as fruit infestation was reduced in the subsequent years and in 2010, per trap catch was 8 per week with the fruit infestation of 2.2 (Figure 5). Fruit infestation was 55% lower and yield (t/ha) was 34% higher in pheromone bait treated plots than the insecticide sprayed plots, which saved pesticide cost @ US$ 480 (Tk. 37,000) per hectare.

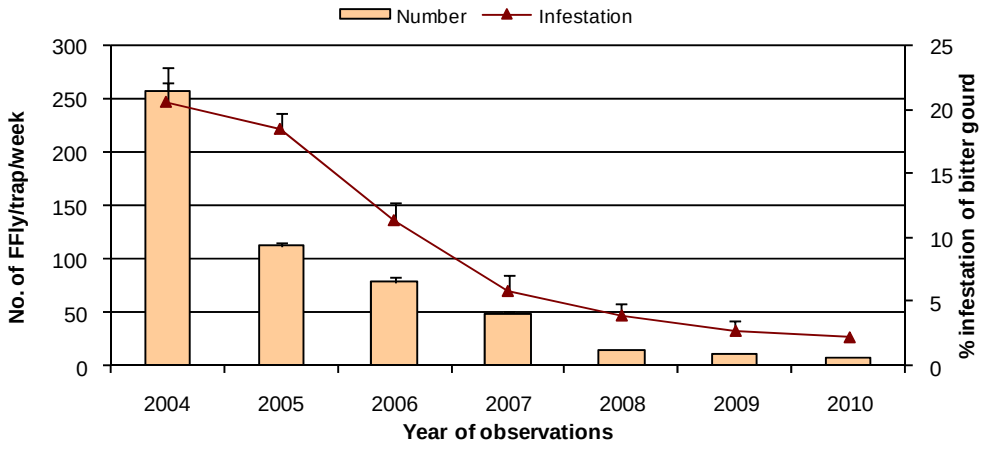


Figure 4. Effect of continuous mass trapping on the population of fruit fly in bitter gourd at Bagarpara, Jessore

Economics of several bio-pesticide based IPM packages

Pest management costs with synthetic toxic pesticides are increasing tremendously due to their high price as well as frequent application. Farmers are indiscriminately applying toxic chemical pesticides to save their crops from severe infestation of different insect pests and diseases. Unfortunately in many case they can't effectively control the pests due to development of pesticide resistant races/strains/biotypes. The developed bio-pesticide based IPM packages are now becoming popular among the farm communities not only due to its effectiveness but also less cost involvement. It is revealed from the Table 7 that around 25-65% yield increase of healthy fruits of different high valued vegetables may happened with 12-48% less cost involvement than the sprayed plots.

Table 4. Economics of several bio-pesticide based IPM packages (Alam *et.al*., 2012)

Sl. No.	Bio-pesticide based IPM packages	% yield increase over non-IPM	% reduction of pest management cost over non-IPM
01.	IPM packages bitter gourd	40-45	45-50
02.	IPM packages sweet gourd	58-65	32-35
03.	IPM packages cucumber	25-30	28-35
04.	IPM packages brinjal shoot & fruit borer	35-40	35-48

Sl. No.	Bio-pesticide based IPM packages	% yield increase over non-IPM	% reduction of pest management cost over non-IPM
05.	IPM packages cabbage/cauliflower	30-35	12-15
06.	IPM packages country bean	35-40	30-32
07.	IPM packages aroids	35-40	35-40
08.	IPM packages tomato	25-28	35-40

Reduction in insecticide use

With the increase of the popularity of bio-pesticide based IPM packages, the reduction of synthetic pesticides use has been started. In 2010-11 for the first time a decline trend of total pesticide use was observed, 3190 mt less used than previous year (PPW, 2011) in the country. Sales reduction of granular, liquid and powder insecticides were 18.7%, 3.34%, and 4.47%, respectively happened in 2012 in comparison to 2011 (Table 8) (BCPA, 2013). Sales of miticides were also decreased by 25.25%, which is mainly used in tea and vegetables. However, sales of fungicides (general) were increased by 5.8% and sulphur by 3.83%. Due to intensive research and promotional works on the development and dissemination of bio-pesticide based IPM packages against different insect pests, several cost-effective packages have been developed and became popular among the farmers community. So, uses of synthetic pesticides especially in case of insecticides are showing a declining trend, whereas the bio-pesticide market is growing. However, for disease management use of bio-pesticide is still lagging behind.

Table 5. Total ex-depot sales of the member companies of Bangladesh Crop Protection association during 2011 & 2012. (Figures in MT/KL)

Name of pesticides		Year 2011		Year 2012		% increase (+) or decrease (-) over 2011	
		FP	AI	FP	AI	FP	AI
Insecticides	Granular	20,335	1,082	16,539	815	(-) 18.7	(-) 24.7
	Liquid	3,574	905	3,455	795	(-) 3.3	(-) 12.1
	Powder	673	360	641	333	(-) 4.8	(-) 7.6
Fungicide	General	3,007	1,704	3,182	1,818	(+) 5.8	(+) 6.7
	Sulphur	12,804	10,228	13,295	10,617	(+) 3.8	(+) 3.8
Miticide		73.8	23.9	55.2	17.2	(+) 25.3	(+) 27.9

Bio-pesticide producers in Bangladesh

Sl. No.	Name, address of the bio-pesticide producers	Product lists	Remarks
Public Institutes			
01.	IPM Laboratory, Entomology Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur 1701. Tel: +88 02 9256404, 9257400, Cell: +88 01713, E-mail: cso.ento@bari.gov.bd, Website: www. bari.gov.bd	Pheromone lures (Brinjal shoot and fruit borer, Cucurbit fruit fly, Oriental fruit fly, Prodenia caterpillar, Fruit borer), Different microbials and bio-control agents	
02.	IPM Laboratory, Department of Plant Pathology, Bangladesh Agricultural University, Mymensingh 2202. Tel: +88 091 54479, Cell: +88 01711 667234, E-mail: bmeah@yahoo.com, Website: www.bauipmlab.org	*Trichoderma* (in pit soil), *Trichoderma* suspension, BAU tablet 1 (garlic), BAU tablet 2 (Allamanda)	
03.	Department of Microbiology, University of Dhaka, Dhaka 1000, Bangladesh. Tel: +88 02 9677268, 9661920-60/7734, Cell: +88 01717 083673, Fax: +88 028615583, E-mail: mhoq@univdhaka.edu	Bt (different strains of *Bacillus thuringiensis*)	
Private Institutes/Companies			
04.	Ispahani Agro Ltd. Head Office: Ispahani Building, 8th Floor, 14-15, Motijheel C/A, Dhaka 1000. Tel: +88 02 9555192-5, Fax: +88 02 9565319 Laboratory: Ispahani Complex, Dewaliabari, Konabari, Gazipur 1701. Cell: +88 01937 900079, 01816 944185	Pheromone lures (Brinjal shoot and fruit borer, Cucurbit fruit fly, Oriental fruit fly, Prodenia caterpillar, Fruit borer), Different microbials, neem formulations, *Trichoderma* (in pit soil) and different bio-control agents	
05.	Russell IPM Bangladesh Ltd., 27/1, Indira Road, Flat C, Tejgaon, Dhaka 1215, Bangladesh. Cell: +88 01728 159074, 01710 990880.	Pheromone lures (Brinjal shoot and fruit borer, Cucurbit fruit fly), Different microbials, neem formulations, Abamectin	

Sl. No.	Name, address of the bio-pesticide producers	Product lists	Remarks
06.	GME Agro Limited, Tapa Complex, 169 Shahid Syed Nazrul Islam Sarani, Purana Paltan, Dhaka 1000. Tel: +88 02 9554440, 9562535, 7176910	Pheromone lures (Brinjal shoot and fruit borer, Cucurbit fruit fly)	
07.	Grameen Krishak Sahayak Sagostha (GKSS), Gabtoli, Bogra Cell: +88 01714 928590, 01716 964234	*Trichoderma* (as Tricho-compost), *Trichoderma* suspension	
08.	Auto Crop Care Limited, House No. 74, Road No. 25, Gulshan 1, Dhaka 1212 Tel: +88 02 9880860, Fax. +88 02 9560680	Spinosad, Abamectin	
09.	Intefa, Gulfesha Plaza, 69, Outer Circular Road, Moghbazar, Dhaka 1217, Tel: +88 02 9342518, 8311348	Spinosad, Abamectin	
10.	East West Chemicals Limited, Hasan Holdings, 52/1, New Eskaton Road, Dhaka 1000, Tel: +88 02 93606658, Cell: +88 01713 464628, Fax: +88 02 9360658	Abamectin	
11.	Atherton Imbros Company Limited, House No. 816, Road 05, Baitul Aman Housing Society, Adabar, Dhaka 1207 Tel: +88 02 9115328, Fax: +88 02 8125498	Spinosad, Abamectin	
12.	Syngenta Bangladesh Limited, House No. 2/6, Block E, Lalmatia, Mohammadpur, Dhaka 1207. Tel: +88 02 9142581-3, 9137030 –1, Fax: +88 02 9134263	Abamectin	
13.	McDonald Bangladesh (Pvt.) Limited, Shanta Western Tower, Level-11, 186, Bir Uttam Mir Shawkat Ali Sarak, Tejgaon Industrial Area, Dhaka 1208. Tel: +88 02 8878748-51, Fax. +88 02 8878752	Abamectin	
14.	National AgriCare Import & Export Limited Concord Centre Point, Farmgate, Dhaka	Abamectin	

Sl. No.	Name, address of the bio-pesticide producers	Product lists	Remarks
	1215. Tel: +88 02 9143440, Fax: +88 02 9140967		
15.	Corbel International Limited, SR Tower, 5th Floor, 49, Old Airport Road, Tejgaon, Dhaka 1208	Abamectin	
16.	Haychem (Bangladesh) Limited, Apartment No. B-1, Building No. B, House No. CEN(B)-11, Road No. 99, Gulshan 2, Dhaka 1212. Tel: +88 02 8835446, 8852990, 9884839, Fax: +88 02 9883429	Abamectin	
17.	ACI Formulation Limited, Novo Tower, 9th Floor, 270 Tejgaon Industrial Area, Dhaka 1208. Tel: +88 02 8870982-7, Fax: +88 02 8870988	Abamectin	
18.	SAMP Limited, House 280, Road 19/C, New DOHS, Mohakhali, Dhaka 1206. Tel: +88 02 9891521, Fax: +88 02 8714964	Abamectin	
19.	A. M. Traders, Globe Center, Flat No. 5-B, 28/1, Indira Road, Farmgate, Dhaka 1215. Tel: +88 02 9127333, Fax: +88 02 8159984	Abamectin	
20.	SAM Agro Chemical, House No. 2/7, Road No. 20, NS, Block A, Banasree Housing, Rampura, Dhaka 1219. Tel: +88 02 8396181-84	Abamectin	
21.	Nokon Limited, House No. 143, Road No. 13/B, Block E, Banani, Dhaka 1213 Tel: +88 02 8860585, 8836295, Fax: +88 02 8852988	Abamectin	
22.	Petrochem (Bangladesh) Limited, ABC Heritage, 3rd Floor, Plot No. 2 & 4, Jasimuddin Avenue, Sector 3, Uttara C/A, Dhaka 1230. Tel: +88 02 7911706	Abamectin	
23.	Mamun Agro Products Limited, Alpona Plaza, 5th floor, 51, New Elephant Road,	Abamectin	

Sl. No.	Name, address of the bio-pesticide producers	Product lists	Remarks
	Dhaka 1205. Tel: +88 02 8620136, Cell: +88 02 01713 013462, Fax: +88 02 9672104		
24.	Bismillah Corporation Limited, Azad Center, 4th Floor-D, 55 Purana Paltan, Dhaka 1000. Tel: +88 02 9571224, Fax: +88 02 9571224	Abamectin	
25.	Bangladesh Agricultural Industries, House No. 816, Road 05, Baitul Aman Housing Society, Adabar, Dhaka 1207. Tel: +88 02 9115328, Fax: +88 02 8125498	Abamectin	
26.	Green Care Bangladesh, House No. 16, Road No. 2, Shyamoli, Dhaka 1207. Tel: +88 02 9111487, Fax: +88 02 9111452	Abamectin	

Monitoring mechanisms

Monitoring mechanism according to pesticide ordinance and laws

Monitoring for quality assurance of different registered pesticides including bio-pesticides has been well documented in the pesticide ordinance and law. The government assigned inspectors are doing field level monitoring. The duties and responsibilities of a Plant Protection Inspector as per Pesticide Ordinance are as follows:

Duties and responsibilities of Inspector

(a) inspect any premises wherein any pesticides is being manufactured or formulated, repacked, the means employed for quality control and testing of pesticides and all record and registers relation thereto;

(b) inspect any premises wherein any pesticide is being sold or stocked or exhibited for sale or wherefrom any pesticide is being distributed;

(c) take samples of any pesticide which is being manufactured or formulated or being sold or stocked or exhibited for sale or is being distributed and forward them for test or analysis in accordance with these rules provided that a sample shall not exceed two pounds (one kilogram) in quantity;

(d) enter and search, at all reasonable times, with such assistance, if any, as he considers necessary, any building, vessel or place in which he has reason to

believe from personal knowledge or from information given by any person and taken down in writing that an offence under the ordinance or these rules has been or is being committed;

(e) seize such pesticide and all materials used in the manufacture thereof and all other articles including registers, cash memos, invoices, bills which he has reason to believe may furnish evidence of the commission of an offence punishable under the Ordinance or these rules.

The sample collected by the inspector are then sent to the Government Analyst for test or analysis by registered post or by hand in a sealed packed. Government Analysts are the "Chemist" working in the Pesticide Analytical Laboratory at PPW, DAE. The duties of Government Analyst for monitoring of pesticides/bio-pesticides are as follows:

- On receipt of a package from a Inspector containing a sample for test or analysis, the Government Analyst shall compare the seal on the packet with the specimen impression received separately and shall note the condition of the seals on the packet.
- In making the test or analysis of pesticide, the Government Analyst shall follow the method of examination of sample adopted or approved by the Standard Institution of the country. The sample should be analyzed in such a way as to determine the pesticide-properties and whether the ingredients as stated on the label are present and whether the pesticides contain any adulterations. If necessary, laboratory or field tests shall be made to determine the effectiveness, laboratory tests shall be made to determine the effectiveness of the pesticides as contained in the label.
- After the test or analysis has been carried out, the Government Analyst shall forthwith supply to the Inspector a report in triplicate of the result of test or analysis.

Offences and penalties

Any person who

(a) sells, offers or exposes for sale, holds in stock for sale or advertises a registered brand of a pesticide which is not of the nature, substance or quality which it is represented to be by the brand or mark on the package containing it or, as the case may be, on the tag or label attached thereto; or

(b) falsely represents a pesticide in an advertisement; or

(c) contravenes any of the provisions of this Ordinance or the rules for the contravention of which no other penalty is provided in this Ordinance, shall be punishable, for the first offence, with fine which may extend to [fifty thousand] Taka [US$650] and for every subsequent offence with fine which

shall not be less than [seventy five thousand] Taka [US$ 975] or more than [one lakh] Taka [US$1300] and in default of payment of any such fine with imprisonment for a term which may extend to [two years].

Field situation of monitoring mechanism

For various reasons, including shortage of manpower and resources, many of these provisions are not working well in the field level. Previously there was only one laboratory 'Pesticide Analytical Laboratory" of PPW, DAE was working on the quality control requirements but now several other well equipped laboratories, viz. Pesticide Analytical Laboratory of Entomology Division, BARI, Gazipur, Department of Chemistry, Dhaka University, Dhaka, Food Safety Laboratory, Mohakhali, Residue Analysis Laboratory of BCSIR, Dhaka are also working on field level purity analysis of pesticides, residue monitoring of different crops and foods. The Government Analysts are taking assistance of those analytical laboratories. Due to that recently the rates of adulteration of different pesticides have reduced. However, as bio-pesticides are newly introduced products in the country, so field level monitoring situation is not up to the mark till now. More training of the related persons, viz. inspectors, government analysts, scientists etc. should be undertaken on these issues.

Future prospects

In Bangladesh commercial use of bio-pesticides in the farm level has been started since 2005. However, the potentiality of bio-pesticides has increased substantially throughout the country after that very quickly. Extensive and systematic research and development works on mass production, storage, transport and application of bio-pesticides, augmentation and application of bio-control agents have improved both in public and private sector in recent years with the ultimate objective of improving its commercial production and use. Moreover, there was no legal system for commercialization of bio-pesticides, which also have opened after the amendment of Pesticide rules 1985 on 2010 with the incorporation of the provisions of bio-pesticide registration. Government also takes initiatives to develop eco-friendly, sustainable, socio-economic acceptable integrated pest management or IPM packages. In rice, Bangladesh has made significant stride in popularizing IPM at the farm level. However, presently more emphasis has been given on bio-pesticide based IPM research and developmental work on vegetables, fruits and other crops. Several effective bio-pesticides (especially sex pheromone) based IPM technologies have already been developed and became highly popular among the farm community to control the major pests of vegetables and fruits. Strengthening of IPM research for development of alternatives of toxic chemical pesticides and dissemination of IPM technologies has given top priorities. Popularity of different mass-produced parasitoids and predators are also being increased due to mass campaign by different GO and

NGOs on IPM and due to establishment of Farmers Field School (FFS) and activities of IPM clubs, Government has officially announced IPM as its pest management policy.

In Bangladesh private initiative on different bio-pesticide products development and marketing has been started since 2005. During 2005, only around 140 ha vegetable lands were cultivated using pheromone and bio-control agent with an approximate sale value of US$ 2200. However, the coverage of bio-pesticide increased several folds thereafter and during 2011 the coverage increased 214 times and sale volume increased 176 times, which is projected to increase to more than 400 time within next two years (Figure 6) in comparison to the initial market (due to opening of the commercial registration).

With the inactiveness of synthetic pesticides for controlling devastating pests due to growing of resistant pest population, increased environmental awareness, increase activities of IPM, widening of organic farming, more R&D of bio-pesticides etc., use of synthetic pesticides especially in case of insecticides are showing a declining trend, whereas the bio-pesticide market is growing. So, in Bangladesh there is a great potential to replace toxic chemical pesticides by bio-pesticides in near future if production protocols can be standardized and the private sector became more active.

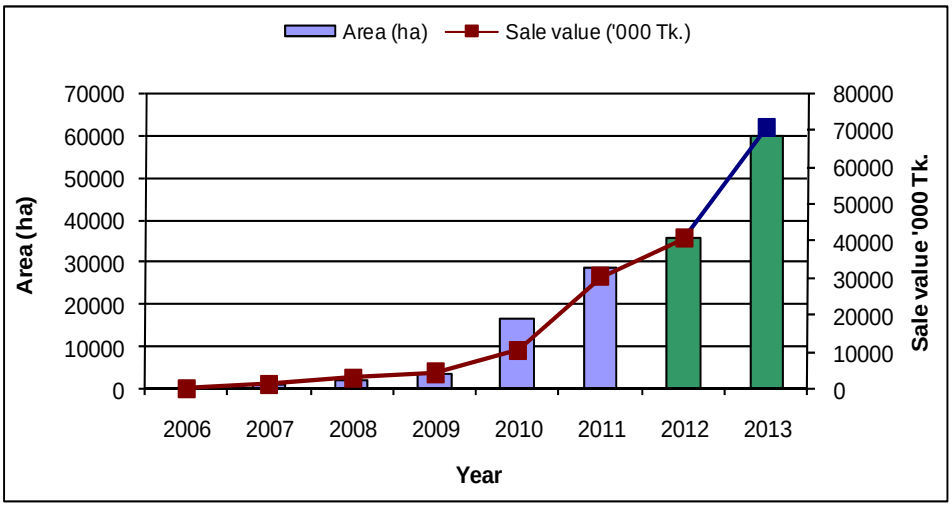


Figure 5. Area coverage and sale volume of bio-pesticides by the commercial companies in Bangladesh

Conclusion and recommendation

Pest management is a dynamic approach and pesticide is still essential for pest management. However, the pest management tools should be safe, cost-effective and have minimum risk or hazard to human and desirable components of

environment. In Bangladesh, till now research efforts have been unexpectedly slow and limited for the development of bio-pesticide based IPM technologies for different crops. As a result, the availability of bio-pesticide based IPM technologies for different crops lagged behind seriously for years, compelling the farmers to have no other option than to rely solely on pesticide use for pest management. So, extensive research work especially in the public sector should be undertaken for the development of effective and cheap bio-pesticide based IPM technologies against major insect pests and diseases. At the same time extensive promotional works all over the country should be undertaken for the quick dissemination of the developed bio-pesticide based IPM technologies. Steps should be undertaken to give legal permission to the authorities for easy availability of different bio-pesticides. Private sector should assist in different aspect to develop the commercial venture of the bio-pesticides, so that those products can be available at the farm level. At the same time strict quality control measures should be undertaken for the commercially available bio-pesticides. There should not be any subsidy for the toxic synthetic chemical pesticides. Massive awareness campaign among the producers and consumers should be done jointly by public – private institutes on the deleterious effects of chemical pesticides. Regional and international collaboration on bio-pesticide research and development should be enhanced. Especially a network among the bio-pesticide producing public and private institutes/companies can be developed under the SAARC umbrella to boost up the bio-pesticide industries in this region very quickly.

In that way a holistic and sustainable way of bio-pesticide based integrated pest management system for different crops should be undertaken thereby reducing the pest management cost with minimum risk or hazard to human and desirable components of their environment.

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CHAPTER 3

Papers from Bhutan

Extent and potential use of Bio-pesticides for Crop Protection in Bhutan

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Going Organic- A policy to develop agriculture in Bhutan

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Role of bio-pesticides in organic agriculture in Bhutan

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Extent and potential use of Bio-pesticides for Crop Protection in Bhutan

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Introduction

The Kingdom of Bhutan is a developing country located in the eastern Himalaya. The land area of Bhutan is 38,394 Sq km (LCMP, 2010) with over 70 percent of the area under forest (Table 9). Only eight percent of the country is arable out of which 2.93 percent is cultivated as small fragmented farmland following low cost subsistence farming methods. Like all neighbouring countries environment is key foundation that guides development in Bhutan. This is not only important to Bhutan's status as a clean pristine land that supports sustainable agriculture and livelihood but also plays extremely important role in the greater climate system across the Himalayas and the global water systems. Bhutan's constitution states that a minimum of 60 percent forest cover will be maintained at all times to come ensuring that this will be protected for the greater good.

Table 1. Landuse in Bhutan

Land cover type	Area (Sq km)	Area (%)
Forest Areas	27,053	70.46
Cultivated Agriculture Areas	1,125	2.93
Built up areas	62	0.16
Other areas	10216	26.61
Country Area	38,394	100

Source: PPD, MOAF,

The farming practiced in Bhutan is mainly traditional and low input systems, but a few intensively grown food crops and cash crops do rely on synthetic agro-chemicals although at very low levels of application. While compared to other countries the usage of agrochemicals per land unit is very low, but there is an increasing trend of herbicide use in paddy and potato mainly due to farm labour constraint. Bhutan is getting more attention as a nation that aspires to be organic by phasing out all synthetic agrochemicals. Currently, a total of 40627 acres of arable land are under organic management of which 2069 acres are agriculture and horticulture crops with organic intent after trainings were given. 38558 acres are under certified organic for wild crafted lemon grass for essential oil in community forests.

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The government ensures that farm inputs are made available at the same price at all district centres but there is no subsidy on the actual cost of the farm inputs. For organic farmers who choose to buy additional compost or bio-pesticide the full cost including transport cost has to be paid since the supply of bio-products are not formalized as regular farm inputs although not excluded explicitly.

Bhutan has a plan to going organic nationwide in the future which indicates that there is need for change in the way farm inputs are made available to the farmers. Currently Bhutan does not have any manufacturing plants of any agrochemicals. There is a need to look at the coordination of supply chain and facilitation of bio-pesticides and bio-fertilizers in the country. The trends in agrochemical pesticides use over years indicates the need to find alternative pests and weeds management methods or for conversion to organic, and keep the increasing trends in check and reverse the growing trend as shown below.

Pesticides use trend

Over the past few decades as a result of various initiatives of the government such as introduction of cash and carry system, phasing out of toxic pesticides in WHO class 1 and 2a, and education awareness about adverse effects of pesticides, the use of insecticides has decreased drastically, while there is a gradual decrease in fungicides use. However, there is an upward trend in use of herbicides due to *Butachlor* application for rice weed control and *Metribuzin* for potato weed control and haulm destruction. Further, the increasing trend in herbicides use has been attributed to shortage and high cost of labour for weeding operation.

Withdrawal of subsidy on pesticides since 1990 in a phase wise manner is another important policy decision taken by the government to discipline commercial orchard owners and farmers from misuse of pesticides. This had a positive impact on all sections of farmers and they have been very careful in placing demand for pesticides.

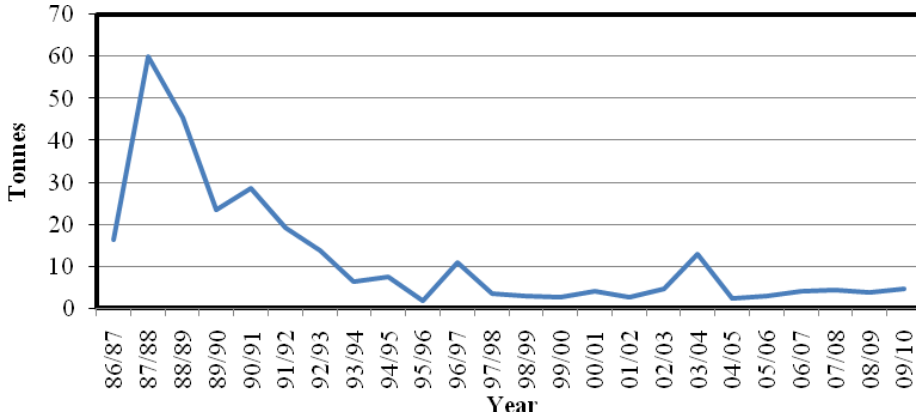

Figure 1. Annual use of insecticide in agriculture

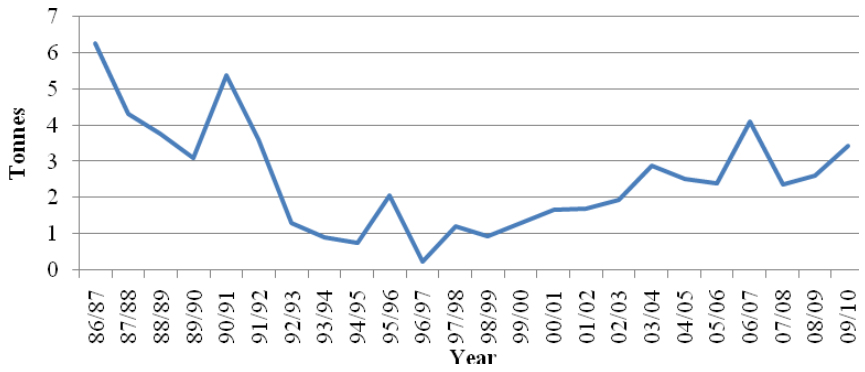

Figure 2. Annual use of fungicides in agriculture

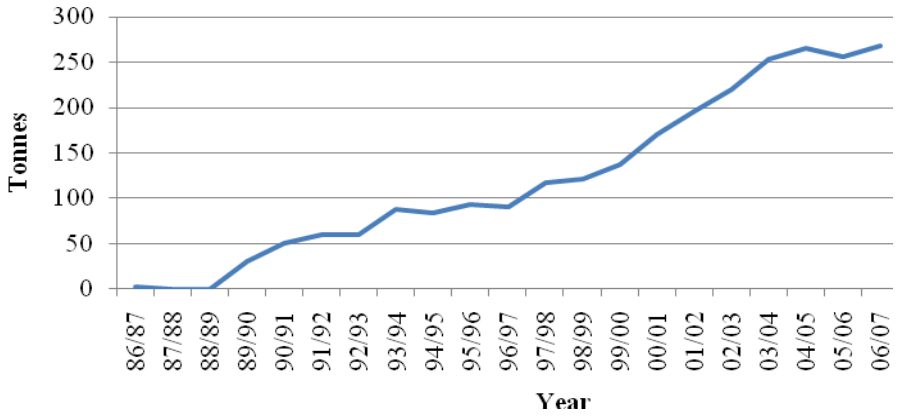

Figure 3. Annual use of herbicide in agriculture

Weed management is a major issue in organic production and one of the biggest obstacles for conversion to organic due to common constraints of labour shortage. This can be seen from increasing trend of herbicide use as compared to other pesticides. MOAF will have to consider alternative measures or investment in R&D of weed management and appropriate tools and machinery suitable to Bhutanese terrain.

Policy and Institutions regulating pesticide use

The Pesticide Act of Bhutan, 2000

The Pesticide Act outlines the import and use of all agrochemical in the country. In this Act one can see from extract below that while the need for pest control is recognized all caution is to be observed to depend on the least harmful methods of pest control. And if needed Integrated Pest Management (IPM) and least toxic agrochemicals that are efficient should be chosen although it does not say anything explicitly on bio-pesticides.

Extract from the Pesticides Act of Bhutan, 2000

In Bhutan although IPM principles are followed as guidelines for pest management, there are no rules and regulations to make it mandatory practice. While the Act exists an implementation plan is not in place to ensure that the Act is followed. Making IPM as the mandatory practice for pest management is an essential step combined with encouragement to choose bio-pesticides will play an important part for conversion into organic system.

The objectives of this Act are:

- To ensure integrated pest management is pursued, limiting the use of pesticides as last resort.
- To ensure that only appropriate types and quality of pesticides are introduced into Bhutan.
- To ensure that pesticides are effective when used as recommended;
- To minimize deleterious effects to human beings and the environment consequent to the application of pesticides; and
- To enable privatization of sale of pesticides as and when required.

Economic Development Policy, 2010

The Economic Development Policy (EDP) spells out tax incentives for commercial farms and organic based business that could also include bio-pesticides production plants and promotion of use of alternative pest management technology. This will indirectly benefit the primary producers of organic sector with safer and wider choice of farm inputs. Other points in this policy that supports businesses based on minimum ecological footprint, sustainable natural resources and reduction of fossil fuel use are in line with organic principles. This document also spells out that agrochemicals will have to be phased out and that there needs to be a policy reform for agriculture and biodiversity. Again this policy is not implemented fully; however there is room in the future for development of bio-pesticide industry in the country supported by this policy as can be seen from the various sections in the policy document below.

Strategies

- Diversify the economic base with minimal ecological footprint.
- Harness and add value to natural resources in a sustainable manner.
- Increase and diversify exports.
- Promote Bhutan as an organic brand.
- Promote industries that build the Brand Bhutan image.
- Reduce dependency on fossil fuel especially in respect to transportation.

Agriculture and Biodiversity- Policy reforms

- Promote organic farming through use of viable alternative farming methods and inputs
- Phase out use of harmful chemical fertilizers and pesticides.
- Promote commercial farming.
- Enable provision of integrated rural services through one-stop farmer services to reduce time and resource farming of organic produces.

Sector specific incentives in agriculture

The Royal Government shall provide the following support and incentives:

- All farm machinery shall be exempted from sales taxes and import duties.
- Sales tax and customs duty shall be exempted on any other agricultural inputs.
- Income tax holiday of 10 years for commercial farming and related processing of its products from the date of first sale and established during 1st January 2010 to 31st December 2015. An additional 5 years tax holiday for commercial farming of organic produces.

Institutions regulating pesticide use

Quality Control of Pesticides

National Plant Protection Centre (NPPC) is responsible for checking the quality of pesticides imported into the country on behalf of the Ministry of Agriculture before such inputs are allowed to be imported. The selected products are listed with names of companies of reputed registered companies in India.

Registration of Pesticide Products and Manufacturers

Bhutan does not manufacture pesticides or bio-pesticides. Pesticides available and used in Bhutan are imported mostly from India. After identification of pesticides, the Bhutan Food and Agriculture Regulatory Authority (BAFRA) will register pesticides and suppliers, based on technical information given by the NPPC. The Bhutanese suppliers launch application for formal registration as “supplier of pesticides in Bhutan”. As soon as the Pesticides Rules are notified under the Pesticides Act 2000 the identified manufacturers of pesticides and bio pesticides as well as new product manufacturers in India and other countries are imported as under the provisions of Pesticide Act and the Rules.

Inventory of bio-pesticides used in agriculture sector

There has been little import and use of bio-pesticides in Bhutan except for trial purpose in the past few years. Below is the biggest quantity of bio pesticides and range of products imported for trials and promotion of use as alternatives to synthetic chemicals. Small quantities of bio-pesticides between 10 litres to 55

litres were imported from 2006 to 2009 for trials and there was no import for two years in 2010 and 2011. The products and the quantities varies according to the trials being carried out in the country mainly by NPPC or for trials and alternative crop protection for organic growers facilitated by National Organic Programme under NPPC's guidance.

Most farmers practicing organic agriculture are encouraged to produce local botanical extracts with available local plants that are not eaten by the livestock or are traditionally known for pest control in crops or animal husbandry. This has been the primary approach because for sustainable farming it is best if farmers can produce solutions for their crop protection in the locality instead of building a dependence on imported bio-pesticides. While this approach may serve the needs of small growers growing for home consumption and local needs, this needs supplementation when the cropping scale increases and there is outbreak of pests and diseases in the crops of economic importance.

Different methods and recipes of making farm inputs are taught to the farmers through farmers' trainings practically by using plants and food materials available in their villages based on cow dung and cow urine. This is compiled in the Training Manuel for Organic Agriculture by NOP. This is the organic farmers' first line of action for crop protection, after which they contact NOP and NPPC for further support through the extension system.

There is very little awareness of the use of and availability of bio-pesticides in Bhutan. The few who are aware of the hazard of agrochemicals and concerned about health do not know about the procedures of indenting for supplies and end up not getting adequate quantities when they want ad as supplies are short.

Table 2. Bio-pesticide products used in agriculture/livestock/fisheries

Bio-pesticide products	Target crop	Target pest/disease	Application mode	Application rate	Remarks
Mycomite	Tea, Plantation/Agro-ecosystem	Red spider mite, other pests such as thrips, aphids, leaf roller, flush worm, tortrix and other caterpillars	Foliar spray	500 ml in 500 litres of water for knapsack sprayer or in 400 litres of water	Multiplex farmer company, India
Niprot	No specifications	No specifications (Antagonistic fungus)	Seed treatment, Nursery bed treatment, Cutting and seedling dip, Soil treatment,	Mix 10 g to coat 1 kg seeds; 5g/litre of water/m^2 area; 200g in 15-20 litres of water; Mix 1 kg in 100 kgs of FYM	PCI, India

Bio-pesticide products	Target crop	Target pest/disease	Application mode	Application rate	Remarks
Bio-power	Cotton	Bollworm, whitefly	Foliar spray	Dissolve 2 kgs of Bio-power in 500 g of jaggery with 400 litres of water	Stanes, India
Biorakshak	No specifications	All kinds of Loppers & caterpillars, Grubs, Red slug caterpillar, Bunch caterpillar, Heliothis, Spodoptera, Diamond back Moth, Tea Twig caterpillar etc	Foliar spray	0.8 ml/litre or 320 ml/ha	Shakti Bio Systematic Pvt Ltd, India
Metarhizium	Vegetables, ornamentals, indoor and outdoor plants, nurseries, green houses, commercial landscape, turf	Soil borne grub, white fly, aphids, mealy-bugs, eggs of lepidopterean pests, adults and larvae of many kinds of pests	Foliar spray	3 g per litre of water at 10 days interval.	Multiplex farmer company, India
Bio strike	All crops	Sucking pests, mites, thrips, lepidopterean caterpillars and fungi	Foliar spray	2-3 ml per litre of water at gap of 15-20 days between the sprays	Multiplex farmer company, India
Baba	Agriculture/Horticulture and Plantation Crops	Whitefly, Aphids, Thrips, Mealy bugs	3 grams in 1 litre of water	Foliar sprays	Multiplex farmer company
Neem ban (1500 PPM)	Cotton, Paddy	Whitefly, boll worm, thrips, stem borer, brown plant hopper and leaf folder	Foliar spray	3-5 ml per litre of water	PCI, India
Neem ban (50000 PPM)	Cotton, Cauliflower, Ladyfinger, Tomato	Caterpillars, Pink mites, Red spider mites, thrips, Aphids, Whitefly, leaf hopper, Pod borer/fruit borer	Foliar spray	2-3 ml per litre of water	PCI, India
Lastraw	No specifications	Spider mites, aphids, thrips, hoppers, mealy bugs and white flies	Foliar spray	Spray 2-3 times at weekly intervals @ 5ml/litre of water.	PCI

Bio-pesticide products	Target crop	Target pest/disease	Application mode	Application rate	Remarks
Su-mona	No specifications	No specifications (Antagonistic bacteria)	Seed treatment, Nursery bed treatment, Cutting and seedling dip, Soil treatment,	Mix 10 g in sufficient water to make slurry to coat 1 kg seeds. 50g/litre of water/m^2 area, 20g in a litre of water, Mix 1 kg in 100 kgs of FYM	PCI

Quantity and extent of use

Bio-pesticide products	Quantity used (Tonnes)
Nalpak	1000 kgs
Trishul	25 kgs
Mycomite	10 ltrs
Niprot	80 kgs
Bio-power	20 kgs
Madhyam	75 kgs
Shakti	25 kgs
Biorakshak	4 ltrs
Metarhizium	25 kgs
Bio strike	200ml
Bio-fertilizer DURGA	20 ltrs
Jivras	50 ltrs
Baba	25 kgs
Azab	25 kgs
Neem ban	170 ltrs
Lastraw	20 ltrs
Su-mona	40 kgs
Spic surabi	1600 kgs
Annapurna	3000 kgs

Best practices in bio-pesticide application

Bio-pesticides are being promoted to be used in all vegetable production so that agrochemical use can be reduced. Even the use of bio-pesticide is being treated like agrochemicals and used as and when required as last resort if homemade botanical extracts do not work or when they do not work adequately. For smallholder farms and small vegetables production which are majority of growers are taught and advised to use homemade botanical extracts from local weeds.

As in all other agrochemicals bio-pesticides need to be imported under the guidance of the NPPC and permission of BAFRA from reputed companies that have adequate research and results to show with accreditation.

Success stories in bio-pesticide use

In 2013 there was an outbreak of armyworms in the country in many of the districts in crops that were in seedling stage. The two districts of Bumthang and Gasa that practice organic vegetables and other crops in a few groups the extension officers informed the NOP early to report the incidence and also request for bio-pesticide to be sent immediately to control the problem. Neem oil was sent to Bumthang and Gasa Dzongkhags (*district*) respectively to be used on armyworms. The problem of armyworm was adequately controlled while in many other districts suffered losses.

Monitoring mechanisms

Currently the use of bio-pesticides is being monitored through the regular system of agriculture extension supervised by the NPPC and additional observation by the NOP in organic farmers groups. BAFRA have field inspectors in every district to monitor and report any defaulters who might import or use illegal farm inputs.

Future prospects

With the promotion of nationwide organic production and unpredictable climate, pest and disease outbreaks there is need to increase research on management of crops with bio-pesticides. There is need to work on local product development and regional information exchange on traditional knowledge and increasing regional capacity to manage crops in more sustainable manner. There is growing interest in using safer plant protection materials such as bio-pesticides and fungicides and for crop production even conventional crops for health reasons. There is however, need to communicate such information on availability of alternative inputs to the public so they do not resort to hazardous synthetics as a first and only solution. There is need to revive promotion and adoption of integrated pest management (IPM) as was tried and found useful in the past coupled with use of bio-pesticides.

If Bhutan is to pursue the goal or becoming organic or phasing out agrochemicals there is need for an equally matching research and development plan in plant protection solutions first along with soil fertility management. With Bhutan's plan for transmission by areas and locations with potential for organic production there is plenty of scope for promoting bio-pesticides in Bhutan.

Bhutan's organic transition plan

Land Category	Status of farming	Development approach
Category 1	Naturally organic, remote areas, areas within National Parks, high altitude areas	For conservation of area/ watershed, biodiversity, household nutritional needs and food basket security. Developing integrated self reliant farming systems. Many NWFPs and highland products may be covered within this category. Local assurance
Category 2	Selected areas selected products linked to potential markets in local proximity	Production for local markets and building towards surplus production for market orientation. Farmer groups organized to produce for mainly local markets, e.g. hotels, resorts. Local assurance organic products for domestic market, certification on demand
Category 3	Any area suitable for production, any products identified as suitable for production for assured market	Contract growing or commercial scale production targeting export markets, may be certified

Bhutan has limited capacity and human resources to carry out extensive work but if one of the bigger countries in the region can lead Bhutan can join force to collect local information and contribute to the larger output. Since Bhutan is targeting to become organic in the future this work is critical and of very high priority. The sooner natural alternatives can be found to replace the toxic chemicals the faster Bhutan can reach the goal of becoming organic as a nation.

Having a good information exchange programme among the regional countries to share practical workable technology at farm level will help many more farms in South Asia to become less dependent on harmful products and result in developing a healthier food system free of agrochemicals.

Conclusions and recommendations

It is a fact that agricultural subsidy in Bhutan is negligible but if conversion to organic is to be promoted there is need to increase support technically, in research and development and human resource capacity to boost organic production. Supports are especially required to make bio fertilizers and bio pesticides available either through imports or local production in country so it is easily available through mainstream channels to the farmers who are involved in organic production.

There is slow growth of use of pesticides and fungicides but rapid growth in the use of weedicide except when there is outbreaks of pests. The growing interest in use of bio-pesticides needs to be supported by developing a system of delivery that is farmer friendly. The biggest concern for Bhutan is the growth in use of weedicide that is due to mainly lack of adequate labour available in the country. Solutions for alternative weed management or environmentally friendly alternative bio-weedicide is critically needed if Bhutan is to reduce the use of agrochemicals in our farming system.

Currently only neem oils (Neemban, Lastraw) and trichoderma are the only products people are beginning to get familiar with while a few other products are being tried with the Research and Development Centres. There is need to upscale the communication and education of users of different products available in the market in the country. To support the vision of going organic, the MOAF has plans to work towards phasing our agro-chemicals where technically possible at the earliest time as and when good alternatives are found. This means Bhutan will need to invest in research, development and investment in promotion of alternatives in a bigger way. Exchange of technical expertise, collaborative research and development may be some way to develop regional knowledge.

Having a collaborative programme for the region for disseminating information, knowledge and skills in plant health management and judicious use of bio-pesticides preferably in local product development and farmer empowerment is recommended so the SAARC region develops a strong knowledge and solution bank for environmentally friendly food production

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Ministry of Economic Affairs, 2010, Economic Development Policy

PAPER 2

Going Organic-A policy to develop agriculture in Bhutan

Mahesh Ghimeray[4]

Background

Bhutan is a small landlocked mountainous country located in the southern slopes of Eastern Himalayas. The country lies between latitudes 26°42'N and 28°14'N, and longitudes 88°44'E and 92°07'E. The country has a total geographical area of 38,394 square kilometers with a population of 745,600 people. The forest cover of the country is about 70.46% but the cultivated land is only 2.93% of the total area. Agriculture is the mainstay of the people with an estimated 69% of the population engaged in farming. Rice, maize, wheat, barley, buckwheat and millets are major cereal crops cultivated in Bhutan, however rice is by far the most important and preferred food crop of the Bhutanese. A wide range of agriculture and horticulture crops can grow year round in the agro-ecological zones from the wet-subtropical (150-600 m) with a mean annual rainfall of 2500-5500 mm to temperate zones (2500-3500 m) of mean annual rainfall of about 500-1,000mm. Agriculture is very important to the Bhutanese economy; the sector accounted for about 17.7% of the total GDP of the country in 2011 (RNR Stats, 2012). Majority of the Bhutanese farmers continue to practice self-sustaining, integrated and subsistence agricultural production system with small land holdings where farmers grow a variety of crops under different farming practices and rear livestock to meet their household food security.

Bhutanese farming systems

Over centuries, farmers have selected and cultivated a wide array of crops and varieties that have adapted well to their micro-climatic niches. The types of farming practices are determined by the agro-ecology, needs of the farmers, market demand and availability of water and farm labour. The country is divided into six major agro-ecological zones corresponding with altitudinal range and climatic conditions (Table 11). The alpine zone which covers the northern region is characterized by alpine meadows and is generally too high to grow food crops. In the cool temperate zone, rearing livestock is the most common way of living with some dryland farming. The main crops grown comprise wheat, potato, buckwheat, mustard, barley and vegetables. The warm temperate zone has moderately warm temperature except during winter when frost occurs and agriculture is widely practiced in terraced irrigated wetlands and drylands. In the wetland agricultural areas, rice is the main crop which is rotated with wheat, potato and several kinds of vegetables.

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The subtropical zone is warm with moderate rainfall allowing the cultivation of a wide range of crops. Rice and maize, mustard, barley, different types of legumes, vegetables a variety of fruit crops are cultivated. The wet subtropical zone has large areas for crop cultivation and suitable agro-ecological conditions that favours intensive agriculture. Rice is the main crop grown in summer which is rotated with wheat and maize that are grown in winter depending on irrigation. Irrigation sources are mostly rain-fed and dry up during winter.

Table 3. Major agro-ecological zones of Bhutan

Agro-Ecological Zone	Altitude (meters)	Temperature (degree Celsius)			Rainfall (mm per year)
		Monthly Maximum	Monthly Mean	Annual mean	
Alpine	3,600-4,600	12.0	-0.9	5.5	<650
Cool Temperate	2,600-3,600	22.3	0.1	9.9	650-850
Warm temperate	1800-2600	26.3	0.1	12.5	850-1,200
Dry Sub-Tropical	1200-1800	28.7	3.0	17.2	850-1,200
Humid Sub-Tropical	600-1200	33	4.6	19.5	1,200-2,500
Wet-Subtropical	150-600	34.6	11.6	23.6	2,500-5,500

Source: RNR Research Strategy and Plan Document, MoA, 1992

Farmers use manures, crop residues and forest litter as the main source of plant nutrients. Farmyard manure is the main source of plant nutrients that farmers apply at the rate of 3 to 5 t/ha. The manure production comes largely from the local cattle which accounts for 80% of the total cattle population in the country. The organic nutrient inputs are supplemented by imported chemical fertilizers and the annual figures reported in the last couple of years remained constant around 3000 MT. This is less than 7-10 kg of plant nutrient/ha of cultivated land coming from external inputs (Bhutan Climate Summit, 2011). The maximum use of NPK fertilizers is in potato in the form of Suphala. In food crops like rice and maize, topdressing of urea is common. The chemical fertilizer use is likely to increase with the demand for more food and the present drive for agricultural commercialization.

For weed control, two weedicide (Butachlor and Metribuzin) are mainly used. Butachlor is used in rice cultivation to control grasses and sedges as a pre-emergence weedicide. A large number of rice farmers in accessible areas use Butachlor. The total annual import of Butachlor amounts to about 400 MT covering about half the rice area. The quantity of Metribuzin (70 WP) used for weed control in potatoes and maize was 1757 kg in 2012. The use of insecticides,

mostly Fenvelerate, Cypermethrin, Chlorpirifos and Dimethoate is around 6339 litres per year. Among fungicides, Captan, Mancozeb and Ridomil are used and the quantity is around 2708 litres per year. Comparatively, usage of non-toxic chemicals like Neem oil and TSO is larger (9388 litres per year). Overall, the use of agro-chemicals is still limited in the country.

Policy on organic agriculture

The Economic Development Policy of the Kingdom of Bhutan (2010) is the apex government policy for all ministries, including agriculture. It aims to "promote a green and self reliant economy sustained by an IT enabled knowledge society guided by the philosophy of GNH philosophy." Two important strategies in the agricultural sector to realize economic self reliance are i) to harness and add value to natural resources in a sustainable manner and ii) to promote Bhutan as a Organic Brand. The policy reform for agriculture and biodiversity sector states that Organic Farming will be a major focus area for the Royal Government to promote Bhutan as an Organic Brand by exploring viable alternative methods and inputs. It also stresses to phase out harmful chemical fertilizers and pesticides. As sector specific incentives for agriculture, a tax holiday of 15 years is proposed for commercial organic farming (EDP, 2010). Promotion of entrepreneurship and businesses based on organic food processing, marketing, trading and retailing will be emphasized. Capacity building of stakeholders and investment in research and development will be prioritized.

In 2007, the Ministry of Agriculture (MoA) officially launched the National Framework for Organic Farming in Bhutan (NFOFB) which serves as policy document for the country. The NFOFB elaborates on the concept and rationale of organic farming in Bhutan, policy framework for promotion, strategic and action plans and the institutional arrangements for implementation of the policy. It asserts that a large rural population still practices traditional farming using forest litter and farmyard manure and there is a great potential of increasing and sustaining production through organic farming which combines scientific knowledge and methods to produce safe food. The stated mission is to develop and promote organic farming that will enable Bhutanese farmers and traders to provide safe, quality food, produce and products for local consumers as well as for other markets. Bhutan's vision is to develop organic farming as a way of life and become fully organic by 2020. Its broad strategy covers all the farming communities of Bhutan including subsistence farmers whose main aim is household food security and semi-commercial farmers who aspire for higher incomes and better living standards. A commodity approach is advocated for niche products that already have established markets. The following strategies and approaches are advocated:

1. Promote organic farming for food security and poverty alleviation in resource poor and remote areas with little access to inputs and markets
2. Maximize potential for organic products for cash income in areas close to markets and have advantage for market oriented production
3. Research, advocacy and awareness, education of producers, public, consumers and buyers to boost organic sector growth by supporting the whole value chain
4. Soil fertility and pest management and input replacement (synthetic fertilizers, agro-chemicals) for conversion to organic farming
5. Appropriate equipment and machinery for Bhutanese farming systems to enhance production and yields and reduce farming costs
6. Collective production, processing and marketing of organic produce by supporting common business platform
7. Provision of a system of regulation and framework for organic trading and administration for the sector.

Mainstreaming and implementation of NOP

The National Organic Program (NOP) is a cross-cutting program in the Ministry of Agriculture and Forests (MoAF). The primary role of NOP is to implement the National Framework for Organic Farming in Bhutan and support the sector development in the country. The NOP is guided by a Technical Working Group (TWG) consisting of 13 members from relevant agencies within the MoAF. The TWG is responsible for developing organic farming in Bhutan and provides overall guidance for the sector. It also coordinates stakeholders involved in agriculture policy formulation, research, extension, and marketing and in developing National Organic Standards. The NOP facilitates and coordinates program implementation and linkages between the stakeholders within and outside of MoAF.

All the MoAF agencies are expected to implement programs to achieve their targets with coordination and technical support from the NOP. All departments and non-departmental agencies under the MoAF are involved in the development of the organic sector and in implementing programs and activities related to their sector (NOP, 2011). Important agencies are:

- ***National Soil Services Centre***: lead in developing soil fertility management approaches and appropriate technologies for farmers
- ***National Plant Protection Centre***: provide a leading role in developing plant protection and disease management approaches and technologies for organic farming

- ***National Post Harvest Centre***: lead research and technology development for post harvest handling and management of organic produce and value addition
- ***RNR Research and Development Centres***: support NOP in generating and disseminating appropriate technologies in organic farming
- ***Bhutan Agriculture and Food Regulatory Authority***: in collaboration with NOP, develop organic standards management system and an organic certification system, regulate standards and facilitate organic certification, including the use of the national organic logo
- ***Department of Agricultural Marketing and Cooperatives***: create infrastructure and mechanisms to move organic produce to local and international markets; conduct market research and product development; make market information accessible to producers and consumers
- ***District Agriculture Extension Services***: lead in implementation of field activities.

Current Context and Future Prospects

Bhutan is known globally for its policies on environmental conservation which can extend to agriculture and food production systems. Bhutanese agriculture is often referred to as traditional which is experiencing a gradual transition to semi-commercial operations. With 69% of the population engaged in farming, RGoB accords a high priority for the development of agriculture sector. In the past, emphasis was laid on the provision of modern varieties and requisite inputs for higher production in line with green revolution elsewhere. However, with the current global movement for clean environment and natural products, Bhutan with a very low usage of agro-chemicals could easily become a pioneer in organic farming (Duba *et al.*, 2007).

As of 2011 there is more than 39,917 acres of land under organic management following organic cultivation and collection principles where awareness and trainings were provided by NOP and assisted in their transition to organic production. Of the total area under organic management over 1300 acres is under cultivation by farmer groups and the rest of the 38,558 acres under wild collection of lemon grass for oil distillation.

Lemon grass essential oil is the only certified organic product as of date and also the only organic product being exported. The area under certification will increase when all the lemon grass comes under certification. A total of 3.8 MT of oil worth Nu. 2.3 million was certified and bought from the distillers by Bio-Bhutan. Other products such as ginger, turmeric are also marketed by Bio-Bhutan. Some food produce is marketed locally and products from Paro and Thimphu are sold at the

Centenary Farmers Market where an Organic Sales Outlet has been opened (NOP, 2011). The farmer groups in the other districts sell their produce in the local market. Sweet buckwheat from Samdupjongkhar is processed and marketed in Thimphu retail shops.

Although abject poverty is almost absent in Bhutan, there are localized pockets where farmers face seasonal food shortages. For such poor and small farmers, food production capacity could be increased by raising yield levels through organic farming practices and linking with markets for income generation. Development of farming practices applicable to the soil and agro-climatic conditions, local crops, crop rotation and intercropping, efficient production and use of vermi-compost and manures from farm waste would greatly increase productivity of traditional farming systems. Conservation of biodiversity and natural resources is possible following organic practices. Organic farming has potential to contribute to eradication of poverty, promote gender equality, ensure environmental sustainability, and ensure better nutrition and health (Duba *et al.*, 2007). As poverty alleviation is one of the principal development goals for Bhutan, organic farming has greater scope for acceptance. Introducing organic farming in Bhutan should be a convincing policy action, simply because already many farms in Bhutan operate within the broad principles of organic farming, with a few exceptions.

Bhutanese farming is attuned to organic agriculture. As many remote areas in Bhutan are ‘organic’ by default and the low use of external inputs even in areas exposed to modern farming, it is relatively easy for conversion to organic agriculture. Traditional production systems are more attuned to organic production than the input-intensive systems. Traditional farming like in Bhutan is less dependent on external inputs and rely more on on-farm bio-resources for fertility maintenance. This requires less investment and effort to convert to organic agriculture.

Organic agriculture provides an opportunity to commercialize small holder farming. This can be illustrated by the case of red rice in Bhutan. Many rice farmers in the high altitude areas produce red rice for the export market (USA and Europe), where more than 300 tons of milled rice is exported annually. The exporter collects rough rice from the farmers at a predetermined price, processes and exports. It is a profitable business both for the producers as well as the exporter. Producers know that there is a ready market for their rice and are encouraged to grow at a larger scale.

Some of the multi-faceted benefits of organic farming are fulfillment of local food and nutrition requirement of growers, long-term maintenance of soil fertility, reduced use of external inputs, efficient risk management in farming, food with high safety standards, reduced environmental contamination and ecosystems balance.

Issue in Organic Agriculture

Lack of awareness and understanding

Being a relatively new concept, there is a lack of general awareness and understanding of organic farming at different levels. There is inadequate understanding on the concept, principles and practices of organic farming among or within the research community, extension workers or policy makers. Organic farming is often mistaken as traditional agriculture and considered regressive in relation to modern farming using green revolution technologies. The non-use of external inputs does not itself qualify as 'organic'. Organic agriculture uses scientific knowledge to improve traditional farming practices. Lack of access to knowledge is still a major constraint for the Bhutanese farmers.

Inadequacy of farm labour

Bhutan is a small country with an even smaller population of about 745,600 people. Of the total population only 69% are engaged in farming. Thus scarcity of farm labour is a critical and national issue impinging on food production and food security as a whole. Adopting organic principles and practices may require additional labour inputs, especially in managing soil fertility and pests than conventional farming. There is a need for more research focus on appropriate technology and farming systems based crop husbandry to improve farming and reduce labour while increasing total farm output.

Over emphasis on modern farming

The research system is basically geared towards testing and adopting green revolution technologies. All the research scientists are trained in conventional agricultural systems. The main focus of research is to increase production and productivity per unit area using modern inputs and technologies. The mainstream national research agenda and strategies essentially excluded organic agriculture in the past and continue to do so. Organic agriculture requires cross-disciplinary research, based on connectedness at all levels from farm to global markets. The entire research culture in the country has to undergo major transformation to embrace organic research. The scientists need to be retrained and reoriented to develop appropriate technologies for organic farming to succeed.

Conflicting role of District extension workers

Like the research system, the district extension network is run by personnel trained on conventional agriculture. Their main mandate is still the supply of inputs such as improved seeds and planting materials and the demonstration of modern farming using fertilizers and machines for labour efficiency and overall productivity. The extension personnel need to upgrade their skills and knowledge to reorient towards organic farming. Such a change has to be carefully considered for a healthy balance between organic and conventional agriculture. Often they

are caught in the dilemma of advising farmers both on modern and organic agriculture that can be conflicting.

Small and subsistence producers

Bhutanese farms are small, isolated, far-flung and widely dispersed. Production pockets in remote areas, where farming is still organic by default, are not easily accessible and the time and costs of getting any agricultural produce to the road head are high. Economies of scale are difficult to achieve under such circumstances. Securing adequate volumes for external markets becomes challenging.

Indifferent local consumers

Although the trend is gradually changing, the consumers within the country are by and large indifferent to organic products generally out of ignorance and a lack of awareness. This is not surprising, as most agricultural and food products produced within Bhutan are considered free of harmful contamination due to low use of pesticides or synthetic fertilizers. Most local consumers do not make a distinction between products from organic or non-organic farms. Price is another deciding factor. If the price of organic produce is significantly higher, which should be the case initially to recover associated losses from conversion, and then consumers may prefer conventional produce given the blurred differentiation between the two. Presently, organic products are sold at the same price as local produce with no premium in the local market. There is a need to differentiate, provide identity and added value to organic produce through consumer education and awareness.

Conclusions

Bhutan's first five year development plan was launched from 1961-66. During this period, the Department of Agriculture was established on 01 October 1961 to spearhead agricultural development. One of the recurrent themes or objectives of the FYPs was obviously to enhance food production and self-sufficiency. The main vehicle to achieve the objectives was through the use of improved varieties and seeds, and associated green revolution based production technologies. Initially, very little importance was attached to indigenous crops and traditional systems in Bhutanese agriculture. Despite this fact, farming systems in Bhutan remain largely traditional, dependent on available farm resources. Except for a few cases such as cash crops like potato, reliance on external or purchased inputs is still low. Traditional agricultural systems cannot be equated with organic farming; however transitioning from one to another can be relatively easy. Bhutan still has this option.

At the government level, there is a strong policy support for organic farming as evidenced by the Economic Development Policy, 2010. The economic policy

strongly supports green self-sufficient economy that bears significance and importance to organic farming. It also provides considerable incentives and tax holidays for commercial organic farming. At the Ministry level, the National Framework for Organic Farming for Bhutan is a potent policy tool to develop organic agriculture. It envisions that the country follows organic principles and practices in farming in line with the overall policy of sustainable development and green economy. Several mainstreaming and implementation mechanisms are already put in place. Prospects of success are high.

However, caution needs to be exercised and a pragmatic approach adopted while mainstreaming organic agriculture in the country. Since the start of planned development, efforts and focus have certainly been on modernizing agriculture based on green revolution technologies in order to rapidly gain a higher level of productivity and food self-sufficiency. Agricultural scientists and extension workers have been attuned to such an approach. A gradual shift and reorientation towards organic agriculture is required. Such a change will require time, patience and efforts. It should also be recognized that organic agriculture may not be amenable or even desirable in all nooks and corner of the country. Potential areas, crops and farming systems need to be identified where opportunities are greatest and success rate high for organic agriculture. A healthy balance between science-based organic agriculture and non-organic but sustainable farming needs to be struck. Bhutan prides herself as a nation of middle path; such a path should be paved for agricultural development in the country.

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Role of bio-pesticides in organic agriculture in Bhutan

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Introduction

Bio-pesticides have gained more impetus in the recent years with increasing concern for safe food and environmental benefits and sustainable agriculture systems. It is not surprising to note that much of the bio-pesticide is used in the conventional agriculture farms rather than organic farms around the world, owing to mainstream food production being under conventional systems. As the farmers do not see immediate direct benefits of bio-pesticide use, the push for use of bio-pesticide in agriculture is rather driven by environmental or consumer concerns or market opportunities from bio-pesticide manufacturers. Bio-pesticides are now an important tool for pest and disease management in under many conventional agriculture systems. However, for organic farming systems bio-pesticides are even more crucial, considering the fact that organic standards around the world do not allow use of any synthetic pest management inputs unless no alternatives are available or those considered as less harmful and required in small quantities. Globally there is a decreasing trend in chemical pesticide use at 1.3% over the last decade and an increasing trend in bio-pesticide use; however, bio-pesticide makes up only 4.2% of the total pesticide market. There is a clear signal that some of the chemicals used in the modern food production are associated with alarming health and environmental effects. Research and investment in bio-pesticide technologies have increased manifold in the recent years; the main reason for this boost may be associated to the need for technologies to replace egregious chemicals used in food production systems that had caused serious human and ecological damage. Similarly, with the growing demand for organic food in the international market, demand for bio-pesticide has increased. At a global scale among many bio-pesticides available, the most widespread key molecules include pyrethrins I and II, cinerins, jasmolins, azadirachtin, spinosad and rotenone.

In Bhutan, the thrust on bio-pesticide has increased in the recent years given that the country aims to make food production as sustainable and as organic as possible. The NOP under the MOAF promotes the use of bio-pesticide which may be prepared locally or availed from commercial manufacturers. These bio-pesticides are used in farms that are organic or those that are in transition to organic and focused of short term horticulture crops. However, the impetus is given on bio-pesticide technologies that can be produced locally rather than commercially available materials, which is guided by the principle of “low

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external input" under organic farming. This approach is also associated to the economic factor (cost of bio-pesticide) and the delivery mechanisms as most of the farmers are small holders and remotely scattered across the country. Therefore, the most efficient approach for pest management under organic systems in Bhutan is through appropriate farm planning, traditional knowledge, and use of local resources for bio-pesticide preparation.

Definition of bio-pesticide

Bio-pesticide technologies are exploited in many countries in different agriculture systems in varying methods of production and use. Thus, there appears to be several definitions for bio-pesticide e.g.: In the EU Bio-pesticides have been defined as "*a form of pesticide based on micro-organisms or natural products*". The US EPA definition for bio-pesticide "*include naturally occurring substances that control pests (biochemical pesticides), microorganisms that control pests (microbial pesticides), and pesticidal substances produced by plants containing added genetic material - plant-incorporated protectants (PIPs).* However, for NOP *"Bio-pesticide are substances or organisms of naturally occurring sources such as plant or animal products or micro-organisms or minerals that can be used for pest control as per National Organic Standards of Bhutan (NOSB)"*. Which clearly indicates that what is classified as a bio-pesticide under one system may not stand true for another system. Further the name 'bio-pesticide' itself is seen to have negative connotation, similar terms such as biological agents and natural enemies also lacks clarity, consumer appeal and does not describe bio-pesticide to its optimum functionalities. There is certainly a need to develop a strategic definition for bio-pesticide that can be understood and applied by its users and also used as generic marketing ploy.

The PROs and CONs of bio-pesticide

Bio-pesticides are seen as the most sustainable tools for pest management under both conventional and organic agriculture systems. Research and technologies on bio-pesticide in general are limited, however, to capitalize on the economic opportunities of bio-pesticide under the current green-sustainable agriculture technologies many multinational corporations are investing in the bio-pesticide R&D. Although, bio-pesticide may offer potentials for a sustainable pest management technology for future agriculture, there are several issues that needs to be addressed before it can become as a mainstream pest management tool. Some of the Pros and Cons of bio-pesticide that are currently discussed are as follows:

Pros

- *Less toxic*; although bio-pesticide may not be altogether safe to health they are much less toxic compared to most of the chemical pesticides
- *Increasing interest in bio-pesticide;* there is a growing interest in bio-pesticide from both growers' and consumers' as it seen as a safer product
- *Biodegrade more quickly*; as compared to many of the persistent chemicals bio-pesticide being of natural sources degrade much faster in the environment
- *More targeted to specific pest*; bio-pesticide are targeted to specific pest or organisms and therefore damage to beneficial insects are minimum
- *Maintain ecological balance*; bio-pesticide are not as effective as chemicals and therefore do not eliminate entire population of an organism and therefore maintain ecological balance
- *Lower cost than chemical pesticides*; when produced locally bio-pesticide can be more effective and low cost

Cons

- *Short shelf life*: in general one of the main concerns with bio-pesticide is short shelf life and sensitive to handling, transport and storage conditions
- *Limited field persistence*: as bio-pesticide do not persist for long in the field, re-application may add up the cost of production
- *Inconsistent Efficacy*: the field efficacy bio-pesticide is varied in different location and environmental conditions in contrast to laboratory results
- *Narrow target range*: bio-pesticide are target specific, therefore farmers have to use range of bio-pesticide to address various pest problems in field
- *Slower acting*: bio-pesticide are much slower in action and therefore may not address pest problems in epidemic scale
- *Labour intensive:* it can be a labour intensive activity if bio-pesticide are produced by growers at farm level

Need for bio-pesticide under organic systems

WHO (1990) reported 25 million acute chemical pesticide poisoning cases each year around the world. Further there is a serious issue of mishandling and storage of obsolete hazardous chemical pesticides in most of the developing countries. At global scale chemical pesticides is seen as a threat to humans and ecology at large, for this reason natural products has been extensively studied as a tool for pest management. Fortunately, for Bhutan due to stringent regulations on

chemical pesticide and sustainable agriculture development policy, there has been very limited issues and negative impact of chemical pesticides. Further the government's vision of promoting sustainable farming system and organic agriculture the importance of eco-friendly and less toxic farm input had become even more important. Bio-pesticide, therefore, plays a vital role in agriculture development in Bhutan. One of the most basic rationales behind choosing bio-pesticide for crop health management under an organic farming scenario is that it is less harmful to the user, consumer and the ecology, besides the fact that it may be more cost effective when produced locally. Over the recent years NOP had experienced that many of the local homemade bio-pesticide prove effective, however the efficacy can be location specific, seasonal and preparation/ application method dependant. Therefore, there is a need for in-depth research and documentation on specificity and efficacy of the local resources used for bio-pesticide preparation. There is also a need to improve technologies used in bio-pesticide preparation from local resources and to standardize locally prepared materials in terms of preparation and application methods.

Sustainable bio-pesticide technologies for organic farmers

Organic agriculture is guided by four core principles, of which minimum dependence on external inputs is extremely vital for the sustainability of the farming system. These principles encourage farmers to innovate and produce bio-pesticide and related pest management tools on farm. On the other hand farmers have access to hundreds of commercially available bio-pesticide in the market. Further, labour shortage, which is seen as a major constraint in organic farming, push farmers to prefer commercially available bio-pesticide, with the idea to save time and labour. Therefore, the question is whether commercially available bio-pesticide is the answer or is it truly sustainable for farmers to produce bio-pesticide on farm or should farmers take a middle path. Some of the central issues that need to be addressed are the high prices and timely accessibility of bio-pesticide to organic farmers. For those bio-pesticides that are produced locally by farmers needs to be standardized and appropriately researched and documented.

Use of local knowledge and locally prepared bio-pesticide has proven to be effective in many successful organic farms around the world. One of the strategies proposed under NOP plan is to institutionalize local bio-pesticide preparation under farmer group or cooperatives based on region specific local resource, knowledge and capacity. These local bio-pesticide products should be supported through basic infrastructure development, capacity building and standardization mechanisms. At individual organic farmer level, specialization and investment of time and resources will be minimum on bio-pesticide preparation and thus, farmers can focus on crop production and management rather than specialized input production.

Bio-pesticide technologies practiced by organic farmers in Bhutan

In general the term bio-pesticide is preferably used for commercially available natural crop protectants, however the use of locally prepared bio-pesticide using traditional knowledge are more dominant among organic and small scale farmers in the developing world (Table 12). In Bhutan many different traditional methods using materials of natural sources are still used by farmers to manage crop disease and pest. Under the NOP initiatives small scale action research and observational trials are carried out to test the efficacy of technologies adopted around the world for pest and disease management. These technologies are mostly picked based on the adaptability, efficacy and cost in Bhutan's local conditions (Table 13). Some of these technologies have been converted into a Training of Trainer tool and practiced by many organic farmers in Bhutan.

Table 4. Some common plants and plant extracts used in local bio-pesticide

	Product description		Product description
1	*Melia azedarach* extract	9	Horsetail tea
2	*Zanthoxylum spp* extract	10	Garlic brew
3	Garlic-chilli-ginger extract	11	Tomato leaf extract
4	Ash	12	Stem paste
5	Herbal tea	13	*Amrit Jalam*
6	Cow urine	14	Liquid manure
7	Artemesia	15	Bio-digester extract
8	Soap solution	16	Wood vinegar

Melia azedarach leaf/seed kernel extract

Melia (*Melia azedarach*) belonging to the family Meliacae is considered as a close relative and a substitute for neem plant. As Melia can be found growing abundantly in Bhutan, use of Melia plants (seeds and leaves) as extract is promoted for pest and disease control. Melia leaf extract is seen to have suppressing effect on feeding of leaf eating caterpillar and Melia seed kernel extract is seem to be effective against leaf miner, caterpillars, borers, hoppers, aphids, leaf folders as an anti-feedant and repellant. The extract is prepared by crushing leaves or seeds and soaking it in water inside a muslin cloth for 24 hrs or more. The extract is suggested to be stored for only 3 days. The preparation is most effective when applied as preventive spray at 15 days interval at the rate of 10%.

Table 5. Some of the common commercial bio-pesticides under trial and demonstration in farmer's field and research sites under NOP

Bio-pesticide	Target pest/disease
Mycomite	Red spider mite, other pests such as thrips, aphids, leaf roller, flush worm, tortrix and other caterpillars
Niprot	Antagonistic fungus for soil borne disease
Bio-power	Bollworm, whitefly
Biorakshak	All kinds of loppers & caterpillars, Grubs, Red slug caterpillar, Bunch caterpillar, Heliothis, Spodoptera, Diamondback Moth, Tea Twig caterpillar etc
Metarhizium	Soil borne grub, white fly, aphids, mealy-bugs, eggs of lepidopteron pests, adults and larvae of many kinds of pests
Bio strike	Sucking pests, mites, *thrips*, lepidopteron caterpillars and disease causing fungi
Baba	Whitefly, Aphids, Thrips, Mealy bugs
Neem ban (1500 PPM)	Whitefly, boll worm, thrips, stem borer, brown plant hopper and leaf folder of paddy
Neem ban (50000 PPM)	Caterpillars, Pink mites, Red spider mites, thrips, Aphids, Whitefly, leaf hopper, Pod borer/fruit borer
Lastraw	Spider mites, aphids, thrips, hoppers, mealy bugs and white flies
Su-mona	Antagonistic bacteria for soil borne disease

Zanthoxylum extract

Zanthoxylum (*Zanthoxylum aromaticum*) commonly referred as Sichuan pepper is very regular spice used in every household in Bhutan. The plant can also be found growing wild in many parts of Bhutan. The spice is known for its valuable aromatic oil. The extract from the fruits and seeds are known to have bio-pesticidal properties owing to the essential oil content. The experiments conducted in RDC-Yusipang reported control of cabbage butterfly larvae (caterpillars) in cole crops.

Garlic – ginger-chilli extract

This extract is prepared from garlic, ginger and green chilies at a ratio of 2:1:1 by mixing crushed 50gm of garlic, 25gm of ginger, 25gm of green chilies in 2Lts of water and 100 ml soap solution. The extract is sprayed on the target pest at 10% solution and the extract can be stored for up to 3 days effectively. Some of the

pests that are effectively controlled are fruit/shoot borers, caterpillars, leaf miner, army worm, aphids and fungal diseases in some cases; however, there is a need to undertake in-depth studies as the results are seen to be inconsistent when adopted in different locations.

Horsetail tea

Horsetail (*Equisetium spp*) is also commonly found weed specie in marshy areas in temperate Bhutan. The plant is known to have medicinal properties and lately horsetail tea is used against fungal diseases (like mildew, rust, scab, soil borne pathogenic fungi) especially on garden crops and also root dip and tree spray. The horse tea solution is prepared by chopping shade dried horsetail plant in fine pieces and soaked in 5Lts of water for 2 days; fine filtrate is sprayed as a fungicide at a 1:10 part solution.

Garlic brew

Garlic brew has been traditionally used for anti bacterial, bio-fungicides and insect repellent properties. Where 500gm of crushed garlic is mixed with 25Lts of cow urine and fermented for 1 week. The clear extract or filtrate is sprayed at 1:10 dilution on target crops for preventive and curative measure to manage pest and disease.

Tomato leaf extract

The tomato leaf extract is a very easy and useful pest management tool, whereby 3 kg tomato leaves and shoots is soaked in a container with 10 litres of water. The container is kept at ambient temperature for three days in shade and mixture is stirred once a day for 3-4 days. The observational results from Toktokha Organic Farm found effective results against aphids and cabbage butterflies, however, more studies are required to confirm the efficacy.

Wood ash

Use of wood ash to protect crops from pest is an age old practice in Bhutan. Wood ash also supplies some nutrients essential for plant growth. This practice is still carried out in many rural parts of the country. Farmers in southern belt of Bhutan have found the practice particularly effective against caterpillars and powdery mildew in vegetables.

Stem paste

The practice of stem paste in fruit trees is found particularly effective in a high altitude orchards, where stem scalding and bark splitting is a major problem. The stem paste provides shield against scorching UV radiation during late autumn to early spring when the trees are bare. The stem paste also provides protection against some stem borers besides supplying some essential plant nutrients. The

stem paste is prepared by making a paste from 50 kg cow dung, 10kg finely sieved sand and 10 kg clay with water. The paste is applied uniformly on the trunk, and main branches and laterals. This technology is practiced and demonstrated in deciduous fruit trees such as apple and stone fruits in RDC-Yusipang.

Herbal Teas

The herbal tea is prepared by mixing many strong smelling leaves or weeds not consumed by livestock (example; Artemisia, parthenium, cannabis, xanthoxylum, lantana camera, vitex Soap-nut, etc). 1kg leaves are finely chopped and boiled in 5 liters of water for 30 minutes. The clear filtrate is used as a spray at 10%.

Amrit Jalam

Amrit Jalam is a fermented cow dung based preparation adopted from practices by Hindu farmers. It is prepared by mixing 1Lt cow urine, 1kg fresh cow dung, 250gm jiggery and 10Lt water. The mixture is allowed to ferment for 1 week with thorough mixing every alternate day and the filtrate is used as a spray to manage pest problems. Farmers and extension workers in Chukha dzongkhag have reported excellent control against soft bodied insects like aphids besides promoting plant growth.

Cow Urine

Cow urine alone is found to be effective pest repellent and growth promoter by many farmers in south Bhutan. The preparation is very simple as cow urine many be directly sprayed with 1:10dilution or fermented. Several farmers and extension workers have reported disease control in crops.

Liquid manure

Liquid manure is a process of fermenting cow dung, cow urine with chopped plant parts. In many cases better results were achieved when insect/animal repellent plants were used. Liquid manure is prepared by mixing 3kg cow dung, 3 lts cow urine, 3 kg green plant material and water. The liquid manure is a good source of plant nutrient besides containing huge population of beneficial microorganisms and acting as a pest repellent. Many organic farmers are practicing this technology as it is proving to be more effective than cow urine alone. Further, many farmers with biogas plant in their farms, use the bio-slurry as an alternative to liquid manure with addition of plant parts to the slurry.

Conclusion

Bio-pesticides are without any doubt a holistic approach to sustainable agriculture in context of both organic agriculture and integrated pest management under conventional agriculture systems. Pest and disease management is a major hurdle in any farming system and this very cause has led to the explosion in the chemical pesticide industries and related businesses. Farmers, consumers and governments around the world are seeking out for sustainable, less harmful to health and ecology yet effective technologies in pest management in food crops. Bio-pesticide may be major part of the solution; however, there are many questions to be answered. There is a need for radical paradigm shift in the pest and disease management approach from an idealistic 100% control using chemicals to a more holistic integrated and sustainable pest population management approach. Promotion of use of multiple cropping system, indigenous knowledge and beneficial organisms as a tool to reduce pest pressure and finally use of less harmful, ecologically friendly and sustainable technologies as a last resort should be the mainstream pest management approach. Most importantly there is need for governments and research institutions to make major investment in bio-pesticide technologies. It is almost probable that many already recognize that bio-pesticide technology will play a significant role in realizing a sustainable agriculture system globally; it is therefore to see when the right attention and investment will be made to make bio-pesticide as the mainstream pest management tool.

Under organic agriculture systems bio-pesticide will remain a vital element in pest and disease management. National Organic Program will continue to support initiatives to promote farm based bio-pesticide production. There is a need to give greater thrust in terms of research and investment in both local and commercial bio-pesticide technologies. Bio-pesticide will certainly have significant role to play in Bhutan's vision of going 100% organic in the long run.

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Status of Integrated Pest Management in Bhutan

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Country Background

Bhutan is a landlocked country in the Eastern Himalayas (26°44' to 28°15' latitude and $88^0$15' and $88^0$44' to $92^0$7' longitude). It is located between the Tibetan plateau in the north and the Indian plain in the south. The total area of Bhutan is about 38,394 Km^2 (LCMP, 2010), and only about 7.8% is arable. The current population is estimated at 742,519 (Statistical Year Book of Bhutan, 2013). More than 69% of the Bhutanese people are engaged in agricultural activities. Bhutan is divided into six agro-ecological zones based on latitude and altitude, experiencing varied climatic conditions (Table 14). Farming in Bhutan is characterized by labor-intensive subsistence nature with relatively low intensity of farm inputs.

Table 6. Agro-ecological zones of Bhutan

Zones	Altitude masl	Temperature (°C)		Mean Temperature (°C)	Rainfall (mm)
Alpine	3600-4600	5.5	0.9	3.2	<650
Cool Temperate	2600-3600	22.3	0.1	9.9	650-850
Warm Temperate	1800-2600	26.3	0.1	12.5	650-850
Dry Sub-tropical	1200-1800	28.7	3.0	17.2	850-1200
Humid Sub-tropical	600-1200	33.0	4.6	19.5	1200-2500
Wet Sub-tropical	150-600	34.0	11.6	23.6	2500-5500

Source: National Statistical Bureau of Bhutan (NSB)

Land Use and Farming System

In Bhutan, only about 2.93% of the total area is cultivated and maximum area (70.46%) is under forest cover (Figure 10).The nature of topography in Bhutan makes agricultural mechanization more difficult, which affects the level of production. Bhutan also experiences extreme climatic conditions (short season). Most of agricultural lands are located in the narrow V-shaped valley bottoms and lower slopes. Farmers in Bhutan practice highly mixed farming system, cultivating both crops and keeping domestic animals, and depending on natural resources as major source of farm inputs. Agriculture production is highly diverse

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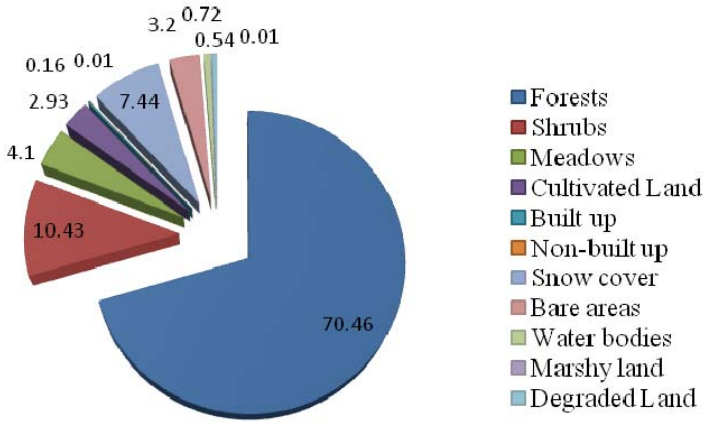
and management practices highly integrated growing multiple varieties of crops. Crops are cultivated both in wet and dry land with little portion utilized for horticulture crops (Table 15). Use of chemical fertilizers and pesticides are very minimal in agriculture production system. Such practices are highly discouraged and prevented through strong policy initiatives, regular awareness programmes and deliberations. Crop sequencing, growing different varieties of crops during different seasons is commonly followed by majority of the farmers.



(Source: LCMP 2010, MoA)

Figure 4: Land cover type in percentage

Table 7 : Cultivated Agricultural Land Use in Bhutan

Sub-class	Total Area (Ha)	Area %
Wetland	31361.23	0.82
Dry land	69670.79	1.81
Apple Orchard	2041.47	0.05
Citrus Orchard	5086.42	0.13
Areca nut Plantation	984.92	0.03
Cardamom Plantation	3397.95	0.09
Others	13.43	0.00
Total	**112556.20**	**2.93**

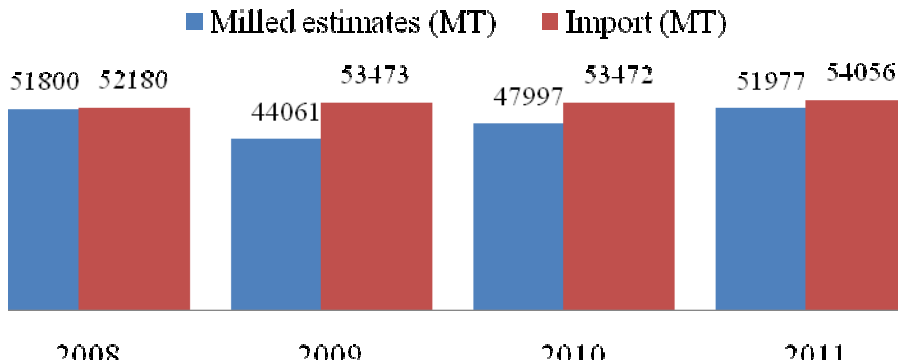
Source: LCMP 2010, MOA

Importance of Agriculture Sector

Agriculture sector is the single largest sector that provides livelihood over 60 percent of the population (Labour Force Survey, 2012), and meet 60% of the

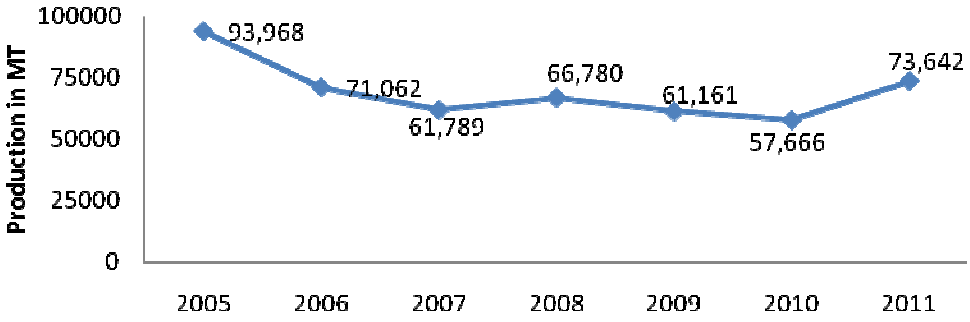
domestic consumption. Currently, the GDP share from Agriculture sector (Agriculture, Livestock, and Forestry) is 16.99%, and crop alone contributes about 9.98% (Statistical Year Book 2013).

Agriculture sector play a vital role in raising the per capita income of rural communities, enhance self-sufficiency in staple crops, and increase productivity of farm labour and agricultural land. Over the last few years, tremendous improvement has been made both in terms of technology adoption and market access development resulting into increased production of both cereal crops and horticulture crops (Fig. 11, 12, 13). Indeed, the growing of vegetable is gaining more importance as an import substitution given the country's current economic situation.



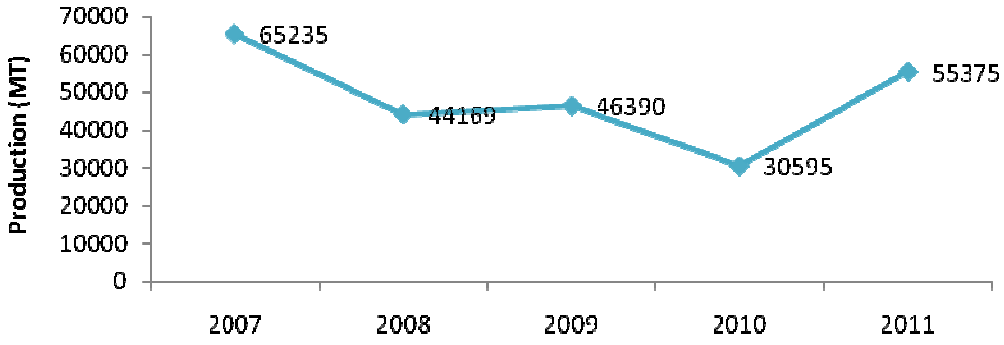
(Source: DoA, Annual Highlights 2012)

Figure 5: Paddy Production Trend



(Source: DoA, Annual Highlights 2012)

Figure 6: Maize Production Trend



Source DoA, annual highlights 2012

Figure 7: Vegetable production trend[1]

Evolution of IPM in Bhutan

The pesticides delivery system saw a significant evolution from unorganized independent procurement system to an organized and centralized system with NPPC institutionalized as the apex body for plant protection service. The program was supported through EU assistance (EEC project) during which many pest management reforms took place between mid 1980s to early 1990s covering 5thand 6th Five Year Plan (FYP) period. Prior to 1980s, pesticides were independently procured and distributed to the farmers. This not only resulted into abuse and misuse of pesticides; huge quantities of obsolete pesticides were accumulated in many agriculture stores across the country. During this EU supported project obsolete pesticides were collected and repacked under the supervision of external experts and stored for disposal. As an important part of pesticides reduction strategy, the subsidy for pesticides was withdrawn in phase-wise manner from early 1990s and simultaneously introduced cash and carry system. A plant protection inspector was also deputed during this period in each district to monitor the pesticide use and plant protection problems. By the 7th FYP, plant protection emerged from a pesticide-based system to an ecological IPM-based. These significant changes were mainly because of fast evolving government policies towards sustainable and environmental preservation. Since then IPM as strategy for plant protection activities was translated into advocating the research and extension knowledge into farmers' practice of pest management on an increasing scale especially during the second period of EU-support on Integrated Pest Management Project (IPMD) from the year 1990 to 2000.

[1] Vegetable production has increased tremendously during the year 2012 and 2013 (data not available) after the introduction of summer and winter vegetable growing programmes in Bhutan.

With fast growing agriculture production sector, agrochemicals like the herbicide use is increasing very significantly due to its effectiveness and ability to substitute manual weeding through hired labourers. Herbicide was never subsidized in the past.

Since the last couple of years, Bhutan has been focusing on identifying certain commodities and location for the organic products by taking comparative advantage of the pristine environment. The research and development efforts required for plant protection services that should make acceptable for organic production and certification has been much easier by already having plant protection services embarked on IPM technology. The IPM approach was also essential to support the promotion of commercialization of agriculture wherever organic production was not recommended due to lack of organic pest management technologies matching the conventional ones, could be demonstrated in crops like citrus, potato, apple and vegetables. The evolution of IPM continued to be the overriding pest management policy for the National plant protection services and gaining more importance under the current crop production systems. There will be further IPM technology development with increasing demand for agriculture production in future ensuring sustainability by practicing best bet pest management technology under the given agro-ecological systems and natural environmental conditions.

Important pest incidences and crop losses in Bhutan

No specific research was carried out for the extent of damages caused by major pest except for field experiences of plant protection personal who are working regularly in the field noted the incidence and extent of visible damages. During the time of significant epidemics, it was observed that Rice blast caused total loss of rice production for some farmers in Western Bhutan in 1995-96, and stem borer over 90% loss in Samtse district (in 2005); Turcicum leaf blight and grey leaf spots damage on maize was estimated as high as 70-80% in Eastern Bhutan in 2006/07; tuber moth, over 95% potato loss in Eastern Bhutan in 2006 and fruit fly up to 80% loss of mandarin orange in 1990. In the recent years, armyworm damage on paddy and maize had been very severe in almost all across the country. Under regular pest incidences, an average estimated loss (but not based on field study) for most of the pests and crops are in between 10-20% or less than 10% under well managed crop-pest systems.

IPM program progression

The foundation for the development and implementation of IPM was laid when the Royal Government adopted sustainable development as policy during 7th FYP (1992-1997). Since then, IPM strategy was geared towards safe and efficient use of pesticides and safeguarding the environment from pollution. Some of the

important strategies that led to the significant progression of IPM since its inception in agriculture pest management are described below.

Centralization of pesticide distribution system

Earlier to 1980s, pesticide procurement and distribution were fully decentralized to districts. Pesticides were independently procured and distributed to the farmers free of cost. Centralization of this system has brought major changes in terms of pesticide utilization and their management, making it more cautious and efficient system.

Collection and disposal of obsolete pesticides stocks

The uncontrolled imports of pesticides not only stimulated overuse of often very toxic insecticides, but also resulted in an accumulation of obsolete pesticides. The collection of unused pesticide stock was initiated since 1980s. In 1995, a total of 66 tones of obsolete pesticides were collected including 13 tones of fungicide, 23 tons of herbicides and 30 tones of insecticides from all agricultural stores all over the country (Table 16). These have been packed under the supervision of international experts and latter incinerated with the assistance of Swiss Government.

Table 8: Obsolete Pesticides

Pesticides	Quantity	Source	Remarks
Insecticides	30	MoA	17 MT of carbofuran returned to manufacturer
Fungicides	13	MoA	
Herbicides	23	MoA	22 MT of herbicide were reused in rice
Medical waste chemicals	4.6	MoH	

Source: MoA

Removal of Pesticide Subsidy

Pesticide subsidy had been a major constraint for IPM implementation. Until 1989, all types of pesticides, despite their persistence, mammalian and eco-toxicity were independently procured and supplied free of cost to the farmers. From early 1990s, the system was completely changed with regard to pesticide subsidies. Subsidies were removed in phase-wise and completely done away by 1995 (Table 17).

Table 9: Withdrawal of Pesticide Subsidy in Bhutan

Year	Withdrawal of subsidy (%)
1990 - 91	15
1991 - 92	30
1992 - 93	45
1993 - 94	60
1994 - 95	80
1995 July	100 (Complete withdrawal)

Source: Mid-Term Review, Final report -1996; IPMD

Cash and carry system of pesticide supply

The complete withdrawal of pesticide subsidies by 1995 has helped to prevent the misuse and abuse of pesticides. Following the subsidy withdrawal, cash and carry system for pesticides was introduced. The districts agriculture officer were mandated to collect the demand requirement before the start of the season and need to be submitted to NPPC along with cash before lifting pesticides. This system has further prevented the accumulation of outdated pesticides, which has been a serious problem in the past. However, the main drawback with this system is the availability of pesticide during the urgent need of farmers. Apart from past experiences, it is difficult to forecast any pests or diseases.

Import banned for toxic chemical

Between 1986-1990, several highly toxic and persistence pesticides like Aldicarb, Aldrin, Aluminum phosphides, BHC, Captafol, Ekaflux, Agallol, Methyl-parathion, Red lead and Thimet were banned for use in agriculture. Such initiatives became possible because of the full authority given to NPPC by the Ministry of Agriculture for the import, distribution and sale of agro-pesticides through extension network.

Policy initiatives and pesticide legislation

Though Bhutan neither manufactures nor formulates any kind of pesticides; the pesticide act of Bhutan was passed in June 2000 to regulate the import of pesticides, where NPPC was only authorized agency for the import, distribution and sale of pesticides. Only safer pesticides (except rodenticides), which are relatively safer to environment, less persistent, and pesticides falling under Class II and Class III categories as per WHO classification by hazard are being imported and used in the country. In addition, quarantine legislation was enacted to prevent the introduction of new pest and diseases. Since then, pesticide import is highly regulated.

Since 1980's, the pattern of pesticide use in Bhutan has changed considerably (Figure 14). The trend of pesticide use remained to be very high in the initial years of subsidization (Fig.14 & 15), but declined as the cost of pesticide rose. After removal of pesticide subsidies, the farmer would buy and use pesticides only if they expect to get a good return from their use.

However, herbicides were never subsidized in the past. There has been a steady increase in the use of herbicides over the years (Figure 15). The explanation for steady increase could be due to its effective control of weeds by herbicides and cheaper to use than manual weeding. Butachlor is commonly used to control almost all kind of weeds in rice except *Potamogeton distinctus* (Sochum) infested weeds that still need to be hand weeded at least three times during cropping season.

It is also worth mentioning the following relevant government initiatives and commitments that helped to develop IPM.

- Signing the Rio de Janeiro Convention (UNCED) in 1992
- Declaration and demarcation of 26% of total land as protected area in 1993
- Passing the Forest and Nature Conservation Act in 1995
- Environment Assessment Act 2000
- Biodiversity Act of Bhutan 2003
- Ratification of the Basel Convention in 2004 and subsequent destruction of obsolete chemicals with fund from Swiss Agency for Development Cooperation (SDC), Switzerland in 2006.
- Wang Watershed Project with focus on Farmers field School in 2000
- Organic program under horticulture division in 2008

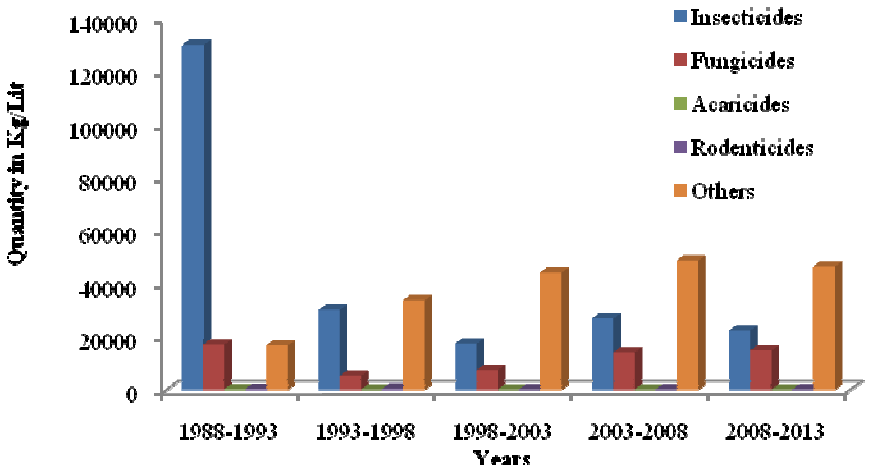


Figure 8: Pesticide use trend in Bhutan (Excluding Herbicides)

This policy initiative had been very helpful towards the promotion of IPM in the past decades. In the 10th FYP, the upgrading of organic section to organic program under horticulture division agriculture development policy to promote "Brand Bhutan" which is underway with plan activities focused on using bio-pesticides in the 11th FYP will help to further strengthen IPM programmes. The IPM programmes as focus of the organic programme will be on promotion of the good agriculture practices (GAP) and organic cultivation. These will be a complementary to the NPPC's programme focusing on the IPM measure for pest management with particular attention on bio control measures, and to further strengthen the future IPM base R& D and extension programmes in the field.

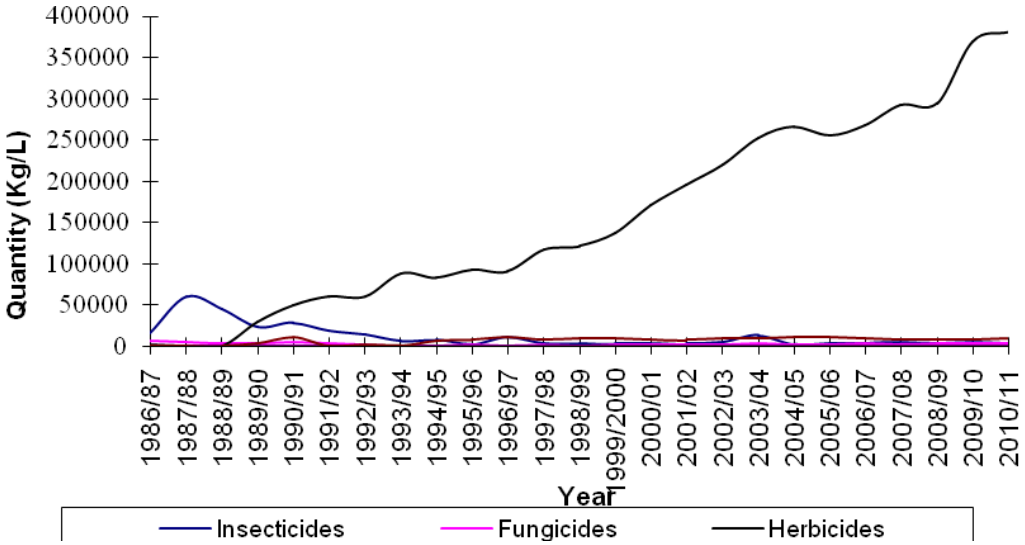


Figure 9: Steady rise in herbicide use as compared to other pesticide

Issues and problems as a result of pesticide use

Insecticides were most commonly used in fruits and vegetables. A prophylactic spray of fungicides was carried out for the control of rice blast in the past and lately for the corn blight control; the latter much integrated with cultural practices including quality seed use. Likewise, the cover sprays in citrus and scheduled sprays in apple and potatoes were commonly practiced before the implementation of IPM as pest management policy.

Many apple orchards before 1980s that followed calendar spraying ranging from 5-6 sprays per season resulted in emergence of spider mite (*Panonichu sulmi*) as a major pest in many orchards. Similarly, diamond back moth was reported to have developed resistance in the past to conventional insecticides in some Cole crops growing areas.

Besides abusive use in the field, huge accumulation obsolete pesticide due to free supply of to the farmers had to be collected and incinerated and some returned to manufacturing company. Until now, no issues related to herbicides use had been observed despite the fact that there is continuous and significant rise in consumption of herbicides like Butachlor. This may cause serious weed succession problem and environmental contamination if the current trend continues. There is high probability that farmers will increase the use of Butachlor if no other equivalent alternative is provided.

Success of IPM programs

Initially**,** the NPPC promoted IPM mainly in areas where farmers practiced calendar spray particularly by educating them on advantages and disadvantage of pesticides use. Subsequently, farmers were trained and encouraged on the concept of "as and when necessary use" of pesticide. This promotion resulted to reduced use of pesticides for the control of pests and diseases in pilot areas which was replicated in other areas at the latter periods. Some of significant achievements made through IPM are;

i. **Abandoned calendar spray in Apple**: With the introduction of IPM since 1993, farmers have given up the practice of calendar spray in apple. Unlike in the past spraying 5-6 times per season, they are practicing need based application of pesticides mainly during critical times. Prophylactic sprays against insect in other related crops had also been discontinued.
ii. **Adoption of bait splashing in Citrus**: After the introduction of bait splashing, farmers have abandoned the practice of cover spray for the control of fruit drop by fruit fly in citrus. Farmers are also carrying out the collection of dropped fruits to reduce the population of fruit flies in the following years as a part of fruit fly management activity.
iii. **Trunk borer and twig borer**: As recommended by NPPC; trunk borer in citrus and apple are managed by cleaning the hole with a flexible wire and inserted with a small piece of cotton wool or piece of cloth of the size of the hole dipped in kerosene. The hole is then plugged with mud. Whereas twig borer are managed through cutting the affected twigs and burning them after collecting.
iv. **Late blight control in Potato**: Farmers are now trained in the identification of the diseases and timely application of fungicides as soon as the disease is seen. This has helped to reduce the damages caused by disease which was very severe in the past that even wiped out whole crop. This has become common practice in all potatoes growing area in the country.

v. **Rice blast control**: Package of practices including seed replacement, seed treatment, disposal of infected straws, farmers training, nursery protection, pest surveillance, cultural practices/sanitation, use of resistant cultivar and as last resort finally spraying the crop in case the symptom is seen, have been put in place and are strictly followed. There is significant reduction of the disease incidences after 1995 rice blast problem after adopting IPM strategy.

vi. **Chili wilt disease control**: Cultural control method introduced by NPPC such as use of healthy seedling, crop rotation, proper spacing, planting in raised bed and a good drainage system has reduced the disease spread and widespread damages.

Socio-economic and income effects of IPM

There is no assessment of the impact except for some pilot areas in the past during the post period of IPM development project in late 1990. Besides being difficult to obtain hard data on the economic impact, it is highly constrained by limited qualified manpower inputs for obtaining reliable figures. In addition, to the sizable regional difference in Bhutan with respect to socio-economic factors, it is compounded by continuous shift in the pest spectrum. Besides the general benefits, some of specific economic impacts of IPM could be highlighted;

- In apple, previous calendar sprays of 5 to 6 times have been replaced with need based 1 to 2 sprays with no reduction in the quality and quantity of crop being harvested. There are reduced expenses for chemical purchase and regular manpower required for the spray.
- Expensive cover sprays in citrus for the control of fruit fly has been replaced with cheaper and specific bait sprays resulting in more economic and effective control of the pest.
- In potato, farmers who practice a reasonably good management of plant protection could obtain 6-7kg for every kg of seed planted in comparison to earlier national figure of 4kg for every kg of seed and likely to increase up to 12-13kg for every Kg of seed.
- In maize, seed change, cultural practices and spray of chemical has reduced the diseases incidences and regaining the optimal yield.
- Wang watershed project based through Farmers Field School that followed IPM approach in combination to good agricultural practices experienced up to 60% higher yields in potato, chili, tomato, cabbage, and broccoli crops.
- Non-required prophylactic spray for the control of rice blast has direct impact on expense for chemical purchase and rice quality improvement, growing organically.

Realignments in the plant protection programs for IPM

NPPC has been advocating IPM approach since late 1980s for managing many plant protection problems including vertebrate pests. Since that time, for the research and development of pest management measures, NPPC has been following the IPM approach in all its activities including extension trainings, presentations and teachings at College of Natural Resources, advisory services or deliberations. As a result, the National Extension System has also taken the IPM approach in the effort of pest management.

Currently, there are 205 blocks under 20 districts with each extension personnel in each block. Under the direct supervision of District Agriculture Officer these extension officers are responsible for the implementation of IPM in the field. NPPC, in collaboration with research centers, extension and farmers is responsible for carrying out research and development activities for the development of IPM measures on particular pest. The IPM measures developed are evaluated, validated through farmers participations are then imparted to extension through various means like training, workshops, visits, and extension materials distribution. The schematic diagram represents collaborative research and development of IPM and dissemination of IPM technology to the farmers (Figure 16).

Beside the formal research and extension system, IPM measures are normally discussed and highlight during important forums like annual planning and review workshops, meetings and conference, etc. to receive feedbacks, discuss technical collaboration, endorsement and policy direction. The technical forum has been very useful in bridging the coordination and linkage gaps between researchers and extension, by fostering the professional exchanges. District extension services is playing huge role in IPM extension through exchanges and deliberations with extension personal during such meetings.

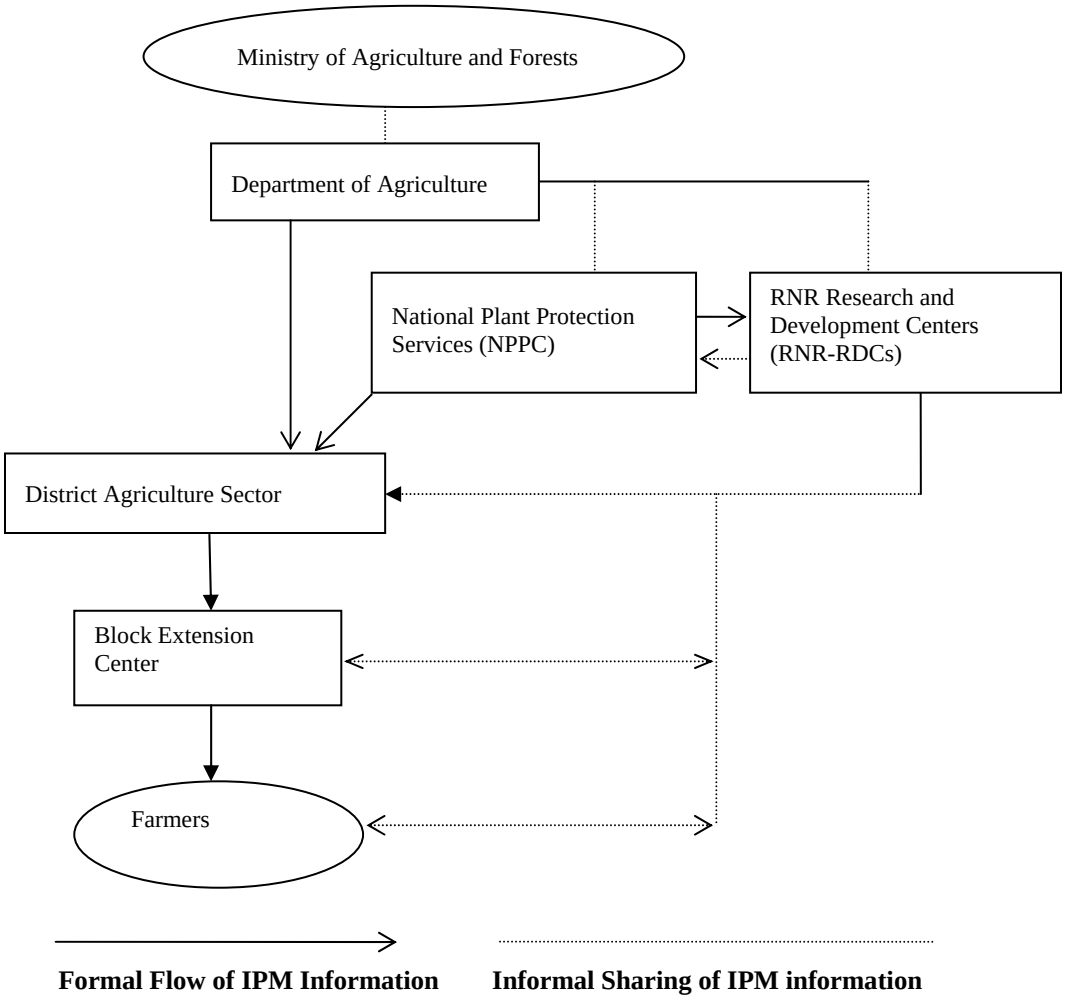


Figure 10. The flow of IPM information and Collaborative research networks

Ongoing initiatives on IPM development

e-Pest Surveillance System

The NPPC has been working on introducing e-pest surveillance system in Bhutan from last few years. Through this system, it is expected to obtain real time information, from location or crops specific pest information for implementing pest specific plant protection service delivery system in future. This will enhance management decision of farmers for selecting pest management options and also would enhance capacities of our stakeholders (Extension, researcher and farmers) on early warning and forecasting system to certain degree. In addition, this system will permit review of pest situation and dynamisms that will enable to study resistance development and resurgence, pest selection and emergence of new pests, environmental and human health risk monitoring. Such information is vital

for development of IPM using real time information which will help to formulate more accurate and suitable IPM packages. This system will be crucial in R&D for pest management as depicted diagrammatically in the Figure 17.

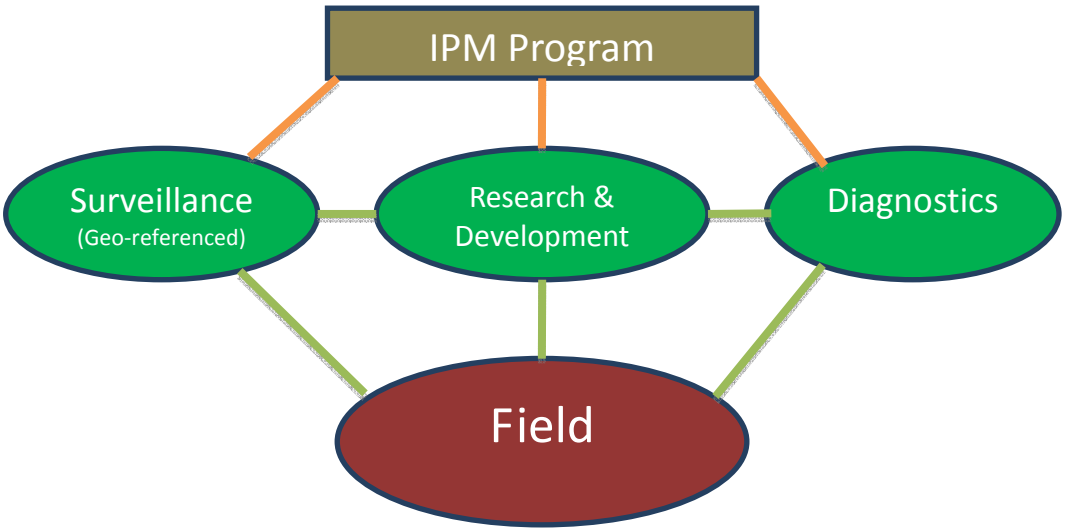


Figure 11. Surveillance as Integral Part of IPM Strategy

The e-governance initiative on plant protection input management system

This is an important initiative towards streamlining plant protection inputs indenting system based on pest information. Such information system will be useful in tracking of plant protection (pp) inputs on stocks at all levels of pp input distribution, from pp distributions points to farmer level, so that accumulation of unused or obsolete products could be reported and record maintained for appropriate disposal.

R&D on ecological pest management

The pest management in the current FYP will mainly emphasize on bio-control research and development mainly for the important pest like Chili fruit borer, Citrus fruit fly, and Potato tuber moth. The undergoing activity includes pheromone monitoring and mass trapping, baiting during egg development stage and destruction of dropped fruits through dumping and burying in case of citrus fruit fly. Inventory of parasites and predators in lepidopteron pests and Psyllids in citrus, and botanicals for pest management will be initiated soon.

Some of other ongoing or completed pest management initiatives research works by RNR RDC, NPPC, and NOP that will have direct contribution on IPM includes;

- Turcicum leaf blight and Grey leaf spot tolerant maize cultivar selection
- Rice blast tolerant cultivar selection
- Disease free potato seed production through tissue culture
- Potato tuber moth management both under field and store
- Marigold as trap crop for *Helicoverpa armigera* in tomato cultivation
- *Neem, Artemisia, Acorus* –based bio-pesticide for the control of fruit borers and aphids in vegetables
- Screening of various herbicides on weeds under wetland condition

The outcome of this important research work will be useful for the development of IPM package for each crop after evaluating their efficacy and adaptability in the field.

Future plans and vision

Given the current scenario of food security issues, rural poverty and income status, agriculture development still has to focus on crop promotion, increasing production and productivity. This convinces that IPM is the only way for pest management, which will foster conservation and protection of ecosystem that will in turn ensure income generation and food production at a minimal environmental cost. Organic production on the other hand gaining momentum will be a complimentary towards the promotion of IPM, but will remain limited to a few locations and varieties. Therefore, IPM will still remain as pest management policy for the national plant protection services towards good agriculture practices (GAP) and sustainable development approach in the current decade and beyond.

For the further promotion of IPM, institutional strengthening is required both at the center, regional and district levels through institution of IPM officers. Collaboration with RDCs, commodity coordinators, extension officials and other agencies still need to be strengthened to achieve more reliable and suitable research outcomes. Integration of bio-pesticides as part of pest management research programs will be essential given its comparative advantage both in terms of social acceptability by its nature of socio-economic and ecological systems. There is high tendency that most of botanicals could be obtained within country as some products like *Xanthoxyllum, Artemesia, Acorus, Melia*, etc., are already promising. Likewise, some of the lost endogenous methods of pest management could be revived through proper surveys and research, which might prove more effective and become more acceptable technology to the farmers. It is also the time that Bhutan should explore that proven and certified bio-pesticide technology from other countries. However, the pesticide act may need to be proposed for necessary amendment to allow the use of bio-pesticides and avoid regulatory and quarantine complications during the process.

Limited access or lack of information is perhaps the main hindrances in addition to manpower input in pest management research. The pest database and e-pest surveillance system will be an integral part of suitable IPM development. Also, to study the adaptability rate of developed IPM and socio-economic impact is another important area to assess the success of IPM as pest management strategy. This will provide better information towards amending suitable packages and further development of IPM. Perhaps, we also should not forget that Bhutanese farmers will not readily accept to kill the insects using pesticides; which mean that we need to focus more into using repellents and trap crops or resistant varieties. Therefore, a norm as such is urging the researchers to find more suitable methods apart from proven technologies in other countries to make it more suitable and acceptable to our farmers and farming systems.

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CHAPTER 4

Extent and potential use of bio-pesticides for crop protection in Nepal

Anisur Rahman Ansari[8], Sunil Aryal[9] and Naresh Dangi[8]

Introduction

Nepal is predominantly an agricultural country and offers employment to 66 percent of the economically active population with the 39 percent contribution to GDP (DOA, 2013). Total area of the country is 14,718,100 hectare. Out of which 3,091,000 ha (21%) is cultivated and 1,030,000 ha (7%) of the cultivable land is still not under cultivation (AICC, 2013). The availability of agricultural inputs including pesticides is more confined to vicinity of urban and suburban areas having access to transport. Chemical pesticides had been widely used approach for plant protection in areas where they are available. Uses of chemical pesticides are in increasing order but in fact, the pest induced loss is on the rise despite increasing usage of the pesticides. Hence, realization of the negative effects of these chemicals have forced many to shift focus on to other safer alternatives and the country has adopted integrated pest management (IPM) as the official system for pest management. Research and development efforts have been increased on use of botanicals and natural enemies including insect pathogens. The claimed efficacy of botanicals and some microbial-pesticides are very encouraging; however their use has remained very low particularly due to unavailability in sufficient quantity in local market, unreasonable cost, relative reliability in comparison to synthetic chemical pesticides, lack of standardized method of extraction and use and lack of industries involved in production and marketing. Rise in income levels due to a growing economy coupled with increasing awareness of health related effects of chemical pesticides in urban areas has increased the demand of organic food. In view of this demand government is encouraging the farmers and growers to include bio-pesticides as the tools in pest management in recent years and tried to mitigate unintended side effects of synthetic chemicals. As an example, inauguration of bio-pesticide production community center in Kushadevi, Kavrepakanchowk on 26th October 2013 jointly by Secretary of Prime Minister's Office Mr. Krishna Hari Baskota and Secretary of Ministry of Agricultural Development Mr. Jay Mukund Khanal highlights the government interest, policy and support in the bio-pesticide production and use.

The history of pesticide in Nepal starts from 1950 as DDT and pyrethrum were

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first time imported for "Malaria Eradication Program" (Rana, 2001). The government imported pesticide for agriculture production in 1956. The use of pesticide in agriculture production is increasing and reached up to 345,032 kg active ingredients of chemical pesticide where bio-pesticides share only 121.7 kg a.i. in 2011/12. There are 5 pesticide formulators, 72 pesticide importers and almost 3000 pesticide retailers registered in the country (PRMD, 2013). The consumption of pesticide in Nepal is still very low as compared to many other countries of South Asia. The quantities of pesticide use per unit area in the commercial agricultural pockets are higher than the national average (Manandhar, 2012). Government of Nepal (GoN) banned twelve pesticides *viz.* DDT, BHC, aldrin, dieldrin, endrin, chlordane, lindane, heptachlor, toxaphene, mirex, phosphamidon and organomercury fungicides in April 2003, methyl parathion and monocrotophos in December, 2007 and endosulphan in November, 2012 (PRMD, 2013). The negative consequences of pesticides after 1960's, forced the nation to adapt safe alternative measures. In Nepal, some insects such as American bollworm (*Helicoverpa armizera*) in cotton have developed resistant to insecticides and outbreak of BPH (*Nilaparvata lugens*) has been observed in rice due to overuse/misuse of chemical insecticides. In these contexts, GoN realized the fate of chemical insecticides and adopted IPM in rice since 1996.

The traditional farming knowledge and skill give the positive avenue for promoting the organic agriculture in Nepal. There are various local organic practices, some practiced from the ages and some are innovating new practices by farmers themselves. Little effort will modify the current farming practices into organic (Tamang, *et al.,* 2011). There are no clear guidelines, definitions and methods for organic farming in the country. Organizations, individuals and farmers themselves are doing what they think is good for this sector from their acquired knowledge and experience only. Therefore, clearly defined standards and measures from the government is necessary to assess the quality and standard of the organic products.

The farming practices followed by Nepalese farmers in hills and mountains are similar to organic farming. In Nepal, major part of agriculture is by default organic but these products are not formally certified as organic with authorized certifying institutes. In this context the statistics on area coverage and number of commercial farm known to be quiet low (Pokhrel and Pant, 2009) however, some study showed around eight thousand hectare is brought under organic farming including some big farm like Kanchanjungha Tea State, Panchthar (90 ha and 50 ton), Guranse Tea State, Dhankuta (300 ha and still in growing stage), District Cooperative Federation (DCF), Gulmi (75 ha and 292 ton).

There are limited and scattered researches on organic farming, which are not properly documented and thus repetitions on the limited issues and resources are observed. The government policy and program should emphasize the organic food rather than market and business oriented agricultural system. The cost of production is high and Nepalese farmers cannot compete with the Indian and other international market. Hence Government must provide support to the organic farmers groups, cooperatives in order to minimize the cost and mass production. Subsidy will be provided based upon the volume of production in order to motivate the farmers for easy marketing of the products. Due to the lack of awareness, consumers are not convinced for the premium price of the organic product. Therefore farmers need to compete in the international market. Arrangement of the subsidy in price and insurance of the production will be a biggest incentive for the farmers and help in its sustainability. There should be separate and interrelated networking of training, research and technology development, verification and extension of organic agriculture for its development. Organic certification is important for the exportable organic product but, small farmers couldn't afford the additional cost and time consuming certification process. There are limited courses and activities on organic farming at school, universities and training institutions. As the consequences, extension services have usually faced problems of trained professionals on organic agriculture. Thus, incorporation of courses related to organic production is necessary in the education programs of primary and secondary school level, universities and training institutions for developing professionals in this field. There is need to document the innovations from the local level to national level. Research and studies can generate certain findings and evidence based knowledge which can be shared with the like minded working agencies and directly to the farmers. The publications and media can play important role in bringing the agenda into village and then to household’s levels. There is growing trend among urbanites for organic products, especially vegetables. Organic agriculture represents one such potential area that is gaining momentum in economic, health and environmental aspects.

Organic agriculture promoting policies in Nepal

Government of Nepal (GoN) has formulated different acts, rules, regulation, directives and working procedure to facilitate and promote organic agriculture. Directives for internal regulation system for community certification to organic agriculture produce, working procedure for providing affiliation to different institution by National Organic Agriculture Affiliation Providing Institutes, guidelines for execution system for participatory quality assessment for organic agricultural produce, working procedure for providing the subsidy in certification while exporting organic agricultural products are some of the directives,

guidelines working procedure endorsed in 2013 (MOAC, 2013). Similarly GoN has pesticide act 1991 and pesticide regulation (1994) to regulate the pesticide import, export, handling, production and use. Likewise Environment Protection Act and Environmental Protection Regulation (1997) and 10th National plan by National Planning Commission also give due emphasis to organic agriculture.

The government policy and programs on organic agriculture first appeared as one of the priority sectors in Nepalese agriculture since the 10th Five Years Plan (2002-2007). The national agriculture policy 2061 clearly stated the promotion of organic agriculture for export. Government organizations such as Department of Agriculture (DOA), Nepal Agriculture Research Council (NARC) and Institute of Agriculture and Animal Science (IAAS) are involved in promotion of organic agriculture. Along with this different organizations i.e. Institute of Sustainable Agriculture in Nepal (INSAN), Nepal Community Support Group (NECOS), Jajarkot Permaculture Program (JPP), Lotus Land Agriculture Farm, Community Welfare and Development Society (CWDS), HASERA Agriculture Farm, Nepal Permaculture Group (NPG), Ecological Services Center (ECOSCENTRE), Organic Nepal, Forum for Rural Welfare and Agricultural Reform for Development (FORWARD) and several other GO and INGOs are also involved in promoting organic farming and some are even issuing organic product certification. Academic institutes are also actively participating in the promotion of organic agriculture. IAAS, Rampur has inbuilt curriculum in its course like ecological agriculture, farming system research and permaculture, ecological environment and IPM. Likewise Himalayan College of Agricultural Science and Technology (HICAST), Bhaktapur also included subjects like sustainable agriculture and rural development. Tribhuvan University, Kathmandu University and Purbanchal University also have sectors of environmental science which teaches the better environment through organic production. The Council for Technical Education and Vocational Training (CTEVT) also provide vocational training to its student about organic farming and permaculture. Similarly schools and other NGOs/INGOs provide short term training courses on organic production. Some of the cooperative involved in coffee production also implemented Internal Control System (ICS) for group certification of smallholders. ICS is intact in the groups and is effectively implemented by cooperatives for quality assurance and compliance to organic production standard (CCU, 2013). Nowadays various institutions, individuals and farmers are emergently engaging in this field. At present, some organic products such as coffee, tea, honey, large cardamom, ginger, etc. are exported to international market.

Great possibility of organic farming exists because many places are still in organic in nature and yet not likely that modern chemical pesticides and fertilizers will reach to them early. For example, Jumla is already announced organic district

by the government, as chemical fertilizer and pesticides are yet not reached. Many of the farmers in Nepal face problems that the organic products are not perfect in shape, size and color in comparison with products produced by using chemical fertilizers and pesticides. So they are in fear about the consumer preference as they (consumer) prefer by evaluation with their eyes and organic products are hard to compete in the market.

During the fiscal year 2066/67, government provided only Rs. 24 corers of subsidies in organic manures and certification process of organic products. Under this limited budget, farmers are confused which part of organic agriculture is to expand by the government sector. There are various non-governmental and cooperatives working in the field of organic farming but many of them are in inactive state. So there is necessity to revitalize their activities for upgrading organic agriculture.

Policy and institutions regulating pesticide use

In Nepal, Pesticide Act (1991), Pesticide Regulation (1994), Environment Protection Act and Environment protection rule (1997) are active to regulate pesticide use and regulation. After pesticide act and rules, Government of Nepal, establish Pesticide Registration and Management Division, under Plant Protection Directorate at Hariharbhawan, Lalitpur for management of pesticide production, import, distribution and use in Nepal.

Inventory of bio-pesticide used in agriculture sector

Many research and development efforts have been made during the recent past against some economically important pests in major crops. Relatively large amount of botanicals are used to protect stored grains in rural areas against stored grain pests. Some encouraging results are presented Table 18 and Table 19.

Table 1. Bio-pesticide products used against target pest and diseases in the field of agriculture, livestock and fisheries

Bio-pesticide products	Target crop	Target pest/disease	Application mode	Application rate	Remarks
Botanicals for insect pest management					
Acorus calamus	Potato	Potato tuber moth	mixing dusting	2-5 gm/kg	Giri et al 2010, 2013
(Finely grounded rhizome)	Wheat	Weevil		25 gm/kg	Paneru *et al.*, 1997a
	Maize (indoor storage)	Weevil		30 gm/kg	Sah, 1999
	Maize (outdoor storage)	*Sitophilus oryzae* L		10-30 gm/kg	Bajracharya *et al.*, 2007
	Maize (indoor storage)	*Sitophilus oryzae*		5-10 gm/kg	Bajracharya *et al.*, 2007
	Maize	*Sitophilus zeamais*		10 gm/kg	Malla *et al.*, 2007
	Pulse	*Callosobruchus maculates* F.		50 gm/kg	G.C. 2006
	Pulse	*Callosobruchus maculates* F.		5 gm/kg	Baral *et al.*, 2007
Pea flour (PF) and mustard cake (MC)	maize grains	*Sitophilus oryzae* L	Mixing dust	10-20 gm PF and 5-10 MC gm /kg	Bajracharya *et al*,.2012
	Cabbage (seedling)	*Plutella xylostella* L. (DBM)	Spray	0.003%	Bajracharya *et al.*, 2011
Tobacco aqueous decoction		*Pieris brassicae* (L.)		0.003%	Bajracharya *et al.*, 2011
		Brevicoryne brassicae (L.)		0.003%	Bajracharya *et al.*, 2011
Commercial aqueous *azadirachtin* decoction	Cabbage (seedling)	*Plutella xylostella* L. (DBM)	Spray	0.003%	Bajracharya *et al.*, 2011
		*Pieris brassicae (*L.)		0.003%	Bajracharya *et al.*, 2011
		Brevicoryne brassicae (L.)		0.003%	Bajracharya *et al.*, 2011
Xanthoxyllum alatum Roxb. seed powder	Maize and Wheat	Storage insects	Grain mixing with powder	2%	Howarth, 1978
Carum copticum L.	Maize (stored)	*Sitotroga cerealella* (Olivier)	Mixing in air tight container		NARC Research Report, 2008/09

Bio-pesticide products	Target crop	Target pest/disease	Application mode	Application rate	Remarks
Lime	Maize	weevil	dipping in and spraying over maize ear	30%	Paneru *et al.*, 1997b
Neem fruits (Aqueous solution)	vegetable crop	*Epilachna vigintioctopunctata* *Spodoptera litura* F. *Athalia lugens proxima* *Phyllocnistis citrella* *Phytomyza horticola*	Foliar Spray	2 kg neem fruit/15 liters	Joshi *et al* 1991
Tobacco decoction (250 gm tobacco mixed with 30 gm liquid shop and water , boiled for 30 minute)	vegetable crop	*Spodoptera litura* F *Athalia lugens proxima* *Phyllocnistis citrella* *Phytomyza horticola*	Foliar Spray	1:4 (Decoction: water)	Joshi *et al* 1991
Tobacco decoction (1 part tobacco mixed with 1 part liquid soap and 20 part water)	vegetable crop	Aphids		1:4 (Decoction: water)	Duwadi *et al* 1993
Neem seed kernel powder mixture	Okra	Cotton leaf hopper (*Amrasca biguttula biguttula* Ishida)	Spray	30 gm/lit	Neupane, 2000
Justicia green leaves leaf extract	Okra	Cotton leaf hopper (*Amrasca biguttula biguttula* Ishida)	Spray	20 gm/lit	Neupane, 2000
	Vegetable crop	Aphids (*Lipaphis erysimi* K. and *Myzus persicae* S.)	Spray	1:4 (Aqueous extract:water)	
Meliaaz azedarach (aqueous extract)	vegetable crop	Aphids (*Lipaphis erysimi* K. and *Myzus persicae* S.)	Spray	1:4 parts water	Vaidaya, 1993

Bio-pesticide products	Target crop	Target pest/disease	Application mode	Application rate	Remarks
Seed pomace (aqueous extract)	vegetable crop	Aphids (*Lipaphis erysimi* K. and *Myzus persicae*S.)	Spray	1:4 parts water	Vaidaya, 1993
Artemisia vulgaris (Fresh leaf extract blended for 1 hours)	Summer squash	Red pumpkin beetle *Aulacophora foveicollis*	Foliar Spray	25g/litre	Neupane & Neupane, 1993
Artemisia vulgaris (Shade dried leaves)	Potato	Red ants (*Dorylus orientalis* W.)	soil application	5mt/ha	G.C. *et al* 1997
Shed dried leaves of *A. vulgaris* or *Eupatorium adenophorumin*	Potato	Red ants (*Dorylus orientalis* W.)		5 mt/ha	G.C. *et al* 1997
Chrysanthemum flower paste	Cole crop	Flea beetle	Foliar Spray	3 gm/litre	Duwadi *et al.*, 1993
Elderberry decoction	Cole crop	Cabbage butterfly	Foliar Spray	1:7 (Decoction: water)	Duwadi *et al.*, 1993
Boketimur or Siltimur *(Zanthoxylum)*	Cauliflower	Red ants (*Dorylus orientalis* W.)	soil application	1 kg or 0.5 kg/6m2	Duwadi *et al.*, 1993
Aqueous extract of neem fruits (over night soaked 50 g fruit dust in 1 L water) or tobacco stem and leaves (200 g tobacco + 30 g liquid soap + 4 litres of water boiled for 30 minutes),	Cole crop	Cabbage butterfly's larvae (*Pieris brassicae nepalensis*), Diamondback moth (*Plutella xylostella*L.) and Cabbage aphid (*Brevicoryne brassicae*L.)	Foliar Spray	1:4 parts water	Joshi 1994

Bio-pesticide products	Target crop	Target pest/disease	Application mode	Application rate	Remarks
or aqueous extract chinaberry fruits (24 hrs soaked 1 kg of fruit dust in 10 L of water)					
Aqueous tobacco extract (mix 5 gm of tobacco with 1 lit water and mixed with 1 part cattle urine and 5 parts water mixed and kept for 24 hours)	Potato (Field)	Red ant	Drenching around plant	25 ml/plant (0.0000045%)	Joshi, 1998
Aqueous solutions and /or powder/oil of botanicals like *Azadirachta indica*, *Melia azedarach*, *Artemisia vulgaris* and Adhatodavasica.	Water melon	Red pumpkin beetle, *Aulacophora foveicollis*(Lucas)	Spray		Thapa, 1999
Aqueous solution of green neem leaves (*Azadirachta indica*), Chinaberry (*Melia azedarach*), malbar nut (*Justicia adhatoda*) and Indian privet (*Vitex negundo*)	Cabbage	Cabbage butterfly (*Pieris brassicae nepalensis*), Soybean hairy caterpillar (*Spilarctia oblique* W.), Tobacco caterpillar (*Spodoptera litura* F.) and Diamondback moth (*Plutella xylostella* L.)	Spray	(each 200 g of leaves per liter of water)	Neupane 1999
Dry wood ash (use early morning)	Cauliflower	Aphids (*Brevicoryne brassicae* L.)	Spray	as per need	Anonymous 1999 in Shrestha, 2006

Bio-pesticide products	Target crop	Target pest/disease	Application mode	Application rate	Remarks
Wood ash (soaked 12 hours)				1:4 parts water	Shrestha, 1999
Aconite root (aqueous extract)	Cabbage	Cabbage aphids *(Brevicoryne brassicae* L.*)*		1%	Shrestha, 1999
Mentha arvensis or *Artemisia vulgaris* (aqueous extract)	Potato	Green peach aphid (*Myzus persicae* S.)	Spray	200 g per 1.33 liter	
	Cauliflower			200 g per 1.33	Vaidya 2000 a
		Mustard aphid (*Lipaphis erysimi* K.)			
Menthaarvensis (aqueous extract)	Potato (lab condition)	Red ants (*Dorylus orientalis* W.)	Spray	200 g per 1.33	Vaidya 2000 b
Toabcco decoction (250 g tobacco mixed with 30 g soap and 4 litre water) mixed with biomultineem solution and biomultineem solution (3 ml/L water)	cauliflower	Aphids *(Brevicoryne brassicae* L.*)*	Spray	1:4 ratio (Tobacco decoction and diluted neem solution)	Paneru *et al.*, 2004
Chopped leaves and tender stem *Lantana camera, Menthaarvensis Eucalyptus sp.*	Potato (Storage)	Potato tuber m/+-+oth (PTM)	Chopped botanical mixed with tubers	300-330 gm/8 kg	Pradhan, 1987, 1988
Artemisia vulgaris (chopped foliage)	Potato (Field)	Red ant	mixed in soil	5 mt/ha	G.C. et al, 1997
		Potato tuber moth	mixed with tubers	300-330 gm/8 kg	Pradhan, 1987, 1988, Giri *et al.*, 2010
		Potato tuber moth		20 gm/kg	

Bio-pesticide products	Target crop	Target pest/disease	Application mode	Application rate	Remarks
Chopped leaves and tender stem *Chenopodium* sp. dust	Potato (Storage)	Potato Tuber Moth	Mixing with stored tubers	10gm dust/kg 300-330gm/8 kg	Entomology Division 2007 Pradhan, 1987,1988
Derisom (*Deris indica*) and Annosom (*Anona squamosa*)	Sugarcane	Sugarcane Leafhopper, *Pyrilla perpusilla* (Walk.)	Foliar spray	5g/l water	Ansari, 2011
Mustard oil	Chickpea (Storage)	Pulse beetle *Callosobruchus chinensis*L.	Mixing with grain	10 ml/kg	Sharma *et al.*, 1995
Insect management through insect pathogen					
Bt (Z-52-strain) (Bt water solution)	Potato (Storage)	Potato tuber moth	Dipping/spraying tubers	1.5 -2 gm/ liter water	Tiwari *et al.*, 2006, Entomology Division 2007
Bt (Z-52-strain) (air dried, 35 gm/ lit. water and 35 gm talcum powder)			Mixing with stored tubers	6 gm/kg	Giri *et al.*, 2010
NPV (NPV water solution)	Potato (Storage)	Potato tuber moth	Dipping/spraying tubers	1.5 -2 gm/ liter water	Tiwari *et al.*, 2006
*Phop*GV powder (20 *Phop*GV infected mixed in one kg of talcum powder)	Potato (Storage)	Potato tuber moth	Mixing with tubers	5 kg/ton of potato	Aryal *et al.*, 2012, Giri *et al.*, 2013
Metarhizium anisopliae (Metsch.) (Barley formulated)	Vegetable and cereals	White grubs	Soil application Larva dipped in solution	20-40kg/ha	Timsina, 2010 Rijal and Basnet 2007
Verticillium lecani and *Metarhizium anisoplae*	Sugarcane	Sugarcane Leafhopper, *Pyrilla perpusilla* (Walk.)	Foliar spray	2g/l water	Ansari, 2011

Bio-pesticide products	Target crop	Target pest/disease	Application mode	Application rate	Remarks
Botanicals for disease management					
Aqueous extract of Ginger (*Zingiber officinale*)	Potato	Collar rot	Spray	20 gm/lit	Budhathoki, 2006
Aqueous extract of Turmeric (*Curcuma longa*) powder (1 part turmeric and 4 part ash)	Vegetable crop	Powdery mildew	Spray	1part extract and 4 part water	Budhathoki, 2006
Onion (*Allium cepa*)	Vegetable crop	Leaf spot and collar rot	Spray	50 gm/lit	Budhathoki, 2006
Pire jhar (*Polygonum hydropiper*)	Tomato and carrot	Blight disease	Spray	25 gm/lit	Budhathoki, 2006
Neem (*Azadirachta indica*) oil	Vegetable crop	Stem blight and root rot	Spray	1 part extract and 5 part water	Anonymous 2006
Aqueous solution of Chilli powder (100 gm chilli mixed with 1 liter of water and little amount soap soaked overnight)	Vegetable crop	Viral disease	Spray	1 part aqueous solution and 5 part water	Anonymous 2006
Tobacco decoction (leaf and stem 1part mixed with 15 part water boiled)	Bean	Rust	Spray	1 part decoction and 4 part water	Anonymous 2006
Sambucus nigra (Flower and leaves cool decoction)	Cucurbits and beans	Powdery and downy mildew	Spray	400-550 gm/3 liter	Anonymous 2006

Bio-pesticide products	Target crop	Target pest/disease	Application mode	Application rate	Remarks
Lemon grass paste	Potato and tomato	Blight disease of potato	Spray	250 gm paste /4 liter water	Sapkota, 2005
Milk (uncooked)	Vegetable crop	Viral disease	Spray	250 ml	Sapkota, 2005
Stored Cattle urine (10-15 days)	Bean Peeper	Root and stem rot of beans, Mosaic virus and powdery mildew of peeper	Spray	1 part urine 5 part water	Sapkota, 2005
Cow dung	Tomato and peeper	Mosaic virus	Spray	2-3 handful/10 lit	Sapkota, 2005
Rodent Management from botanicals					
Neem seed power Neem oil Custard apple seed powder	field and storage crop	*Rattus rattus*	Bait	100gm seed powder 20 ml/kg 100 gm/kg mixed in normal diet	Shrestha, 2007

Table 2. Quantity and extent of use of bio-pesticide in 2011/12

Bio-pesticide products	Imported total a. i. (kg or L)	Total formulated Quantity (kg or L)	Area coverage (Hectare)
Botanicals	6.07	7230 liter	Not available
Microbial	115.62	9823 kg	Not available

Source: PRMD, 2012

Best practices in bio-pesticide application

Farmers prepare locally available plant material by decomposing after chopping and kept for fermentation in cow urine for several days commonly known as *Jhol-mol* and using it in standing crop to manage the insect pest as well as for the purpose of plant nutrition. Another practice of the farmer is the use of botanicals in crude form after drying and grinding specially on storage products to manage stored grain's insect pests. Farmers are also using commercial bio-pesticide mixing with cow dung while applying in soil and some are spraying in standing crop. Commercial bio-pesticide and pesticide produced by some research organization are being tested in fields and has been proved effective in several cases.

Some good agricultural practices have been prepared for some commodities by different agencies and many are under different stages of preparation. Submitted GAPs are under verification processes and after the approval MoAD will be notified and be endorsed for general use.

Success stories in bio-pesticide use

Use of *Helicoverpa Nuclear Polyhedrosis* Virus in chickpea and pigeon pea

The cotton bollworm or the legume pod borer (*Helicoverpa armigera*) is one of the biggest problems of cotton, chickpea and pigeon-pea for Nepalese farmers. The area under cotton, chickpea and pigeon-pea were greatly reduced and replaced by other crops in majority of the areas where these crops were successfully cultivated previously due to the occurrence of this insect. *Helicoverpa* management practices in the country were completely based on chemical pesticides. There are some reports indicating development of pesticide resistance in the insect for some commonly used insecticides, making the pest management practices more difficult.

To address this issue, the Nepal Agriculture Research Council (NARC) in collaboration with International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) established bio-pesticide production units in eleven villages in Western Nepal (Dang, Banke and Bardiya, Kailali and Kanchapur districts). In

each of the selected villages one farmers group (20-25 members each group) were created in leadership of Pradeep Thapa of D gawn, Bageswori, Jagadish Karwal of Bankatawa, Ek Ram Khan of Jhakarpur and Mata Prasad Barma of Betahani in Banke district; Dil Bahadur Tharu of Manikapur, Sambhu Prasad Dhungana of Tara Tal, Shanti Chetri of Sitapur and Kali Ram Tharu of Belawa in Bardiya district; Dev Mani Chaudary of Satbariya in Dang district; Goma Bhandari of Masuria in Kailali district and Prem Lata Gautam of Amar Basti in Kanchanpur district. The leaders and two members of each group were trained for HNPV production and use jointly by NARC and ICRISAT scientists.

Field collected *Helicoverpa* larvae were used for multiplying the NPV. Larvae were collected from pigeon-pea or chickpea fields and fed with an NPV-infected diet (presoaked chickpea grains) till they died due to infection. The NPV were extracted from the dead larvae by grinding, filtration and centrifuging; stored in refrigerator and sprayed to manage *Helicoverpa* attack mainly in chickpea and pigeon pea. Monitoring for quality parameters and supply of fresh nucleus culture each year was done by NARC scientists. In this way use of HNPV was promoted among Nepalese farmers. Farmers experienced great success in *Helicoverpa* management with greatly reduced quantity of chemical pesticide use and significant reduction in cultivation costs (Ansari and Ghimire, 2008).

The farmers used to produce NPV since they were getting active technical and financial support from the project and gradually the production was reduced due to unavailability of nucleus stock of NPV and quality assessment. Now, Regional Plant Protection Laboratory, Khajura, Banke, has restarted production of HNPV and farmers could get support from the laboratory in near future.

Use of *Acorus calamus* rhizome powder against Potato Tuber Moth, *Phthorimaea operculella* (Zeller) in stored potato

Tukucha VDC-5 of Kavrepalanchowk district is the potato growing pocket area and farmers are involved in commercial cultivation of potato since more than two decades. The potato is grown mainly in two seasons where farmer harvest their produce in last of October and second week of May. There is a severe economic damage by Potato Tuber Moth in storage to the potato harvested during May. Major means of management was chemical pesticides like Malathion dust, methyl parathion in general but in severe cases even phorate and aluminum phosphide were also used in potato stores. Insecticides were used in 2-3 weeks interval depending upon infestation. Mr. Harisharan Dulal and Binod Dulal states that the participatory action research on Potato Tuber Moth management by Entomology Division (NARC) was a breakthrough because they became aware that locally available dust of *Acorus calamus* is equally effective in managing Potato Tuber Moth. Dulal brothers are now using this technique for last three years and from them the technology is rapidly disseminating to other farmers. According to them

this novel technique is low cost, locally available, does not alter the taste of potato and easy to sell their product. The use of the botanical helped them drastically reduce the negative impact of insecticide on their health. Besides, Dulal brothers, Mr. Hiramani Dulal from the same community have started cultivating *A. calamus* on their marginal lands for self-use.

Use of local isolate of Granulosis Virus against potato tuber moth

Local isolate of granulosis virus of potato tuber moth was collected, isolated, multiplied, tested and found effective against the pest in laboratory as well as in farmer's storage condition in Kavrepalanchowk and Makwanpur districts. Farmers highly appreciated the technology and are ready to adopt the bio-pesticide but availability in local market is main problem in its large scale adoption. Discussion with Agricare Nepal Private Limited, Bharatpur, Chitwan is on progress in direction towards its commercial production.

Organic Production entrepreneurship adopted by Farmer.

Market practices of organic agriculture in Nepal show individual farmers, entrepreneurs and cooperatives that are taking the practice forward as a remunerative enterprise. For example, one of the organic farm entrepreneurs in Nepal, Mr. Prem Lama of Aashapuri Organic Farm, Sanga, farming about 5 hectares of land, is selling about 300 kg of organic products daily and generating more than NRs. 500,000 (US $6,250) a month. He is providing more than 50 organic products including ground apple, shitake mushrooms, cauliflower, cabbage and cucumber to restaurants and star hotels in Kathmandu. He is also exporting asparagus, ground apple and mushrooms to Singapore (ANSAB, 2011).

Bio-pesticide producers (contact address)

A. Government Sector:

1. Entomology Division, Nepal Agricultural Research Council, Khumaltar, Lalitpur, PO.Box. 976, Kathmandu, Nepal is producing and maintaining various kind of bio-pesticide and biocontrol agent in its laboratory. Those are:

- *Trichogramma chilonis*
- *Trichogramma japonicum*
- *Chrysoperla carnea*
- *Cotesia plutellae*
- *Curinus coeruleus*
- *Coccinella sempempuntata*
- Nuclear polyhedrosis virus of *Helicoverpa*
- Nuclearpolyhedrosis virus of *Plusia*
- Granulovirus of potato tuber moth

- *Metarhizium anisopliae*
- *Beauvaria bassiana*

2. Regional Plant protection laboratory, Harihar Bhawan, Lalitpur, Nepal

- *Metharhizium anisopliae*
- *Steinernema* sp.
- *Heterorhabditis* sp.

3. Regional Plant protection laboratory, Pokhara, Kaski, Nepal

- *Trichogramma chilonis*
- *Trichogramma japonicum*

4. Regional Plant protection laboratory, Khajura, Banke, Nepal

- HNPV

5. Regional Plant protection laboratory, Sundarpur, Kanchanpur, Nepal

- *Trichoderma viride*

6. Regional Plant protection laboratory, Biratnagar, Morang, Nepal

- *Acorus calamus*

B. Community Centers

1. Community Resource Center, Kushadevi, Kavrepalanchowk

- *Trichoderma viride*
- *Steinernema* sp.
- *Heterorhabditis* sp.

2. Community Resource Center, Banke

- *Trichoderma viride*

3. Community Resource Center, Kailali

- *Trichoderma viride*

These are the some of the active community group of farmers producing bio-control agents and there are some more which needs to be explored and documented.

C. Private Sector

Agricare Nepal Private Limited, Bharatpur-6, Chitwan, Nepal, Tel: +977-056-522127, email: agricarenepal@gmail.com, website: www.agricarenepal.com, has in the process of registering its company and has started the test production which are given Table 20. This is the single industry from the private sector that comes forward in the field of bio-pesticide production.

Table 3. Proposed bio-pesticides for production

Product Name	Active Ingredients
Guard	*Pseudomonas fluorescens* $1x10^9$ CFU/g
BIOJEB	Biojeb is a botanical based fungicide. It contains a complex of physiologically active alkaloids isolated from selective Himalayan herbs
Maha-shakti	*Bacillus Thuingensis Var. Kurstaki* $1x10^9$ CFU/g
Pecilo	*Paecilomycesfumosoroseus* $1x10^9$ CFU/g
Teer	*Ampelomyces quisqualis* $1x10^9$ CFU/g
AGRIGUARD	Pongamia glabra, Acorus calamus, Azadirachta and Lantana
AGRI-SAKTI	*Beauveria Bassiana* $1x10^9$ CFU/g
BIOCIDE MANIC	*Metarhizum anisopliae*
Biocide trivi	*Trichoderma viride*
DHANUS	*Fusarium proliferatum* $1x10^9$ CFU/g

Monitoring mechanism

Government of Nepal appoints pesticides inspector as per necessity to implement and supervise pesticide use under Pesticide Act (1999). The Plant Protection Officer of the District Agriculture Development Offices (DADOs) is appointed as Pesticide Inspector for regulatory work in the districts. Pesticide Inspector has full authority to implement the Pesticide Act (1999). The functions, duties and powers of the pesticides inspector under the Pesticide Act and regulations states that the Pesticides Inspector shall investigate a case related with the offense under this Act and upon completing the investigation shall file the case before Adjudicating Authority. In investigating and filing the case pursuant to Sub-section (1), the Pesticides Inspector may seek opinion of the Government Attorney. Government of Nepal will plaintiff in a case under the Pesticide Act.

Future prospects

- Exploration, inventory preparation of native botanicals and insect pest pathogenic organism (fungus, virus, bacteria and others) from different agro-ecological zones of the country.
- Developing cost effective mass production technology and efficacy testing of botanicals, predators and parasitoids, entomopathogens and antagonist of plant diseases in economically important pests.

- Validation of native and commercial bio-pesticide.
- Development of cultivation practices of important plant species having effective properties as botanical pesticides.
- Conservation of indigenous plant species having pesticidal property and establishment of botanical garden.
- Chemical analysis of effective botanicals and develop extraction techniques with appropriate formulations, packaging and storage for commercial production.

Conclusion and recommendation

Most of the bio-pesticides used in the country are in research phase and very few have been utilized by farmers in current context. Government is now giving due emphasis on promoting use of bio-pesticide and organic agriculture by formulating various rules, regulation, directives, guidelines and working procedures. The existing acts and regulation should be amended so that it can encourage the registration of the bio-pesticides. Use of commercial bio-pesticides imported from other countries is not sustainable. So, already proven native bio-pesticides need to be mass produced and for that government should give subsidy for the industry/individual/groups that comes forward to produce such bio-pesticide locally. Similarly, organic product certification rules should be enforced with due emphasis. The pricing system for the organic and other products should be started to motivate the producer towards organic agriculture. The registration procedure must be updated and revised as and when necessary. Screening and cancellation of more toxic registered pesticides should be periodically done. Similarly act, rules, directives, guidelines and working procedures for the organic agriculture should be enforced and implemented effectively.

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PAPER 5

Extent and potential use of bio-pesticide for crop protection in Pakistan

Dr. Javed Iqbal[10]

Introduction

Agriculture is important for the progress of human civilization as it provides food, feed and security to a nation. It is the mainstay of economy of Pakistan. It provides livelihood directly to 65.9% of the rural population and earns about 70% foreign exchange from the sale of agricultural commodities like cotton, rice and fruits etc. Agriculture sector of Pakistan constitutes about 25% of the national economy and it has important forward and backward linkages, especially with regard to the supply of raw material to the end users. Imported commodities are oilseeds and pesticides.

The history of agriculture is full of instances and examples, where man's interference with the natural balance has resulted into the multiplication of insect pests and diseases and their spread in larger areas; thus creating famine or near famine situations. Introduction of delta pine cotton in Pakistan has resulted in changing the status of very minor pests e.g. *Heliothis* and *Spodoptera* to serious pests of cotton, resulting in ban on deltapine cultivation. Similarly cultivation of vice vanity IR 6 is responsible for introduction of rice hoppers.

In years of borer epidemic on rice, 30 - 70% of the crop was lost in large tracts of Pakistan. In 1935, in Dera Ghazi Khan and Muzaffargarh districts 46.9 to 87.1% borer damage occurred in the late sown rice crop, respectively. In 1942, there was almost total destruction of the crop in Nara Valley region of Tharparker district. In 1952, there was a serious outbreak of rice borers in Tando Mohammad Khan tract of Hyderabad district. In 1952 - 1953, borer caused 30-50% damage in the Tharparkar district. The borer epidemic cycle in Larkana district and around started in 1956 -1957 and lasted for about 3 years. In 1957, the destruction of the crop ranged generally between 30 - 60 %, while it was not uncommon to find fields, where the crop was totally destroyed by borers. The damage was so high that the estimated yield would not pay for the cost of harvesting and hence the crop was abandoned. In 1958, in the same tract in even after repeated treatment of nurseries with pesticides, the loss of crop in several fields was as high as 35%. In the same year, the damage caused by borers at the Rice Research Station, Dokri was very high, despite repeated application of large doses of contact and systemic pesticides to both the nurseries and transplanted crop. In Jacobabad district, the

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losses were observed to range between 30 - 50%, while sight of fields with 70 to 80% white ear heads was common. Prior to 1955, in the districts of Gujranwala, Sheikhupura and Sialkot, which comprise major rice growing area of Punjab; borers were seldom reported to cause any appreciable damage. However, in 1955, the damage was unusually heavy (Irshad, 2008).

History of plant protection with pesticides in Pakistan started in 1947 with only 508 hand sprayers and 16 vehicles. In 1951, locust problem became severe; hence aircrafts for aerial spraying were obtained and utilized. Later on, aerial spraying was done against *Pyrilla* infestations on sugarcane in NWFP. After initial success, it was extended to cotton, rice and orchards in the whole country. In many cases, economic returns have only been possible by chemical control. The most widely practiced method, the chemical control is now often and widely criticized for its ill effects especially for disturbing the ecological system/balance. Consumption of pesticides in Pakistan has increased many folds (i.e. from 665 tons in 1980 to 73632 tons in 2010), without significant gains in the yield of crops. Chemical based control program in crops has actually increased the pest problems, disturbed the agro-ecosystem and has killed the non-target and environment friendly organisms such as parasitoids, predators and birds. Chemical control is now considered as the root cause of many hazards. However, there may be some exaggeration in this criticism for the developing countries because the standards practiced in the developing countries are different from developed countries. Developing countries have to provide sufficient food to its population to avoid starvation and famine (Irshad, 2008).

Organic farming policy

Due to hazards of chemical pesticides, plant extracts are gaining much importance. Use of indigenous botanicals has been greatly appreciated. It has now been realized that chemical and other factors have been detrimental in safe environment. Therefore polices are being shifted to non chemical methods. This is now the theme of organic farming. Lesser use of fertilizers and pesticide are now recommended. In organic farming emphasis are on lesser use of chemicals especially pesticides. For this purpose Integrated Pest Management is being strongly advocated. IPM Models for different pests on various crops have been designed. Moreover Farmer Field Schools are in operation all over the country. In these schools particepatory approach is under action. The technical inputs are provided by staff of Research and Development Departments.

Policy and institution regulating pesticide use

Previously Ministry of Food and Agriculture was mainly responsible for food security. Now ministry of National Food Security and Research has been given this responsibility. However, Department of Plant Protection working under

National Food Security and Research is responsible for regulating pesticides and quarantine affairs.

Inventory of bio-pesticide used in the country

Due to hazards of chemical pesticides, plant extracts are gaining much importance. Use of indigenous botanicals has been greatly appreciated. In the ancient times it has been a practice to mix neem materials in stored products for protection against insect pests. Use of neem materials and the protection it offers to stored products is experience driven rather than being based on knowledge. The characteristic odor of neem products permeating in closed storage environment repelled insects and the bitter compounds present in neem materials mixed with the stored grains deterred feeding. Farmers of Punjab and Sindh usually keep neem leaves with grains or rub fresh leaves against the inside the walls of stores. Sometime water extracts of the neem is applied to gunny bags. Neem tree has long been recognized for its properties against insects. Other plants which have been used include *Azadirachta indica, Curcuma longa, Acorus calamus, Skimia laureola, Sausarea lappa, Valariana officianalis, Peganum harmala* (Iqbal, 2006)

Many spices and herbs and their extracts are known to possess insecticidal activities, which are frequently present in the essential oil fraction. Essential oil show great promise for the control of the major store products insects and are found to be active fumigant at low concentration. The toxicity of large number of essential oils and their constituents have been evaluated against a number of stored product insects. Moreover essential oil of *Pogostemon heyneanus*, *Ocimum basilicum* and *Eucalyptus* shows insecticidal activities against *S. oryzae*, *T. castaneum* and *C. chinensis*. Toxic effects of the terpenoid d-limonene, linalool and b-terbineol are observed on several coleopteran damaging post harvest products. Fumigant, toxic activity and reproductive inhibition induced by a number of essential oil and their monoterpenoids against the moth *Sitotroga cerealella* are recorded.

The traditional use of plant material is based on the personal experience. In Pakistan, scientific studies have been undertaken and neem, turmeric and sweet flag appears to be most promising. This component lowers the pest population by repellent, antifeedant effects and through inhibition of reproduction and growth. Their effectiveness can be compared with any synthetic compound however, more efforts are needed. The extracts of various plants have been tested against stored grain insects. Neem plant possess maximum repellent property. The maximum repellency was exhibited by seeds compared with leaves, flowers and fruits. It was further observed that the adults of *Rhyzopertha dorninica* were less affected. The flour beetle fed on neem flour failed to reproduce (Jilani and Malik, 1973).

Three plant materials that are common in Pakistan, *Crucuma longa* (turmeric) *Azadrachta indica* (Neem) and leaves of *Trigonella graecum* (Fenugreek) were evaluated for their repellency against the adults of three species of stored-product insects. *Tribolium castaneum*, *Sitophilus granarius* and *Rhyzopertha dominica*. Turmeric was the most effective of the three against *S. granaries* and *R. dominica*. For each plant material petroleum ether extracts were more effective than the acetone and ethinol extracts. The petroleum ether extract of fenugreek deteriorated much faster than the similar extracts of turmeric and neem. The petroleum ether extract of neem was the most effective of the three plant materials against *R. dominica* (Jilani and Su, 1983).

Powders of five plant species, rhizomes of *Acorus calamus, Allium sativum,* and seeds of *Azadirachta indica, Carum copticum* and leaves of *Xanthoxlyum almaturn* were tested for their effectiveness against *Rhyzopertha dominica, Sitophilus oryzae* and *Sitotroga cerealella. Acarus calamus* proved to be the best for completely checking development of insects. *A indica* and *A. sativum* gave good results (Jilani and Haq, 1984).

Out of thirty indigenous plant species tested for their repellent properties in the form of powders and petroleum ether extracts against the red flour beetle adults, five materials namely; rhizomes of *Acorus calamus*, roots of *Valariana officianalis*, leaves of *Xanthoxylum armatum* and *Artemesia maritima* and seeds of *Azadirachta indica* were found to be promising, showing persistent repellency against the test insects (Jilani *et al.,* 1984).

Out of ten plant materials tested, n-hexane extracts of *Neslia apiculata*, leaves, *Lmoniumil cabalicum* whole plant and *Achillea millefolcum*, flowers exhibited more than 40 per cent average repellency over 8 weeks against adults of red flour beetle, *T. castaneum.* Repellency was considerably high during first week of testing, which decreased to lower levels in second, fourth and eighth weeks. *A. millefoliun* flower extract also showed similar trend, while leaf extract of *N. apiculata* was persistently repellent even after 8 weeks providing more than 41 per cent repellency. Plant derived repellent materials are expected to be safe, efficient and economical for insect control (Jilani *et al*., 1989).

Jilani & Saxena (1988) reported that oils of neem, turmeric, sweet flag and Margosan-O (a commercial neem based insecticide) had repellent and growth inhibiting effects against *T. castaneum* at 200, 400 and 800 µg/cm^2 on filter paper. Repellent effect was dose dependant. Neem oil or Margosan-O was more persistant. The adults fed on wheat flour having 200 ppm of each of the oil separately produced fewer and underweight larvae, pupae and adults compared with control. Jilani and Saxena (1990) found that the above materials also had repellent and feeding deterrent effects against *R. dominica* at 200, 400 or 800 µg/cm^2. Turmeric oil and sweet flag oil were significantly more repellent during

the first two weeks than neem oil and Margosan-O but thereafter their repellency decreased rapidly than that of neem oil or Margosan-O.

Tahir *et al*. (1992) tested the toxicity and residual effects of malathion, dimilin and a neem extract (neem extract factor B, (NfB)) against *S. oryzae* using filter paper treatments technique. The LD_{50} were 1.04, 28.0 and 86.46 µg/cm^2, respectively. The largest concentration used (0.05, 0.25 and 0.5 %, respectively) were effective for 7-10 days after treatment.

N-hexane extracts of *Astragalus anisacanthus, Foeniculum graecium,* plants and leaves of *Sophora griffithi* exhibited less than 40% repellency against the adults of red flour beetle over a period of 8 weeks. Repellency values decreased from first week showing gradual loss in effectiveness (Jilani *et al.*, 1991). Among the plant materials tested for grain protectent qualities as repellent N-hexane extracts of *Agriophylum latifolium* whole plant, *Ferula copoda* stem and leaves and *Stocksia brahuica* whole plant against red flour beetle were promising providing repellency for 8 weeks (Jilani *et al.*, 1995).

Insects showed 11.1, 22.5 and 4.7% mortality at exposure period of 3, 5 and 7 days of *Acorus calamus* oil against *Trogoderma granarium.* Population reduced both with increase in dose and exposure time (Hasan *et al.*, 2006). It was found to be effective in storage (Rasool *et al.*, 2002).

Jilani *et al*. (2003) tested neem seed oil from five localities of Pakistan against red flour beetle as growth inhibitor and found significant reduction in the progeny at 250 ppm or higher rate in all the samples.

Nazli *et al*. (2003) evaluated the repellency of neem seed oil of Karachi, Hyderabad, Dokri, Shikarpur and Faisalabad in Pakistan against red flour beetle. All the samples proved promising repellent at 600 µg/ cm^2. Highest average repellency was 52.25% after 8 weeks in Hyderabad sample followed by 50.13 and 44.75 % in Shikarpur and Dokri samples, respectively.

Iqbal (2005) evaluated extracts of seeds of neem (*Azadirachta indica)*, rhizomes of sweet flag (*Acorus calamus)* and turmeric (*Curcuma longa)* each in petroleum ether, acetone and ethanol at different application rates for their repellent, growth inhibiting, feeding deterrent and synergistic effects against the red flour beetle (*Tribolium castaneum*), angumois grain moth (*Sitotroga cerealella*) and lesser grain borer (*Rhizopertha dominica*). Petroleum ether extracts of neem and sweet flag applied to wheat grain, bag or both compared with Coopex dust (0.5 %) and polythene enclosure (0.2 mm), provided efficient protection to wheat upto six months. Among the test plants, sweet flag was significantly better repellent upto two weeks but neem showing comparatively lower repellency upto two weeks persisted better upto eight weeks in Treated Paper Strip Repellency Method (contact repellency). For olfactory repellency, evaluated in an Olfactometer for five minutes, sweet flag proved better repellent. In growth inhibition studies (*T.*

castaneum fed for five days on wheat flour treated @ 1000, 500, 250, and 125 µg/gm of the plant extracts) significantly lower progeny (larvae, pupae and adults) was produced in sweet flag. Other plant extracts were also promising growth inhibitors. In feeding deterrent studies conducted by confining *R. dominica* adults on extracts treated filter paper discs treated at 1000, 500 or 100 µg/cm^2 in a micro-cage paper treated with neem extracts had significantly lower number of feeding punctures as compared with those having turmeric and sweet flag extracts. Among solvents, extracts in petroleum ether were significantly better repellents and growth inhibitors but those in ethanol were significantly better feeding deterrents. Repellent, growth inhibition and feeding deterrent properties were dose-dependent. At higher application rates comparatively higher repellency, growth inhibition and feeding deterrence were achieved. Petroleum ether extracts of sweet flag being the most effective repellent and growth inhibitor was chemically fractionated by Thin Layer Chromatography (TLC), using petroleum ether:acetone (3:1) and five major fractions obtained from column chromatography using Silica gel 60 G and elution with petroleum ether:acetone (3:1). Fractions 2 and 3 having Rf values of 0.75 and 0.63 respectively, were significantly better repellent and growth inhibitor. In synergistic studies or combined application of the petroleum ether extracts, sweet flag synergized with neem in different ratios but not with turmeric for inhibition of *S. cerealella* progeny. *T. castaneum* was less affected by combined applications. In warehouse trials, neem and sweet flag extracts applied to both bag @1000 µg/cm^2 and wheat grain @ 1000 mg/kg provided efficient protection against major stored grain insects.

The powders of Basil (*Ocimum basilicum* L.), Lantana (*Lantana camara* L.) and Gardenia (*Gardenia jasminoides* Ellis) against *Callosobruchus chinensis* L. showed significant effect on survival of adult beetles. Mortality increased with increasing amount of leaf powders. Highest and significant mortality was observed in 2:50 ratio of leaf powders and chickpea seeds combination. Development time (Larval + pupal durations) was prolonged with increasing amount of leaf powder. Emergence and egg hatching was significantly low in the leaf powders treatment (Ahmed and Din, 2009).

Extracts of *Acorus calamus*, *Azadirachta indica* and *Curcuma longa* prepared in petroleum ether, acetone and ethanol were evaluated as growth inhibitor against *Sitotroga cerealella*. Among these extracts, petroleum ether extract of sweet flag at application rates of 1000, 500 and 250 µg/g and its acetone extract at 1000 and 500 µg/g completely inhibited emergence of adults. Petroleum ether extract of neem was next to sweet flag. Turmeric was less effective than neem extract especially at 1000 and 500 µg/g application rates (Iqbal *et al*. 2010).

Neem oil, against sucking insect pest complex of cotton under natural, semi-natural and under controlled conditions gave significant control of jassids, thrips and aphids (*et al.,* 1996). The efficacy of a neem product (phytopesticide FWB) was compared with perfekthion [dimethoate] against sucking pests of cotton (jassids [Cicadellidae], thrips [Thysanoptera], aphids and whiteflies [Aleyrodidae]). Perfekthion proved to be more toxic but its effect lasted for 4 days only while the neem product (FWB) was less toxic but its effect lasted for 6 days. In addition, neem product is much safer and non-polluting (Aslam *et al.,* 2000).

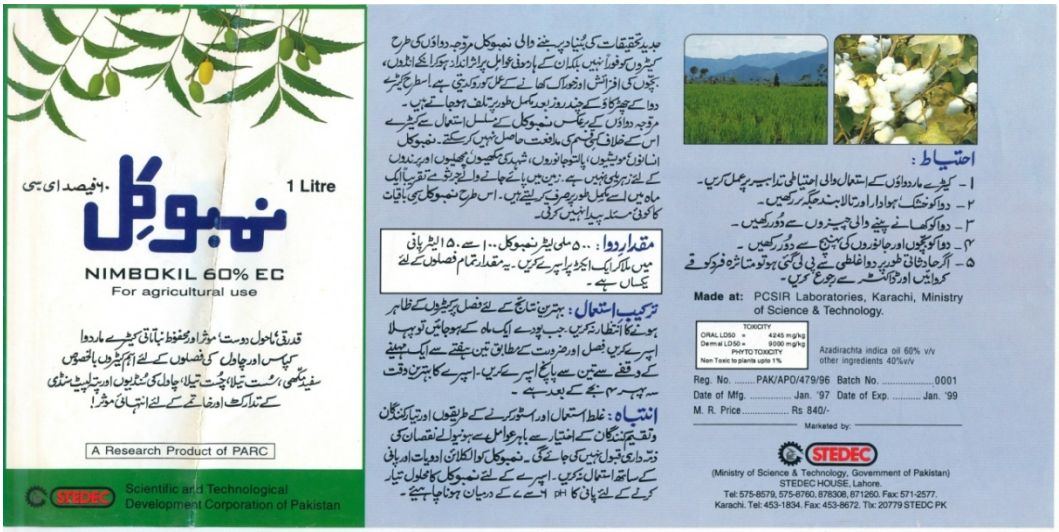
The extracts (0.25, 0.50 and 1.00% w/w), powders (seed kernel powders at 1.25, 2.50, 5.00 and 10.00 % w/w and leaf powder at 30%) and parts (kernel pieces and whole kernels) of neem (*Azadirachta indica*) seed kernels and leaves were tested for their repellent properties against *Tribolium castaneum* and *Rhyzopertha dominica*. The greatest repellency was observed with fresh seed kernels extracted in ethyl alcohol at 150 mg/cm. Dried kernel powder at 10% protected wheat against *R. dominica* for up to one year (Zahoor *et al*., 2002). An extract of *Acorus calamus* and cypermethrin were tested for their effect on enzymatic activities of *Sitophilus oryzae*. Alkaline phosphatase activity was reduced to 11.11 and 13.13% by treatment with the LC_{50} of *A. calamus* extract and cypermethrin, respectively, while acid phosphatase activity was reduced to 15.55 and 31.57%. Total protein content was also reduced by these treatments (Ahmad *et al*., 2000).

Three concentrations, 1, 0.5 and 0.25%,of Neemcos Technical, Neem oil and Neem Bio-pesticide proved sublethal to *T. castaneum* These concentrations of three neem formulations had statistically significant difference among them. Larval and pupal duration had non significant difference in three concentrations of each product. A significant effect on fecundity of *T. castaneum* was observed. Neem products and their concentrations had significant difference among them and also with control. The fecundity of beetles from treated neem oil with substrate was comparatively and statistically lower than other two products (Ahmed *et al.,* 2009 & Irshad, 2011).

Most of the plant materials are used as raw material (powder or liquid). Application rate are variable for different situation. Bio-pesticide product produced are few which include following.

During 1993 through a Memorandum of Understanding (MoU) between Scientific and Technical Development Corporation of Pakistan (STEDEC) of Pakistan Council for Scientific and Industrial Research (PCSIR), Ministry of Science and Technology, Govt. of Pakistan and Grain Storage Research Laboratories Karachi of Pakistan agricultural Research Council, Islamabad managed to produce bio-pesticide in the country. STEDEC manufactured two products namely **Nimbokil** and **Nimboli**.

Nimbokil 60 EC was recommended for insect pests of rice and cotton especially white fly, aphid jassid, rice borers and leaf folders. Packing was of one liter with Maximum Retail Price of Rs. 840.

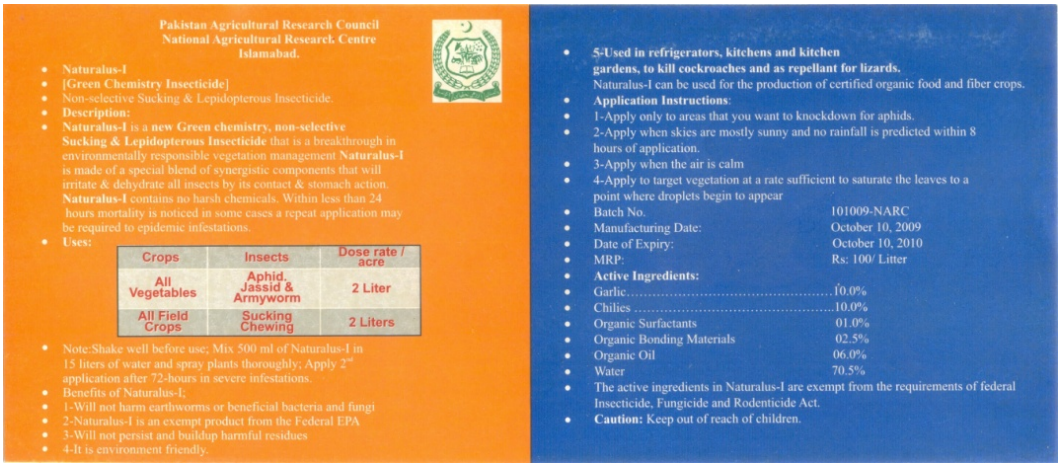


Nimboli was recommended for house hold insect pests especially cockroaches, flies, mosquitoes. Packing of 500 ml was costing Rs. 90. This activity remained continuous for many years and in 2002 it was discontinued due to unknown reasons.

Bio-pesticide produces

In 2008 Pakistan Agricultural Research Council (PARC) took an initiative to produce organic agriculture and for this preparation of Bio-pesticides, Bio-herbicides and organic nutrients were started to prepare/produce. Plants have been installed and produce is underway for certification process. The sale is carried out through PARC AgroTech Company (PATCO). PETCO has started production of Bio-pesticides (Naturalus-1), Bio-herbicides (Herbinarc) and Micro Nutrients (NE 210). The details are as under:

Naturalus-1



Pakistan Agricultural Research Council
National Agricultural Research Centre
Islamabad.

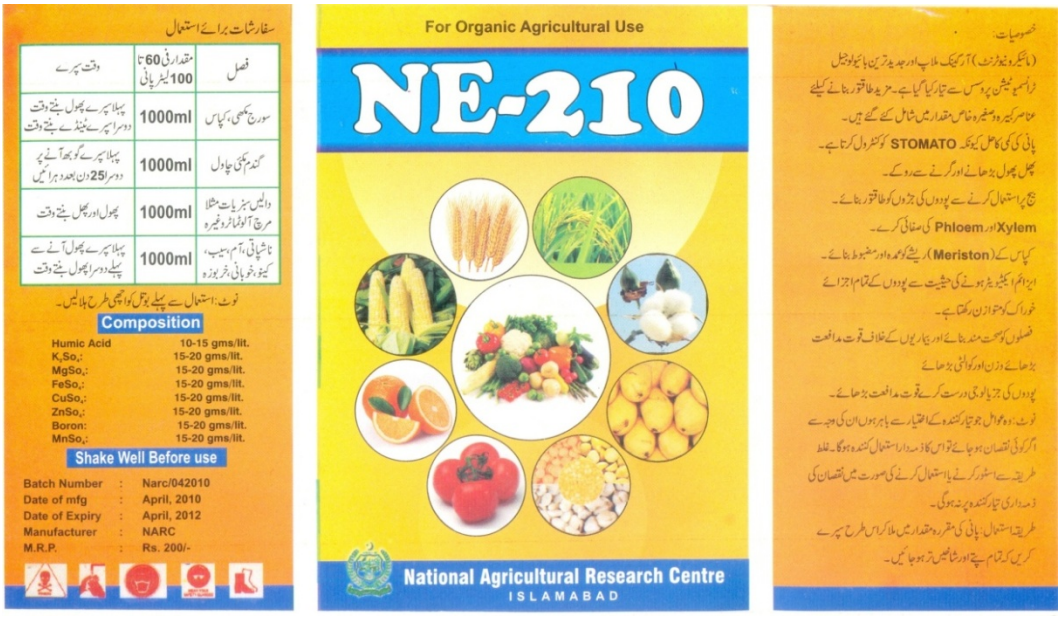
- Naturalus-I
- [Green Chemistry Insecticide]
- Non-selective Sucking & Lepidopterous Insecticide.
- **Description:**
- **Naturalus-I** is a **new Green chemistry, non-selective Sucking & Lepidopterous Insecticide** that is a breakthrough in environmentally responsible vegetation management **Naturalus-I** is made of a special blend of synergistic components that will irritate & dehydrate all insects by its contact & stomach action. **Naturalus-I** contains no harsh chemicals. Within less than 24 hours mortality is noticed in some cases a repeat application may be required to epidemic infestations.
- **Uses:**

Crops	Insects	Dose rate / acre
All Vegetables	Aphid, Jassid & Armyworm	2 Liter
All Field Crops	Sucking Chewing	2 Liters

- Note:Shake well before use; Mix 500 ml of Naturalus-I in 15 liters of water and spray plants thoroughly; Apply 2nd application after 72-hours in severe infestations.
- Benefits of Naturalus-I;
- 1-Will not harm earthworms or beneficial bacteria and fungi
- 2-Naturalus-I is an exempt product from the Federal EPA
- 3-Will not persist and buildup harmful residues
- 4-It is environment friendly.
- **5-Used in refrigerators, kitchens and kitchen gardens, to kill cockroaches and as repellant for lizards.**
Naturalus-I can be used for the production of certified organic food and fiber crops.
- **Application Instructions**:
- 1-Apply only to areas that you want to knockdown for aphids.
- 2-Apply when skies are mostly sunny and no rainfall is predicted within 8 hours of application.
- 3-Apply when the air is calm
- 4-Apply to target vegetation at a rate sufficient to saturate the leaves to a point where droplets begin to appear
- Batch No. 101009-NARC
- Manufacturing Date: October 10, 2009
- Date of Expiry: October 10, 2010
- MRP: Rs. 100/ Litter
- **Active Ingredients:**
- Garlic.....10.0%
- Chilies 10.0%
- Organic Surfactants 01.0%
- Organic Bonding Materials 02.5%
- Organic Oil 06.0%
- Water 70.5%
- The active ingredients in Naturalus-I are exempt from the requirements of federal Insecticide, Fungicide and Rodenticide Act.
- **Caution:** Keep out of reach of children.

Recommendations for Naturalus-1are as under

Crops	Insects	Dose rate/ acre	Price
All vegetables	Aphid, Jassid & Armyworms	2 liter	Rs. 100 / liter
All field crops		2 liters	



سفارشات برائے استعمال

فصل	مقدار فی 60 تا 100 لیٹر پانی	وقت سپرے
سورج مکھی، کپاس	1000ml	پہلا سپرے پھول بننے وقت دوسرا سپرے نیڈے بننے وقت
گندم مکئی چاول	1000ml	پہلا سپرے گوبھ آنے پر دوسرا 25 دن بعد دہرائیں
دالیں سبزیات مثلاً مرچ آکوٹما ٹرومیٹو	1000ml	پھول اور پھل بننے وقت
ناشپاتی، آم، سیب، کینو، خوبانی، خربوزہ	1000ml	پہلا سپرے پھول آنے سے پہلے دوسرا پھول بننے وقت

نوٹ: استعمال سے پہلے بوتل کو اچھی طرح ہلالیں۔

Composition

Humic Acid	10-15 gms/lit.
K_2So_4:	15-20 gms/lit.
$MgSo_4$:	15-20 gms/lit.
$FeSo_4$:	15-20 gms/lit.
$CuSo_4$:	15-20 gms/lit.
$ZnSo_4$:	15-20 gms/lit.
Boron:	15-20 gms/lit.
$MnSo_4$:	15-20 gms/lit.

Shake Well Before use

Batch Number	:	Narc/042010
Date of mfg	:	April, 2010
Date of Expiry	:	April, 2012
Manufacturer	:	NARC
M.R.P.	:	Rs. 200/-

For Organic Agricultural Use

NE-210

National Agricultural Research Centre
ISLAMABAD

خصوصیات:

(مائیکرو نیوٹرنٹ) آرگینک ملاپ اور جدید ترین بائیولوجیل ٹرانسمیٹ ٹیشن پروسس سے تیار کیا گیا ہے۔ مزید طاقتور بنانے کیلئے عناصر کبیرہ وصغیرہ خاص مقدار میں شامل کئے گئے ہیں۔

پانی کی کمی کا حل کیونکہ **STOMATO** کو کنٹرول کرتا ہے۔

پھل پھول بڑھانے اور گرنے سے روکے۔

بیج پر استعمال کرنے سے پودوں کی جڑوں کو طاقتور بنائے۔

Xylem اور **Phloem** کی صفائی کرے۔

کپاس کے (**Meriston**) ریشے کو مضبوط اور مضبوط بنائے۔

ایزاٹمز ایکٹیویٹر ہونے کی حیثیت سے پودوں کے تمام اجزائے خوراک کو متوازن رکھتا ہے۔

فصلوں کو صحت مند بنانے اور بیماریوں کے خلاف قوت مدافعت بڑھائے وزن اور کوالٹی بڑھائے

پودوں کی جڑ نالوں کو درست کرے قوت مدافعت بڑھائے۔

نوٹ: وہ عوامل جو تیار کنندہ کے اختیار سے باہر ہوں ان کی وجہ سے اگر کوئی نقصان ہو جائے تو اس کا ذمہ دار استعمال کنندہ ہوگا۔ غلط طریقہ سے اسٹور کرنے یا استعمال کرنے کی صورت میں نقصان کی ذمہ داری تیار کنندہ پر نہ ہوگی۔

طریقہ استعمال: پانی کی مقررہ مقدار میں ملا کر اس طرح سپرے کریں کہ تمام پتے اور شاخیں تر ہو جائیں۔

Conclusions and Recommendation

This sector needs more technical input in the shape of research technology and human resource development. A number of plant materials have been traditionally used for pest control for centuries. These have been widely studied against insect pests of field crops and storage. Unlike ordinary insecticides based on single active ingredients, the bioactive components of plants are a complex array of novel compounds with diverse behavioral and physiological effects on insects. Commodities treated with plant extracts repel insects and deter their feeding. However, the complexity of chemical structure of majority of these compounds precludes their synthesis on a practical scale. Therefore, the use of simple formulations of plant derivatives such as oils and extracts needs to be popularized. These being safe to non-target organisms such as predators and parasites, make them ideal insecticides for use in Integrated Pest Management Programmes.

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PAPER 6

Extent and potential use of Bio-pesticides for Crop Protection in Sri Lanka

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K.A.N.P. Bandara[13]

Introduction

Sri Lanka is mainly an agricultural country where the agriculture sector contributes to 11.2% to GDP in 2012. Share of GDP of Agriculture and livestock is 8.9% while a Plantation crop is 1.1% and minor export crops shares 1% (Central Bank Annual Report, 2012). In 2007, land area under food production is 57% of the total land of Sri Lanka (AgStat, 2012). Around 1.7million agricultural holdings are small scale which is less than 0.10 ha lands (Department of Census and Statistics, 2002).

In the history of more than 2500 years, Sri Lankan farmers have traditionally used plant material with pesticidal properties to protect their crops from pest and diseases. Traditional pest control methods such as mixing natural plant materials like neem, citrus and basil leaves, wood ash, plant oils *etc.* with stored grains, mixing of crushed plant materials with irrigation water in paddy fields, spraying of plant water extracts to agricultural crops and treating wounds of livestock with neem oil have been used by the farmers for centuries. With the increase of population and the demand for increased agriculture productivity, the traditional sustainable agriculture gradually turned into commercial agriculture with the use of agrochemicals. At present, the commercial agriculture, lead the farmers of Sri Lanka to depend mainly on the use of pesticides to protect their crops from pest and diseases. During 2010, a sum of 4,557,000 US$ worth of insecticides and 2,785,000 US$ worth of fungicides were imported to Sri Lanka. Indiscriminate use of pesticides by the farmers raised problems viz. environmental pollution, health hazards to human and development of resistance to chemical fungicides by many soil borne pathogens. Due to these reasons, there is an increasing concern over the usage of synthetic pesticides among the farming community as well as general public. In this context, bio-pesticides are coming up as an ecology-conscious, sustainable alternative strategy for pest and disease management. Locally produced botanical extracts are used to control pest and diseases in the organic farms in small scale throughout the country where synthetic pesticide

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usage is low. In 2003, a South Asian regional training workshop on bio-pesticides funded by UNESCO was held in Sri Lanka to educate researchers regarding the recent trends in bio-pesticide development in order to face the challenges of the 21st century.

In Sri Lanka, the Ministry of agriculture, other government institutions and universities conduct mainly research and production activities for development and application of bio-pesticides. Large amount of research information on the bio-efficacy of various plant extracts against several agricultural pest species are available. However, as there is no proper government organization engaged in production process and commercialization of bio-pesticides, various individual institutions and non-governmental organizations working in isolation are involved in formulation and marketing of bio-pesticides. Lack of collaborative efforts and national programme to develop bio-pesticides, difficulty in testing for toxicological data and controlling the quality of the commercial products are the drawbacks in the development of bio-pesticide industry in Sri Lanka. Imported formulated products of bio-pesticides such as synthetic insect pheromones, juvenile hormones, enzymes, botanicals and natural plant regulators are registered and extensively used in Sri Lanka. However, commercial products of botanicals, bio- control agents and microbes are not registered or imported to Sri Lanka.

Policy and Institutions regulating pesticide use

The Control of Pesticides Act No.33 of 1980 and its amendment No.6 enacted in 1994 regulate the importation, packing, labelling, storage, formulation, transportation, sales and use of pesticides in Sri Lanka. The designated licensing authority is the Registrar of Pesticides attached to the Department of Agriculture. Pesticide Technical Advisory Committee advice the Registrar of Pesticides on all the matters pertaining to the Pesticide Act. All the pesticide products used in the country are required to be registered under the Pesticide Act. Bio pesticides including botanicals also regulated under the same Control of Pesticides act. However, at present the locally produced botanical extracts (without adjuvants and formulation types) are exempted from registration and hence do not carry a label approved by the pesticides regulatory authority. If a local producer needs to get a registration for bio-pesticide, the production procedure and the product are required to meet the criteria for registration of other pesticides. Importation and registration of bio-pesticides with bio control agents and micro organisms manufactured elsewhere will not be granted registration until rules and regulations are in place.

Further, some bio-pesticides formulations with *Bacillus thuringiensis israelensis* locally and elsewhere produced are registered for mosquito control to minimize the dengue epidemic. The marketing and use of these products are monitored with the assistance of the Ministry of Health.

Inventory of bio-pesticides used in agriculture sector

Table 1. Bio-pesticide used in agriculture/livestock/fisheries

Bio-pesticide products	Target crop	Target pest/ disease	Application mode	Application rate	Remarks
Neem seed kernel water extract	Vegetables Legumes Mushroom	i. Aphids ii. Leaf eating caterpillars Dipteran flies aphids	Foliar Spray Foliar Spray Foliar Spray	25-50g fresh seed kernals/L	Recommended by the Department of Agriculture
Gannoruwa kohomba palibodhanashakaya	mushroom		Foliar Spray		Unregistered product
Lakgro Neem	Cabbage Beans Chilli/ Capsicum Tomato Flowers Mushroom	i. Aphids ii. Leaf eating caterpillars iii. Pod borers iv. Scales and mealy bugs v. Mites	Foliar spray	3-5 ml/ L	Unregistered product
Neemgro	Rice Vegetables Onion Potato Flowers Mushroom Tea Tobacco Betel	Leafminers Whiteflies Thrips Aphids Pod Borers Stem Borers Paddy bugs Cutworms Lepidopteran Caterpillars Nematodes & Mites. Mushroom pests	Seed treatment/ Foliar Spraying/ Soil drenching	10 to 15 g per acre	UnRegistered product

Bio-pesticide products	Target crop	Target pest/ disease	Application mode	Application rate	Remarks
NeemTee	Tea	Insect pests Nematodes Mites Blister blight	Foliar spray	100g per 1000L per Ha	UnRegistered products
NeemMite	Fruits Flowers	Mealy bugs Mites Nematodes Sap sucking pests Leaf eating insects	Foliar spray		
NeemMat	Seed potato in Storage Stored grains	Tuber moth Weevils Beetles Pulse bruchids	Mix with seeds	50g/5kg seeds Or 50 kg seed potatoes	
Neemazal F	Cabbage	caterpillars	Foliar application	14-28 ml in 13.5 L of water	Registered product Currently the product registrations are lapsed
	Mushrooms	Eye flies, Beetles, Earwigs	Application to growing medium after harvesting	14 ml in 13.5 L of water	
Neemazal TS 1% EC	Rice	Leaf folder	Foliar spray	2000 ml of	Currently the

Bio-pesticide products	Target crop	Target pest/ disease	Application mode	Application rate	Remarks
(Azadirachtin)	Cabbage			mixture/ Ha (5 ml/1 L of water)	product registrations are lapsed
Neemazal TS 1% EC	Tea	Nematodes	Soil application	**Nurseries-** 30 ml of mixture (3 ml Neemazal TS in 1 L water) per single plant quantity of soil	
				Young tea- Same rate as above repeated at 2 months interval for 1 yr	
				Old tea- Same rate as above repeated at 2 months interval until Nematode symptoms disappear or up to 2 yrs 30 ml	
Neemazal TS 1% EC	Coconut	Coconut mites	Spray onto nuts	4ml Neemazal TS in 1 L water)Spray 1 L of the mixture to 4-5 trees. One spraying in 1-2 months interval	

Bio-pesticide products	Target crop	Target pest/ disease	Application mode	Application rate	Remarks
Kemisal	Rice Vegetables Fruits Tea Other field crops	Hemipteran and Lepidopteran pests	Foliar Spray	3ml per liter	Unregistered product
Garlic+ mineral oil & soap mixture	Coconut	Mites	Foliar Spray on nuts		Recommended by the Coconut Research Institute
Trichoderma spp. (*T.viridae* and *T.harzianum*) grown on saw dust	Tomato, onion, collocasia	*Colletotrichum gloeosporoides, Fusarium oxysporum f. Sp.cubense, Aspergillus flavus, Penicillium* spp., *Alternaria porri, Rhizoctonia solani, Pithium* spp.	Soil incorporation	Mixing 2.5kg inoculums with 1000kg compost	Recommended by the DOA
HORDI-Tricho (Talc based innoculum)	Soil pathogens	*C. gloeosporoides, F.oxysporum f. Sp.cubense, A. flavus, Penicillium* spp., *Alternaria porri, R. solani, Pithium* spp.	Soil incorporation Seed treatment	5g/ 1sq.m. or 100g/ 1 cube of compost and 1kg innoculum/sq.m soil 5g/kg for small seeds 10g/kg large seeds	Recommended by the DOA

Bio-pesticide products	**Target crop**	**Target pest/ disease**	**Application mode**	**Application rate**	**Remarks**
Liquid *Trichoderma viridae* Innoculum					
Fluorescent *Pseudomonas* spp.					
Lakgro bait	Cucurbits and fruits	Melon fly Fruit fly	Spot application as foliar spray	1-2 L per ha	Registered product
1.Dried, powdered citrus leaves 2.Dried neem leaves 3.Wood ash 4.Paddy husk ash 5. Rhizome and root powder of wild ginger, *Zingiber purpureum*	Stored grain pests -Do- -Do-	1.Cowpea Bruchids 2. Rice moths 3.Maize weevil Cowpea bruchids Cowpea bruchids	Mixing with stored grains	4% or above	Traditional practice
Bio-pesticide products	Target crop	Target pest/ disease	Application mode	Application rate	Remarks
Wormi-compost			Soil incorporation		Unregistered product
Fibrosoil Neem Cake			Soil incorporation		
Nugacim			Foliar spray		New product
Crude extract of			Foliar spray		Traditional practice

Bio-pesticide products	Target crop	Target pest/ disease	Application mode	Application rate	Remarks
Derris scandens					
Cinnamon, *Cinnamomum verum* leaf extract	Chilli	Anthracnose	Foliar spray		Traditional practice
Chitosan					New Product
Biovaccine (*Trichoderma viridae*)		*Pithium*, *Rhizoctonia*, *Fusarium* fungi	Mixing with soil/ Soil application	3 L In 3 Tonnes compost per acre 3L in 200 L water	Unregistered product
BioGold (*Azotobacter chroococcum* and *Pseudomonas fluorescens)* in liquid formulation	Cardomum Potato Vegetebles Fruits Cereals				

Quantity and Extent of use

Bio-pesticide products	Quantity used (Tonnes)	Area coverage (Hectare)
Gannoruwa Kohomba Palibodhanashakaya	Not available	Not available
Neemazal TS	250kg/yr (in 2007)	Not available
Neemgro/ NeemTee/Neem	Not available	Not available
Kemisal	Not available	Not available
Garlic+ mineral oil+ Neem extract		
Trichoderma spp. innoculum	300-400 kg/Yr	
LakGro Bait	270 L/Yr.	Not available
Lakgroneem	360 L/Yr.	Not available
Chitosan	To be commercialized	Not available

Success stories in bio-pesticide use

Neem Seed Kernal extract (NSKE):

NSKE was identified as a highly effective botanical pesticide for several decades. After many years of research on the bio efficacy of NSKE at various research institutions, mainly at the Horticultural Crops Research and Development Institute potential of using NSKE to control many insect pest species was identified and the Department of Agriculture recommended usage of NSKE against a wide spectrum of insect pests mainly the cabbage caterpillar complex. The technique for preparation of the crude water extract and its benefits as a pesticide was disseminated to the farmers through various extension methods. A booklet with cartoon type pictures was prepared which was very effective in disseminating the technology to the rural farmers. Until such time, farmers used a range of synthetic insecticides indiscriminately for cabbage cultivation which polluted the environment heavily and leaving toxic residues in the produce. With the introduction of NSKE, many small scale farmers switched into it while most organic farms and home gardens practiced use of NSKE for almost all crops. Further to that commercial neem based pesticides were developed in Sri Lanka.

Protein bait

Use of protein bait to control Tephritid fruit flies is practiced in many counties in the world as a successful control technique for the difficult to control pest *Bactrocera* spp. Studies conducted at Horticultural Crops Research and

Development Institute (HORDI) have reported that the local product of protein bait is highly effective. In the field experiments it showed 96% effectiveness in controlling melon fly in cucurbit crops and it could be successfully used to attract both male and female fruit fly and melon fly species.

Sri Lanka produced its first protein bait in 2003 which was the base of the successful story of controlling fruit fly and melon fly in an environmentally friendly manner. Farmers were using chemical pesticides indiscriminately for cucurbits to control melon fly. With the development of the protein bait a development programmed was implemented to educate the farmers in the Central region of Sri Lanka on usage of protein bait to control melon fly damaging cucurbit crops. Large scale production of local protein bait was started by a private company and the first commercial product was patented and registered as Largo bait®. Although cucurbit farmers were educated on this product some are reluctant to use it as they do not see the dead fruit flies as in the pheromone traps. A national programme to build awareness on the potential use of protein bait is planned to be implemented in the near future.

Bio-pesticide producers

Product	Contact address
Largo bait & Largo Neem	Lanka Agoutis (Pvt.) Ltd. No.164 A, Kandy Road, Pilimatalawa, Sri Lanka
NeemGro & NeemTee NeemMite NeemMat	NeemLanka (Pvt.) Ltd. 444/11, Pitakotte, Kotte, Sri Lanka
Gannoruwa kohomba palibodhanashakaya, Gannoruwa Peradeniya, Sri Lanka	Gannoruwa Peradeniya Sri Lanka
Kemisal	U. K. Hithayathullah 222A/3, Al-hilal Road, Sainthamaruthu-13 Kalmunai 32280, Sri Lanka
Trichoderma spp. Innoculum	Pathology Division Horticulture Research and Development Institute, Gannoruwa, Peardeniya, Sri Lanka
Trichoderma spp. Liquid formulation Biovaccine BioGold	Biopower Lanka (Pvt.) Ltd. No.125, St.Michael's Road, Colombo 3
Fibrosoil Neem cake	JayampathiLanka Exports (PVT.) Ltd. Muththettugala, Kurunegala, Sri Lanka

Future prospects

Collaborative national programmes to identify, study and develop bio-pesticides are required to improve bio-pesticide industry in Sri Lanka. Systematic studies on various aspects of bio-pesticides to be conducted in joint-venture efforts of institutions which work in isolation at present. Knowledge on bio-pesticides with individual could be directed towards an action programme to develop efficient bio-pesticides to assure food security and safety by forming an institution for bio-pesticide research and development.

HORDI, Gannoruwa is involved in identifying and testing the efficacy of plant-based extracts at laboratory and at field level since long. Few bio-pesticides were developed and are in use by the farmers. Proper training on extraction techniques and research methodologies would improve the knowledge of scientists to carry out various developmental activities on bio- pesticides.

Conclusions and recommendations

Collaborative effort of government institutions, universities, private sector organizations and non-governmental organizations towards bio-pesticide development is required. Once local bio-pesticides are developed there should be a mechanism to ensure the quality of the product. Proper registration procedure for bio pesticide formulations should be developed. Facilities to be strengthen for testing the bio pesticides to ensure that they meet the requirements of registration of pesticides in the country in order to grant registration. Rules and regulations be imposed to enable importation of highly effective bio-pesticides. Government involvement to encourage scientists to carryout research and development of bio pesticides will lead to investigations and exploration of novel bio pesticides from the vast amount of medicinal herbs with pesticidal properties available but not explored yet. This process will enable to strengthen bio pesticide industry to be able to successful development and formulation of bio-pesticides to assure food safety and security of Sri Lanka.

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Concept Note

Extent and Potential use of Bio-pesticides for Crop Protection in SAARC Countries

Background

The agriculture land in SAARC region extends to more than 345 million hectares which is spread across various agro-ecological zones. The diversity of crops grown in the region and pest and disease prevalent in the region poses enormous challenges to the farmer to save their crops from the pest. The challenge to produce more food to fulfill the need of rapidly growing population has forced growers to use pesticides to protect crops and secure higher production. The indiscriminate use of pesticides has raised the concern and lead to enactment of global declaration “International Code of Conduct on the Distribution and Use of Pesticides - Guidance on Pest and Pesticide Management Policy Development” in 2010. The inappropriate use of pesticides in public health, industries, and household sanitation can pose risk to public health and environment.

As an alternative, use of bio-pesticides (botanical and microbial) are widely promoted as safe and environmentally friendly means to counter the pest and diseases at the same time contain the harmful effects of the chemical pesticides. Many of these bio-pesticides are within the range of farmers’ reach in terms of cost and many of these formulations can be prepared by farmers too.

The prospect for use of bio-pesticides in SAARC region is enormous. At the same time the technological innovation in developing bio-pesticides also exist in the region. Aligning to the food safety needs, application of environmentally safe bio-pesticide vis-à-vis the integrated pest management approach is fast becoming a popular approach in agriculture. With the range of bio-pesticides available in the market with varying efficacies it is important to have adequate knowledge about the bio-pesticides before applying it. As bio-pesticides are narrowly selective and pose few problems to non-target organisms including natural enemies it is safe. However, specific mode of action, slow acting, safer than chemicals, limited field persistence, high unit cost of can make it more expensive. Considering that most countries are promoting organic products and food safety measures, the common knowledge of bio-pesticides used in the region and their efficacy can enhance the potential use of bio-pesticides.

Therefore, SAC initiated a regional workshop on bio-pesticides to basically bring together the regional experts to consolidate the technical information and promote exchange of information.

Objectives:

The objectives of the regional study are as follows:

- Prepare an inventory of bio-pesticides and its extent of use in agriculture
- Documentation of best practices in use of bio-pesticides
- Directory of bio-pesticides producers in the region

Proceeding

Regional expert consultation meeting
on
Extent and potential use of bio-pesticides for crop protection in SAARC Countries

Held in Pema Karpo Hotel, Wangdue, Bhutan
during 23-25th December 2013

Program

Regional expert consultation meeting on extent and potential use of bio-pesticides for Crop protection in SAARC Countries, held in Pema Karpo Hotel, Wangdue, Bhutan during 23-25th December 2013

DAY 1 (23rd December 2013) : INAUGURAL AND TECHNICAL SESSION

INAUGURAL SESSION		
9:00	Arrival of the all the participants	
9:00-9:30	Registration	
9:30	Arrival of the Chief Guest	
9:35	Marchang	
9:40	Welcome speech	Ms. Singye Wangmo, PD-ICS
9:45	Remarks Special Guest	Dr. Abul Kalam Azad, Director, SAC
9:50	Synopsis of the Country paper	Dr. Tayan Raj Gurung, Senior Program Specialist (NRM), SAARC Agriculture Centre
10:15	Remarks by Guest of Honour	Director General, CoRRB
10:25	Inaugural speech by Chief Guest	Hon'ble Secretary, MoAF
10:35	Vote of Thanks	PD-RNRRDC
	Photo Session and Tea Break	

TECHNICAL SESSION I: Country presentation of Afghanistan, Bangladesh, Bhutan		
Chairperson		
Rapporteur	RDC-Bajo	
11:15:11:30	Opening remarks by Session Chairperson	
11:30-11:50	Country paper - Afghanistan	Associate Prof. Dr.M.Z. Sharifi Head of Department of Agronomy Faculty of Agriculture Kabul University, Afghanistan
11:50-12:00	Discussion	
12:00-12:20	Country paper - Bangladesh	Dr. Syed Nurul Alam, Chief Scientific Officer/Head, Entomology Division, BARI, Gazipur
12:20-12:30	Discussion	
12:30-12:50	Country paper – Nepal	Mr. Anisur Rahman Ansari, Chief of Entomology Division, NARC, Kathmandu, Nepal
12:50-13:00	Discussion	

13:00-13:15	Remarks by Session Chairperson	
13:15-14:30	LUNCH	

TECHNICAL SESSION II: Country presentation of Pakistan, Sri Lanka and Bangladesh

Chairman

Rapporteur	RNRRDC	
14:30:14:45	Opening remarks by Session Chairperson	
14:45-15:05	Country paper – Pakistan	Dr. Javed Iqbal, Director (Technical), Pakistan Agriculture Research Council (PARC), Postal Code 44000, Islamabad, Pakistan
15:05-15:15	Discussion	
15:15-15:35	Country paper – Sri Lanka	Ms. Damayanthi Galaniha, Head, Division of Entomology, Horticultural Crop Research and Development Institute, Gannoruwa, Peradeniya Sri Lanka
15:35-15:45	Discussion	
15:45-16:05	Country paper - Bhutan	Ms. Kesang Tshomo, Coordinator, National Organic Program, Department of Agriculture, Simtokha, Bhutan
16:05-16:15	Discussion	
16:15-16:30	Concluding remarks by Chairperson	

DAY 2 (24th December 2013) : TECHNICAL AND CLOSING SESSION

TECHNICAL SESSION III: Special Invited Papers

Chairman

Rapporteur

9:30-9:45	**Paper1**: *Going Organic- A policy to develop agriculture in Bhutan*	*Mr. Mahesh Ghimeray, Specialist (Rice), DoA*
9:45-9:55	Discussion	
9:55-10:10	**Paper 2:** *Role of bio-pesticides in organic agriculture in Bhutan*	*Tshewang Namgay, NoP*
10:10-10:20	Discussion	
10:20-10:35	**Paper 3**: Integrated pest management in Bhutan	*Jigme Tenzin, NPPC*
10:35-10:45	Discussion	
11:00-11:30	TEA BREAK	

TECHNICAL SESSION IVa: Group work

Facilitator: Dr. Tayan Raj Gurung, SPS (NRM), SAC

11:30-13:00	Group work - Draw a regional perspective of Bio-pesticides in SAARC Region
13:00-14:00	LUNCH
14:00-15:00	Group work – Continue

TECHNICAL SESSION IVb: Plenary		
Chairman	**Dr. Abul Kalam Azad, Director, SAC**	
Rapporteur	RNRRDC	
15:00-15:40	Group presentation (3 Groups)	
15:40-15:50	Discussion	
15:50-16:00	Closing remarks by Chairman	
CLOSING SESSION		
Chairperson	**Director General, CoRRB**	
16:00-16:15	Workshop summary (Draft)	Dr. Tayan Raj Gurung, SPS (NRM), SAC
16:15-16:30	Offering of Mementoes and Felicitations	Chairperson
16:30-16:45	Concluding remarks	Chairperson
16:45-16:50	Vote of Thanks	Ms. Singye Wangmo
16:50	Tea	
18:30	Closing Dinner	Hosted by Director, SAC
DAY 3 (25th December 2013) : INSTITUTIONAL VISIT (Only foreign delegates)		
8:00-10:30	Visit to RNRRDC, Bajo;	
11:00-12:30	Visit to Punakha Dzong	
13:00-15:00	Visit to College of Natural Resources	
DAY 4: Foreign delegates leave to respective countries		

Proceedings of the consultation meeting

SAARC Regional Expert Consultation Meeting on 'Extent and potential use of bio-pesticides for crop protection in SAARC Countries'

Day I: Opening Ceremony

Ms. Singye Wangmo, Program Director, Information and Communication Services, Ministry of Agriculture and Forests, Bhutan on behalf of the organizing committee extended a warm welcome to the Hon'ble Secretary of Agriculture, Royal Government of Bhutan, Director General, Council for RNR Research of Bhutan, Director of SAARC Agriculture Centre, Director General of College of Natural Resources, District Commissioner of Wangdue, delegates from SAARC member countries and all the participants of the meeting. She made a special mention of the Director, SAC who despite his busy schedule kindly accepted the invitation of the Ministry of Agriculture and Forests to participate in the meeting.

Dr. Abul Kalam Azad, Director, SAARC Agriculture Centre, Dhaka, Bangladesh gave a brief introduction of the centre and its mandates and activities. He specially thanked Hon'ble Secretary of Agriculture and Director of SAARC Division, Bhutan for kindly approving the hosting of this meeting in Bhutan. As a venue for this emerging science of bio-pesticides in agriculture, Bhutan is the apt venue as the organic movement and strategies are mainstreamed and efficiently implemented. He also emphasized the importance of natural products in crop protection in view of the sustainable development agenda that resonates in all national policies.

Dr. Tayan Raj Gurung, Senior Program Specialist (NRM), SAC presented a detailed summary of the country status report. He highlighted that most of the botanicals used in the region as pest repellents are common and are a safe alternative to the harmful effects of the chemical/ pesticides. Bio-pesticides are also widely reported as an integral part of the integrated pest management strategies. The common knowledge of bio-pesticides available in the region and their efficacy can enhance the potential use of bio-pesticides.

Dasho Sherub Gyaltshen, Secretary, Ministry of Agriculture and Forests, welcoming the distinguished delegates from Afghanistan, Bangladesh, Nepal, Pakistan and Sri Lanka and Director of SAARC Agriculture Centre to Bhutan, expressed his appreciation on convening the regional meeting on bio-pesticide in Bhutan. He highlighted that South Asia as a vibrant region is heavily pressured by 22% of the world population that lives in the region. To enhance food production and ensure safety to the consumers and environment in general, concerted efforts

will be required to face the challenges in the region and we urgently need collaborative research and development in agriculture. With more than 33% of the population under poverty and declining crop yields, the attainment of higher food production has become the priority development goal of all the member countries. He also reminded the meeting that, no technology is a panacea; every technology has good and bad sides with differences in their intensities. The debate on pesticide for crop protection is an open topic which is widely discussed and it should remind us of potential problem and keep alert on any emerging side effects.

Mr. Yadunath Baggai, Officiating Program Director, RNR Research and Development Centre proposed vote of thanks and invited the guests and the participants for the reception tea.

TECHNICAL SESSION: Country paper presentations

First technical session comprising of five country presentations was chaired by Mr. Ganesh B. Chettri, Specialist (Agriculture), Department of Agriculture

Paper 1: Associate Prof. Dr.M.Z. Sharifi, Head of Department of Agronomy, Faculty of Agriculture, Kabul University presented a comprehensive report on extent and Potential use of bio-pesticide in Afghanistan. He made a brief report on agriculture in Afghanistan and indicated that domestic food production do not suffice the national requirement. He highlighted that three types of bio-pesticides (Trichoderma, Madex plus, dipel 150 dust) are commonly used in the country. As the rule on use of chemical pesticides is becoming stringent, use of bio-pesticide increasing.

Some of the discussions following the presentation were as:

- Farmers are yet to understand the benefits of bio-pesticides as it was introduced just three years back.
- Government needs to promote bio-pesticides.
- Bio herbicides are used in horticulture crops.
- The data extend of use of conventional pesticides and bio-pesticides unavailable.
- Lack scientific approach/backing to its use as farmers have been using it without scientific information.
- Currently, all bio-pesticides are imported and there is no domestic production. Bio-pesticide imported from other countries in Afghanistan.
- Bio-herbicide (Phytopthora) initiated in horticultural crops.

Some of the actions suggested for Afghanistan bio-pesticide program by the meeting are as listed below:

- Add information on usage of chemical pesticide in the country for comparison.
- Involve the extension system to reach the farmers.
- Bio-pesticide regulation necessary.
- Adaptive research on imported bio-pesticide needs to be strengthened.
- Work on how to improve the availability and then the use of bio-pesticides.
- Needs regulation for bio-pesticides like the convention pesticides as there aren't any regulations on bio- pesticides as of now.

Paper 2: Dr. Sayed Md. Nurul Alam, Chief Scientific Officer and Head of Entomology Division, Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh made an elaborate presentation on extent and potential use of bio-pesticides for crop protection in Bangladesh. Dr. Alam highlighted the importance of agriculture in Bangladesh where 84% of people are engaged in farming. As in anywhere, Bangladesh too depended heavily on toxic synthetic chemicals (herbicide, pesticide, fungicide) for crop protection, and the impacts of indiscriminate usage of chemicals are observed in environment, health and biotic life (fish), resistance, resurgence and residue. One of the solutions for widespread use of chemicals is the promotion of bio-pesticides which are safe and economical.

Some of concerned raised by the participants were as follows:

- Methyl euglena used for citrus pheromone trap.
- Several disease resistant crops used and more focus in vegetables by the govt.
- Bio-pesticide started to be registered in Bangladeshi govt. It is a good initiative to be followed.
- Bio-pesticide to reduce use of chemicals. Bio-pesticide commercialization necessary
- Farmers group producing organic produces.
- For export, lab analysis carried out for pesticides residue check.

Actions discussed based on the presentation are as follows:

- Commercialization of bio-pesticides needs to be further promoted including research and development.
- Legal regime for bio-pesticides needed.
- Awareness and advocacy campaign.

Paper 3: Ms. Kesang Tshomo, Coordinator, National Organic Program, Department of Agriculture presented the paper 'extent and potential use of bio-pesticides for crop protection in Bhutan" which gave a detail presentation on the

organic policy and situation where commercial bio-pesticides are of recent introduction. It was also indicated that farmers used plant parts and extracts in agriculture crop protection. While Bhutan has managed to drastically reduce the use of chemical pesticides and fungicides, the use of herbicides is in the increase as weed crop take bulk of the farm labour in crop production. She also highlighted the enabling policy environment to promote organic farming such as Economic development policy 2010 which gives special consideration to organic farming in Bhutan. While the use of bio-pesticide is new, BAFRA as the agency to regulate the use of pesticide is stringently implementing the policy to ensure food safety and avoid environmental hazards. She also reiterated that Bhutan has to learn lots from countries like India, Bangladesh and Pakistan where the use of bio-pesticide and its commercial production is done in large scale.

Some of important points discussed were:

- EAs need information indenting (place order) of bio-pesticide in the country for farmers.
- In short term import bio-pesticides and give certain subsidy by the govt. and make bio-pesticides available and in the long run produce in the country itself

Meeting suggested some pragmatic actions based on what was presented:

- Need to have bio-pesticide enterprise in the country.
- Relook the pesticide act and look into the subsidy side for bio-pesticide.
- Focus on bio-weedicide as an alternative to chemical pesticides.
- Research to be done on various imported bio-pesticides.
- Study tour / exchange programs on the SAARC region on bio-pesticide for relevant people.
- Need to do vigorous campaign/awareness on ill effects of chemical pesticides in Bhutan. This will indirectly encourage bio-pesticides.
- Strengthen IPM programs in Bhutan with bio-pesticides.
- Mainstreaming of procurement of bio-pesticides along with other PPC with NPPC. Need for advocacy on BP for extension staff.
- More holistic way of promoting like advantages of bio-pesticides. Vigorous campaign on harmful health and environment effect of PPC to promote BP rather that leaving it as option like it is follow now.

Paper 4: The country paper on Nepal was presented by Mr.Anisur Rahman Ansari, Chief of Entomology Division, NARC, Kathmandu, Nepal. Mr. Ansari explained that major part of agriculture in hills are organic by default, as farmer largely depend on farmyard manure and compost due to poor access to inorganic products. In Nepal one of the district “Jumla” has been declared organic to

promote organic production and experiment the approach. As there is immediate action of pesticides, rice farmers mostly use heavy dose of pesticides. Although IPM has been promoted nationwide, limited awareness on negative effects of pesticides is a major concern in adoption of bio-pesticides. While public institutions are aggressively promoting production and use of bio-pesticide, farmer take up is still slow. The recent move to engage communities in production of bio-pesticide formulation is gradually encouraging the farmers to participate in local production and use of bio-pesticides.

Some of the points discussed were as follows:

- Accessibility of bio-pesticides is a problem and slow action of bio-pesticides is a main constraint.
- Bio-pesticide production locally is cost effective in community centres than purchasing.
- Intentionally farmers are not using crop residue to suppress the weeds.

Actions recommended were:

- Long term demonstration plots/research studies need to be done for bio-pesticide efficacy.
- Exploration of local resource and inventory of BP.
- Amendment and existing acts and regulations.
- Unavailability and high cost issue. Need for subsidy.

Paper 5: Dr. Javed Iqbal, Director, Pakistan Agricultural Research Council, Islamabad, Pakistan presented paper "Extent and potential use of bio-pesticides for crop protection in Pakistan". His paper presentation highlighted that plants extracts are gaining importance due to health hazards of chemicals in Pakistan. He also explained a detail list of botanicals used in bio-pesticides. A need for review and enforcement of existing laws to include bio-pesticides was also mentioned. He highlighted that A*corus calamus* is proved to be the best storage bio-pesticides and needs to be promoted. It gives better result when used with neem.

Some of actions discussed were as follows:

- Needs more technical inputs in terms of research and human resource development.
- Traditional and cultural knowledge has to be researched and more materials developed.
- *Storage pest also need to be emphasized.*
- Review the Legal aspect for promoting bio-pesticides.
- There is need to regulate the quality and the standards for assurance and gain confidence of the farmers.

Paper 6: Ms. Damayanthi Galaniha, Head, Division of Entomology, HORDI, Sri Lanka presented paper "Extent and potential use of bio-pesticides for crop protection in Sri Lanka". She highlighted the gradual expansion of bio-pesticide use in agriculture in Sri Lanka. Presently the neem seed kernel extract (NSKE) is highly effective botanical insecticide. Apart from this, straw mulch controls virus and weeds in chili and is a common practice with the farmers.

Some of the questions raised were:

- What are the causes for non availability of these proven bio-pesticides to the farmers?
- Neem based products are in the market but not passed through the DoA. Commercial bio-pesticides are not readily available to the farmers.

The actions proposed following the paper presentation were:

- Bio-pesticides should be commercially available like other chemicals so that these are easily available to farmers.
- Local production of bio-pesticide to be encouraged in the country and commercialize it.
- Coordination for government and private in bio-pesticide producers.
- Bring some policies for encouraging bio-pesticide like easy registration etc.
- Facilities strengthened for testing of BP.

Day II: Technical Session 2-Special papers

To provide a comprehensive standpoint on organic farming, pesticide use and integrated pest management strategies in Bhutan, three special papers were invited from three agencies, (i) the Department of Agriculture which oversees the agriculture research and development in the country, (ii) National Organic Program which implements the organic agriculture program in the country, and (iii) National Plant Protection Centre which develops and implements IPM program in the agriculture.

The session was chaired by Mr. Namgay Wangchuk, Director General, CoRRB, Ministry of Agriculture and Forests.

Paper 1: Mr. Mahesh Ghimirey, Rice Specialist, RNR Research and Development Centre, Bajo, Bhutan presented a paper titled "Going Organic- A policy to develop Agriculture in Bhutan". He reiterated that Bhutanese agriculture is largely traditional and limited to farm based inputs like compost, manures and plant extracts. Aligned to the local practices, policies have been pro-organic farming as is evident from highly regulated pesticide use. He emphasized that organic agriculture provides an opportunity to commercialize small holder farming. This can be illustrated by the case of red rice in Bhutan. Many rice

farmers in the high altitude areas produce red rice for the export market (USA and Europe), where more than 300 tons of milled rice is exported annually. The exporter collects rough rice from the farmers at a predetermined price, processes and exports. It is a profitable business both for the producers as well as the exporter. Producers know that there is a ready market for their rice and are encouraged to grow at a larger scale. Some of the multi-faceted benefits of organic farming are fulfillment of local food and nutrition requirement of growers, long-term maintenance of soil fertility, reduced use of external inputs, efficient risk management in farming, food with high safety standards, reduced environmental contamination and ecosystems balance. He also raised some of the issues related to organic farming such as lack of awareness and understanding, inadequacy of farm labour, over emphasis on modern farming, conflicting role of district extension workers, small and subsistence producers, and indifferent local consumers.

Some of the points raised during the discussion were:

- Organic production is equally good for food production and there is also ~~is~~ modern organic agriculture for higher food production and food security.
- The strategies for organic farming and translated it into 11^{th} FYP.
- NOP given a top priority by government to promote organic program.
- There is no need to duplicate any research that has been carried out in other SAARC countries and if it is applicable to our country, we need to adopt the successful technologies.
- Good policies are in place and we are in the process of developing a master plan for next 15-20 years.
- Extra investment on research is required.

Meeting suggested some action as:

- Minimize duplication of research in the region and share best practices and technologies.
- Develop master plan for organic farming in Bhutan.

Paper 2: Mr. Jigme Tenzin, Pest Surveillance, National Plant Protect Centre of the Department of Agriculture presented paper on status on Integrated Pest Management in Bhutan. He gave an elaborated overview of the plant protection program in Bhutan. He also mentioned that pest and diseases are the most important constraints to agricultural production in Bhutan. From the start of agriculture development, Department has been cautious on promoting pesticides and implementing IPM approach.

Some of the issues discussed were:

- Hazardous chemical phased out.

- Herbicide usage is high due to shortage of labour problem
- Since Bhutan is going for IPM, we need to think about bio based IPM.
- Go for integration like pheromone which is sustainable method. It can be cheap if produced locally.
- Herbicide increase every year as shown in the presentation. It might lead to environmental problem in the future if same trend continues.
- Mulching to reduce the use of herbicides.

Meeting suggested some actions such as:

- IPM to be bio-based.
- Initiate weed control by mulching/cover crops.
- Bio-pesticide formulations should be made readily available to the farmers.
- Encourage local production for cheaper BP.
- Use chemicals as last resort and epidemic.

Paper 3: Mr. Norden Lepcha from National Organic Program presented a paper on "Role of bio-pesticide in Organic Agriculture in Bhutan. While explaining pros and cons of bio-pesticides, he highlighted the pest and disease management strategy developed by the NoP and emphasized the need for research on locally prepared bio-pesticide formulations.

Meeting raised issues on:

- Bio-pesticides are slow in action and we need to schedule when to spray bio-pesticides.
- Botanicals availability is a question. Preventative approach is required.
- Formulated bio-pesticides, for example from Bangladesh, could be availed.
- The botanical and other bio-pesticides can be imported and used effectively but as far as microbial are concerned, local isolates are more effective as practiced in Nepal

Following actions were suggested:

- Facilities to produce local microbials are required.
- Research has already been carried out and now we need to take action in identifying private entrepreneurs who will produce bio-pesticides in business mode.
- Need to make the best use of locally available resources from sustainability point of view.

Group outputs (Issues and Actions)

Issues raised from the meeting:

Policy

- Inadequate policy /varying national policy of member states.
- No clear lead agency
- Registration system is time consuming and tedious for the pesticides
- Inconsistent labeling of harmful inputs

Research

- Several indigenous knowledge and practices are in the region but due to lack of documentation, availability of botanicals is limiting their adoption.
- Lack of standardized technologies in extraction, formulation and mass production
- Limited collaborative research

Extension and Development

- Field level efficacy of bio-pesticides/up-scaling
- Lack of education/awareness on the advantages and disadvantages of use of bio-pesticides
- Farm level accessibility of effective bio-pesticides
- Quality control and monitoring
- Networking in the private-public institutes in the SAARC countries
- Capacity development
- Limited production facilities

Actions

Policy

- Legal framework for commercialization of bio-pesticide needs to be doveloped by respective government
- Promote and support private sector to manufacture/formulate bio-pesticides within the country.
- Facilitate trade among the member countries (conducive trading policies/regulations, tax exemption, tariffs, subsidies, etc)

- Identification/establishment of referral lab in the SAARC region which is accredited to carry out testing and revalidation of bio-pesticides.
- Adopt FAO guided fast track registration system for bio-pesticides.
- Labeling of hazardous materials to be made mandatory in member countries
- Harmonization of bio-pesticide promotion policies of SAARC member states

Research

- Initiate collaborative research on testing and promotion of most promising bio-pesticide
- Testing the bio-efficacy of botanicals and other bio-agents; development methods/mass production of bio-agents and extraction methods for botanicals; cultivation methods to be developed for important botanicals (domestication of wild plants e.g. sweet flag)
- Lead agency and laboratory may be identified for research and development on bio-pesticides in all the member countries
- Conservation technologies (in situ and ex situ) to be developed for the effective biological agents and botanicals (e.g. establishment or incorporation within existing botanical gardens or gene bank or herbarium)
- SAC should develop a centre of excellence for product development, toxicity testing of botanical pesticides and taxonomic identification of bio-agents.

Extension and Development

- Organize training on bio-pesticide formulation and product development
- Awareness building- Publicity and advocacy (News and awareness in print and electronic media, radio, poster programmes, curriculum at School and college level)
- Establish networking among the SAARC countries for knowledge and technology sharing
- Documentation, promotion and sharing of traditional knowledge on pest management at local level with proper acknowledgement and keeping in mind the international treaties
- Assist private sector in exclusive bio-pesticide business

Workshop recommendations

a). Policy and regulations

1. Need to review/ develop policies and legal framework for inclusion of bio-pesticide. Frame rules and regulations for registration.
2. Provide subsidy for wider promotion and use of bio-pesticide.
3. Establish and monitor standards and quality parameters of bio-pesticide.
4. Develop policy to engage private entrepreneurs in manufacture and sale of bio-pesticide.

b). Bio-pesticides availability

1. Given the limited access and availability of bio-pesticide at the local/ farmers level, there is need to encourage and promote local entrepreneurs in commercial bio-pesticide production.
2. Improve the existing supply and demand system (proper indenting like in Bhutan).

c). Information, awareness and networking

1. Create awareness on
   a. advantages of bio-pesticide, highlighting the negative aspects of conventional pesticides on environment, human health through mass media, trainings, campaigns,
   b. the available bio-pesticide through mass media, trainings, and campaigns.
2. Collaborate and cooperate on exchange of best practices / success stories /technology on BP and on organic farming. This will not only lead to only exchange of knowledge and skills but also reduce the duplication of work thereby saving time and resources.
3. Promote exchanges of technical expertise in the region through exchange visits, study tours, trainings.

d). Research and Development

1. Carryout need based research using locally available resources.
2. Validate local knowledge and practices with scientific research.
3. Establish long term trials for showcasing the efficacy and benefits of bio-pesticide.
4. Ensure adequate funds for research for development purposes.

Participants

SAARC Regional Expert Consultation Meeting on 'Extent and Potential use of Bio-pesticides for Crop Protection in SAARC Countries'

Date: 23rd to 25th December, 2013. Venue: Hotel Pema Karpo, Bajo,Wangdue,Bhutan.

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Glimpses of Regional Consultation Meeting

Participants with Hon'ble Secretary, Ministry of Agriculture and Forests

Inaugural session

Country presentation: Ms. Damayanthi Galaniha from Sri Lanka making country presentation

BIOPESTICIDES

Trigonella graecum *Sitophilus granarius* *Rhyzopertha dominica* *1901* *Pogostemon heyneanus,*

Mentha arvensis or *Artemisia vulgaris* (aqueous extract) *Azadirachtin* decoction *Peganum harmala* *Skimia laureola,*

SNPV- (Single-embedded Nuclear polyhedrosis virus) *Justicia adhatoda* *Ocimum basilicum* Nimboli *Trichoderma*

Chrysanthemum flower paste

Spinosad Tobacco aqueous decoction *Spedoptera litura* pheromone

Pheromone bait trap *Acorus calamus* *Mentha arvensis* (aqueous extract)

Vitex negundo *Eucalyptus* Methyl Euginol (pheromone) for oriental fruit fly (1 product) *Sausarea lappa,* Nimbokil *Lantana camera,*

Abamectin Lime

Bt *Xanthoxyllum alatum* Roxb. Neem fruits (Aqueous solution)

HNPV-(Helicoverpa nuclear polyhedrosis virus for *Helicoverpa armigera*)

Cuelure (pheromone) for cucurbit fruit fly (3 products) Brinjal shoot & fruit borer pheromone *Carum copticum L.*

Elderberry decoction **Adhatoda vasica** *Tribolium castaneum,*