The FFTC Journal of Agricultural Policy
http:/ap.fftc.org.tw/e-journal

Applications and Commercialization of Biopesticides in Bangladesh

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Received June 17, 2024; Accepted November 1, 2024

ABSTRACT

Biopesticides are essential tools in sustainable agriculture and do not harm the soil, water supply, or wildlife, including beneficial insects. This is one of the main advantages of introducing them into an environmentally friendly farming system. In recent years, the use of biopesticides has increased substantially throughout the world, including Bangladesh, considering human health and environmental factors. With increased environmental awareness, more integrated pest management (IPM) efforts, widening of organic farming, more research and development (R&D) of biopesticides, the use of synthetic pesticides, especially in the case of insecticides, is showing a declining trend, whereas the biopesticide market is growing. Extensive and systematic R&D on the mass production, storage, transport, and application of biopesticides have improved in Bangladesh's public and private sectors to enhance commercial production and use. Data show that the use of chemical pesticides is decreasing in the country due to IPM techniques, balanced use of fertilizers, and growing awareness of pesticide use and training. However, biopesticides are faced with challenges in Bangladesh related to formulation, registration, marketing, acceptance and adoption, as well as the costs when compared to chemical pesticides. There is great potential to replace toxic chemical pesticides with biopesticides in the near future if production protocols can be standardized and the private sector becomes more active. The use of biopesticide-based pest management systems should be accelerated to reduce pest management costs with the minimum risks or hazards to humans and their environment. This review paper gives an overview of biopesticide development, production, policy acts, evolution and trends, commercialization, and applications in sustainable agriculture, including by small-scale farmers.

Keywords: Bangladesh, pesticides, pest, integrated pest management (IPM), organic agriculture

INTRODUCTION

The economy of Bangladesh is primarily dependent on agriculture. With about 85% of the total population living in rural areas and directly or indirectly engaged in a wide range of agricultural activities, the agriculture sector plays a critical role in the national economy, accounting for 11.22% of total GDP in 2012–2022 (Bangladesh Bureau of Statistics, 2022). Bangladesh grows a variety of crops, and rice is the predominant one, accounting for about 77.31% of the area's coverage. As the people's staple food, rice is cultivated throughout the country in three different seasons. Bangladesh generally enjoys a subtropical monsoon climate. The annual rainfall ranges from 1,429 mm to 4,338 mm making it possible to grow various agricultural crops throughout the year (Bangladesh Bureau of Statistics, 2022).

Bangladesh's agriculture is transforming from subsistence to commercial farming (Hazra, 2008). Vegetable production has more than doubled over the years, making it one of the fastest-growing vegetable producers in the world (Ahmed, 2017). Bangladesh is now in the world's top third (after China and India)

for rice production, accounting for 7% of the global production (USDA, 2024). Like other countries, pest attacks are one of the most important limiting factors to different crop production in Bangladesh. Indiscriminate and excessive uses of toxic synthetic pesticides are common scenario to combat with the destructive pests and diseases. However, the continuous application of synthetic fertilizers and indiscriminate use of toxic chemical pesticides have already created a resistant pest population and adverse effects on soil properties (Alam, 2013). In Bangladesh, the frequency and amount of pesticide applications per unit area are the highest in the high-valued crops. Brinjal, country bean, cabbage, cauliflower, summer tomatoes, okra, mango, litchi, chili, etc. receive the highest amounts of pesticides due to severe pest damage. According to the Bangladesh Crop Protection Association (BCPA, 2006), pesticide use for growing vegetables was six times higher than for rice (1.12 kg/ha for vegetables, while only 0.20 kg/ha for rice). In addition, frequent use of toxic pesticides has boosted the population of many minor pests like whiteflies, fruit borers, prodenia caterpillars, cutworms, red mites, aphids, and different viruses. Just before one decade none of those pests were considered as the major pests of vegetables or fruits (Alam, 2013).

Synthetic pesticides have become a health hazard for humans and the environment due to their toxicity and pollution. Biopesticides are potential alternatives. Sources of biopesticides are readily available, easily biodegradable, exhibit various modes of action, are less expensive, and have low toxicity to humans and nontarget organisms (Alam, 2012). The reduction or discontinuation of the use of synthetic chemicals within organic farming systems can ensure sustainable crop protection and reduce environmental hazards and possible adverse effects on humans and wildlife. The most common organic materials currently used worldwide are biofertilizers and biopesticides (Alam, 2013). Synthetic chemicals overtook the use of natural products due to their efficacy, reliability, and quick knockdown effects.

PESTICIDE USE PATTERN IN BANGLADESH

Pesticide use in Bangladesh started in the mid-1950s and gained momentum in the early 1970s with the introduction of the Green Revolution through the use of high-yielding variety (HYV) rice. From 1996-1997 to 2007-2008, pesticide consumption increased by 328.4%, and per-hectare pesticide use increased- by 598.8%, with insecticides being the dominant item (57%), followed by fungicides, rodenticides, and herbicides (Alam, 2013).

Total pesticide use was 45,172 metric tons in 2009 in Bangladesh, which decreased to 37,422 metric tons by 2020 (Mazed *et al*., 2022) (Figure 1). Bangladesh used around 44,423 tonnes of pesticides worth US$ 90.96 million in 2011, which came down to 37,422 tonnes worth US$81.08 million in 2020 (1 US$ = 83 Bangladeshi Taka), according to the Plant Protection Wing (PPW) of the Department of Agricultural Extension (DAE) (Pesticide use sees decline. The Business Standard, 2021).

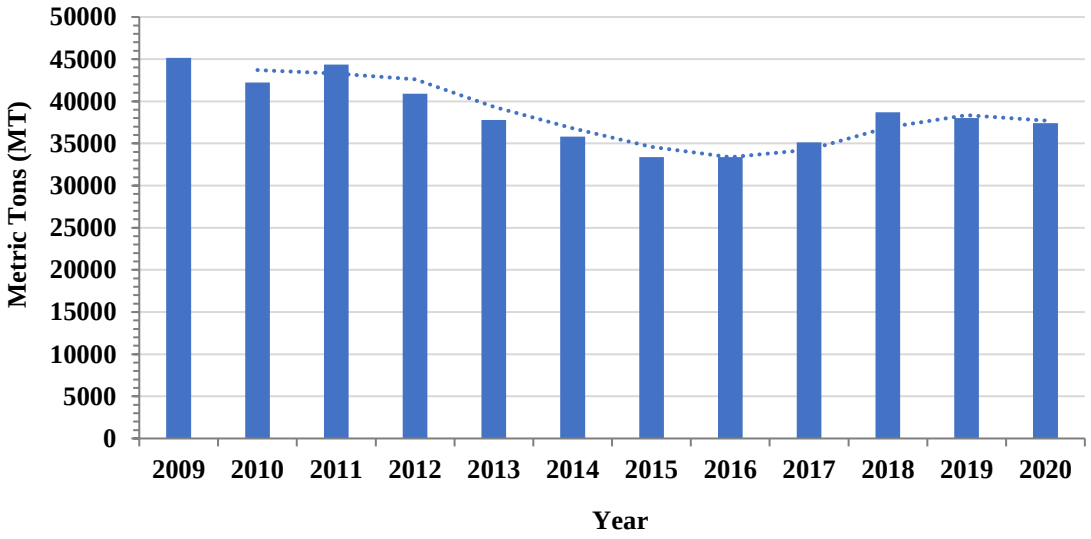

Figure 1. Year-wise pesticide use patterns in Bangladesh (Source: derived from Mazed *et al.*, 2022).

EXISTING ACTS/RULES ON PESTICIDES IN BANGLADESH

In Bangladesh, registration is compulsory before any pesticide can be imported (except for research purposes), manufactured, sold, stocked, or advertised. In 1971, a pesticide ordinance was passed to regulate pesticide import, manufacture, formulation, distribution, and sale. The specific rules were gazetted in July 1985 as "The Pesticides Rules, 1985. The Pesticide Ordinance, 1971" was revised in 2007, and its name was changed to "The Pesticide Ordinance (Amended), 2007". The Pesticide Rules, 1985 did not contain the wording "bio" or a protocol for biopesticide registration. The Pesticide Rules, 1985 were amended by incorporating the provisions of biopesticide registration and a few other changes during 2010. In 2018, the Pesticides Act was gazetted with further modifications of the Pesticides Ordinance.

A Pesticide Technical Advisory Committee (PTAC), a Pesticide Technical Advisory Sub-Committee (Sub-PTAC), a laboratory, government analysts, inspectors, and licensing are engaged for pesticide handling, manufacture, import/export, packaging, labeling, and storage in the country. The rules/ordinance are administered by the Ministry of Agriculture through the Plant Protection Wing (PPW) of the DAE and Bangladesh Agricultural Research Council (BARC). Proposed Biopesticide Regulations, 2022 (under the existing Pesticide Act, 2018) are now being processed and have not yet been gazetted.

EVOLUTION OF BIOPESTICIDE USE IN BANGLADESH

Due to several advantages, biopesticides supplement synthetic pesticides in Integrated Pest Management (IPM) programs, which offer potentially higher crop yields and can dramatically reduce the use of synthetic pesticides. The Pesticide Rules, 1985 were amended by incorporating the provisions of biopesticide registration and a few other changes during 2010. The Bangladesh National Agriculture Policy, 2018, and the 8th Five Year Plan (2020-2035) advocated the use of eco-friendly biopesticides instead of harmful chemical pesticides in 2018.

In 2012, Ispahani Biotech was first licensed by the regulatory authority to produce two Integrated Pest Management (IPM) products. Mohsin Enterprise first got registration for a microbial biopesticide (Dicoprima) in 2015. Currently (up to July 2023), 118 biopesticide brands are registered in Bangladesh (BCPA, 2023). Tricost 1% WP, Monexe 0.5WP, Biomax M, Lycomax, Bactro-D, Q-Phero, K-Mite, Biotrin, and Sopodo-lure are some of the biopesticides produced and used. Chemical pesticide use fell by 11.4% in Bangladesh over the last decade (Biopesticide use, market swell on safe food demand. Business Post, 2021). Currently, 25 companies (listed below) are manufacturing biopesticides in the country.

Biopesticide producers

The major biopesticide-producing public and private institutes/companies in Bangladesh (with their products in italics) are listed below:

Public Institutes (3)

- IPM Laboratory, Entomology Division, Bangladesh Agricultural Research Institute, Gazipur: *Pheromone lures (Brinjal shoot and fruit borer, Cucurbit and Oriental fruit fly, Prodenia caterpilla), Different microbials and biocontrol agents*
- IPM Laboratory, Department of Plant Pathology, Bangladesh Agricultural University, Mymensingh: *Trichoderma (in pit soil), Trichoderma suspension, BAU tablet 1 (garlic), BAU tablet 2 (Allamanda)*
- Department of Microbiology, University of Dhaka: *Bt (different strains of Bacillus thuringiensis)*

Private Institutes/Companies (25)

Ispahani Agro Ltd, Russell IPM Bangladesh Ltd., GME Agro Limited, Intefa, Grameen Krishak Sahayak Songstha (GKSS), Auto Crop Care Limited, East West Chemicals Limited, Atherton Imbros Company Limited, Syngenta Bangladesh Limited, McDonald Bangladesh (Pvt.) Limited, National AgriCare Import & Export Limited, Corbel International Limited, Haychem (Bangladesh) Limited, ACI Formulation Ltd. SAMP Limited, A. M. Traders, SAM Agro Chemical, Nokon Limited, Petrochem (Bangladesh) Limited, Mamun Agro Products Limited, Mohsin Enterprise, Green Care Bangladesh, Bismillah Corporation Limited, and Bangladesh Agricultural Industries.

Biopesticides used in the agriculture sector

In Bangladesh, biopesticide marketing is very much in the initial stage. Some of the developed technologies for biopesticide-based pest management, especially pheromone-based insect pest management approaches, are becoming popular among the farming community (Alam, 2013). The government has also focused on environment-friendly tools and approaches for the pest management of different crops. The descriptions of different biopesticides are shown in Table 1.

Table 1. Biopesticides used in agriculture (derived from Alam, 2013)

Biopesticide products	Target crops	Target pests/diseases	Application mode	Application rate
Pheromone	Cabbage, cauliflower, mustard, aroids, chili, tomato, bitter gourd, etc.	Prodenia caterpillar, *Spodoptera litura*	Set in water trap within 3 weeks of seed sowing	40 lures (traps)/ha
Abamectin (natural fermentation product)	Brinjal, tea, rice, cotton, litchi	Red spider mite, aphids, jassid, mosquito bug etc.	Foliar application	1.25 ml per liter of water
Azadirachtrin (neem-based formulation)	Vegetables, mustard, tea	Aphid, jassid, red spider mite, thrips, mosquito bug	Foliar application	1–3 ml per liter of water depending on formulation
Bt formulation (*Bacillus thuringiensis*)	Vegetables, chili, cotton, etc.	*Lepidoptera* pests	Foliar application	0.4 g per liter of water
Trichoderma (as trichocompost)	All vegetables and spices (chili)	Soil-borne diseases	Mixed with the topsoil (6 inches) 1 week before planting	3 tons per ha
BAU tablet (Garlic and Alamanda 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 min	12 tablets/ha of seeds

Biopesticide-based management practices

It is difficult to control a pest only by applying a single tactic. Developing a complete management package for replacing toxic chemical pesticides is essential to achieve better results. Biopesticide-based best management practices are outlined in Tables 2 and 3.

Table 2. Biopesticide-based management practices (against major diseases) (Bangladesh Agricultural Research Institute, 2022)

Major diseases	Biopesticide-based management practices
Root knot nematode and bacterial wilt of tomato	Integration of Trichocompost @ 2.5 t/ha with stable bleaching powder @ 25 kg/ha and Furadan 5G @ 2 g/plant.
Seedling disease caused by *Sclerotium rolfsii* and *Fusarium* sp.	Seed treatment with chemical fungicide Provax @ 2.5 g/kg seed and *Trichoderma inocula* (spore concentration 1×107 ml/liter).

Major diseases	Biopesticide-based management practices
Root knot nematode of cucurbit crops	Soil amendment with poultry refuse (PR) @ 6–8 kg/pit or neem oil cake/mustard oil cake (MOC) @ 1 kg/pit applied 21 days before seedling transplanting, or Tricho-compost @ 2 kg/pit applied 5 days before seedling transplanting, or sawdust burning along with application of Furadan 5G @ 15–20 g/pit at the time of seedling transplanting can effectively control root knot nematode in cucurbits.
Downy mildew of pumpkin	Mix 2 g of Dynamic- WP (biological fungicide) per liter of water and soak all plants and leaves thoroughly for 7–10 days.
Fusarium wilt and sigatoka of banana	Collect sucker from disease-free plants, dig a pit, and mix Lycomax @ 5 g per pit + Dynamic @ 2 g per/liter of water before planting. Clean suckers before spotting or yellowing of leaves occurs and add Propiconazole group fungicides every 15 days by mixing Dynamic @ 2 g per/liter of water with foliar spraying after 15 days.

Table 3. Biopesticide-based management practices (against major pests) (Bangladesh Agricultural Research Institute, 2022)

Major pests	Biopesticide-based management practices
Fruit flies on cucurbit fruit	A small quantity of a paste/gel-like substance composed of cuelure pheromone and a biopesticide is placed on the creeping stems or on bamboo supporting a trellis (2–3 ft above ground level) along the boundary lines of the field at 10–12-m intervals. Fruit flies are attracted to the hydrolyzed protein as they search for protein sources to support egg maturation and are killed upon contact with biopesticide.
Spodoptera litura pests on tomatoes	Spray SNPV (Spodo SNPV or Virumax SNPV) periodically after 10–12 days by mixing 0.2 g per/liter of water.
Borer pests of litchi fruit	If the shape of the fruit is similar to motor seeds, the Spinosad group of organic pesticides is sprayed once @1.2 ml/per liter of water. When the shape is marble-sized, the fruit bunch should be covered with a 60-mesh nylon net.
Black and white flies on betel leaves	Yellow pheromone traps can be effective. FIZImite or Biotrin is mixed at 1 ml per/liter of water and sprayed on affected leaves to wet them thoroughly.
Mealybug pests of papaya	Clean the papaya garden, then mix Fitroclean (potassium salt of fatty acid) @ 8–10 ml per liter of water and spray on the affected papaya plant leaves.

BIOPESTICIDE-BASED IPM PACKAGES

Pest management costs with synthetic toxic pesticides are increasing tremendously due to their high price and need for frequent application. Farmers are indiscriminately applying toxic chemical pesticides to save their crops from severe infestation by different insect pests and diseases. Unfortunately, they cannot effectively control the pests in many cases due to the development of pesticide-resistant races/strains/biotypes. Biopesticides are derivatives of plants, microorganisms, and insects. Biopesticide-based IPM packages are becoming popular among farming communities due to their effectiveness and lower cost. Table 4 shows that around 25-65% yield increases in healthy high-value vegetables may be possible at 12-48% lower cost than required on plots sprayed with synthetic pesticides).

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

Biopesticide-based IPM packages	Yield increase over non-IPM (%)	Reduction of pest management cost over non-IPM (%)
IPM packages bitter gourd	40-45	45-50
IPM packages sweet gourd	58-65	32-35
IPM packages cucumber	25-30	28-35
IPM packages brinjal shoot and fruit borer	35-40	35-48
IPM packages cabbage/cauliflower	30-35	12-15
IPM packages country bean	35-40	30-32
IPM packages aroids	35-40	35-40
IPM packages tomato	25-28	35-40

BOTANICAL PESTICIDES

Botanical insecticides are naturally occurring chemicals extracted from seeds, flowers, leaves, stems, and roots, called "botanical pesticides." Botanical pesticides (also called "botanicals") are characterized by bioactive mixtures/extracts/compounds from plant materials, which serve as insecticides and repellents but also as bactericides, fungicides, herbicides, and nematicides (Isman, 2006). Recently, botanical pesticides have been widely adopted in rural areas, promoted mainly by Non-governmental Organizations (NGOs) to small-scale farmers.

Resources for botanical pesticides

Plant parts used to formulate botanical pesticides include barks, leaves, roots, flowers, fruits, seeds, cloves, rhizomes, and stems. Neem, pyrethrum, cotton, and tobacco are known sources of botanical pesticides and have already been commercialized. Other sources of botanical pesticides include garlic, euphorbia, citrus, and pepper, among others. *Trichoderma*, *Bacillus*, *Pseudomona*s, and *Beauveria* have been commercialized as microbial pesticides. The plant part depends on the targeted bioactive compounds and their abundance within that particular part (Ramjan, 2021).

Use in pest control

Botanical insecticides can be crude plant extracts or dried and grounded plant materials, or essential oils isolated from the plants which are used for pest management in plants (Isman, 2008). Most plant extracts act on insects by repelling, deterring feeding and oviposition, toxicity, lethal activity, and interfering with physiological activities. Essential oils isolated from the plants have also pesticidal properties. Lemongrass essential oil, Citronella essential oils, Tea tree essential oils and Oregano essential oils are the commonly used essential oils against the pests (Gupta *et al*., 2022). The multiple roles of botanical insecticides against insect pests make them popular in the market.

Method of preparation and application

Botanical pesticides have strong activities such as stomach toxicity, repelling, avoiding multiple pests, and excellent control efficiency. In addition, the insecticide ingredients come from pure plant sources, and therefore botanicals are an excellent environmentally friendly insecticides (Table 5).

Table 5. Methods of preparation and applications of botanical pesticides (Ramjan, 2021)

Botanicals	Parts used	Preparation method	Pests controlled
Annona sp. (sweet and sour soap)	Leaves	Chop ½ kg leaves, place in 2 liters of water, boil until reduced to 1 liter, and mix with 10 liters of fresh water.	Aphids, caterpillars, DBM, flea beetles, etc.
Basil	Leaves, stems	Chop 300 g fresh basil, place in 2 liters of water, boil until reduced to 1 liter, and mix with 10 liters of fresh water.	Red spider mites, leaf miners, fruit flies

Botanicals	Parts used	Preparation method	Pests controlled
Chilli and peppers	Fresh chillies	Chop 500 g fresh chillies, place in 3 liters of water, boil for 15–20 minutes, and mix with 10 liters of fresh water.	Ants, scales, caterpillars, aphids, DBM
Chilli powder (dry)	Fruit	Spray the chilli powder around the plant from near the stem to the outermost leaves.	Ants and termites
Neem	Seeds, leaves, skin (bark)	Chop 1 kg fresh leaves and place in 5 liters of water or pound ½ kg unripe fruit and place in 4 liters of water, allow to stand for 2 days, and then spray on plants every 4 to 5 days. Alternatively, mix ½ liter of neem oil in 4½ liters of water and spray on plants every 4 to 5 days.	Controls most insects
Garlic	Seed cloves	Chop 500 g garlic, add to 8 liters of water, and allow to stand 2 to 3 days before spraying on plants.	Aphids, leafhoppers, squash bugs, whiteflies

BIOPESTICIDE PREPRATION BY SMALL-SCALE FARMERS

The use of organic pesticides on crops is gaining popularity among small-scale farmers as the insecticidal ingredients are nontoxic. Easy preparation methods and low-cost ingredients of organic pesticides also help reduce the cost of agricultural production. Government institutions and NGOs have been receiving good responses from farmers when they arrange training programs on the preparation of organic pesticides (Organic pesticides catching on. The Daily Star, 2021). The training sessions include practical lessons on the treatment of seeds with dung and urine of local cows, the creation of a suitable environment for soil nutrient and microbial growth, retention of moisture and carbon through mulching or covering the soil with crop residues after harvesting, biopesticide preparation, and use. Figure 2 shows some biopesticide preparation images, where farmers use garlic, ginger, and green chili mixture to control different types of pests, such as shoot borers, fruit borers, stem borers, hairy caterpillars, armyworms, aphids, green plant hoppers, mealy bugs, and white flies.

Figure 2. Biopesticide preparation by small-scale farmers (Source: The Author Himself, FIVDB Livelihood Enhancement Program, 2015)

MARKET GROWTH

The global biopesticide market is projected to reach US$ 13.9 billion by 2028 from US$ 6.7 billion in 2023 at a compound annual growth rate (CAGR) of 15.9% during the forecast period in terms of value (Markets and Markets, 2023). In addition, the adoption of *Trichoderma*-based biofungicides has increased in recent years, and around 210,000 kg was used in Bangladesh in 2022 (Personal communication, BCPA). The growing awareness of the harmful effects of synthetic pesticides on human health and the environment has led to increasing demand for biopesticides. This significant growth will also contribute to more widespread

adoption of organic farming practices. Consumers are now more aware of the benefits of organic food for human health and environmental protection, particularly after the COVID-19 pandemic (Brata *et al.*, 2022).

In addition, due to growing concerns for soil health, agricultural sustainability, and environmental safety, biopesticides are increasingly used to improve soil fertility and prevent plant infestation. In Bangladesh, commercial use of biopesticides at the farm level started from 2005. The biopesticide market size in Bangladesh is US$ 6.02 million in 2021. The government and many NGOs encourage farmers to use biopesticides, playing a significant role in expanding their market growth, which is currently at 20% annually (Biopesticide use, market swell on safe food demand. Business Post, 2021).

Progress in the biopesticides market

Expansion in the biopesticides market in Bangladesh increased significantly in 2022 compared with previous years (Figure 3). This may have been due to the government policy of eco-friendly farming promotion and greater awareness of different stakeholders, including farmers.

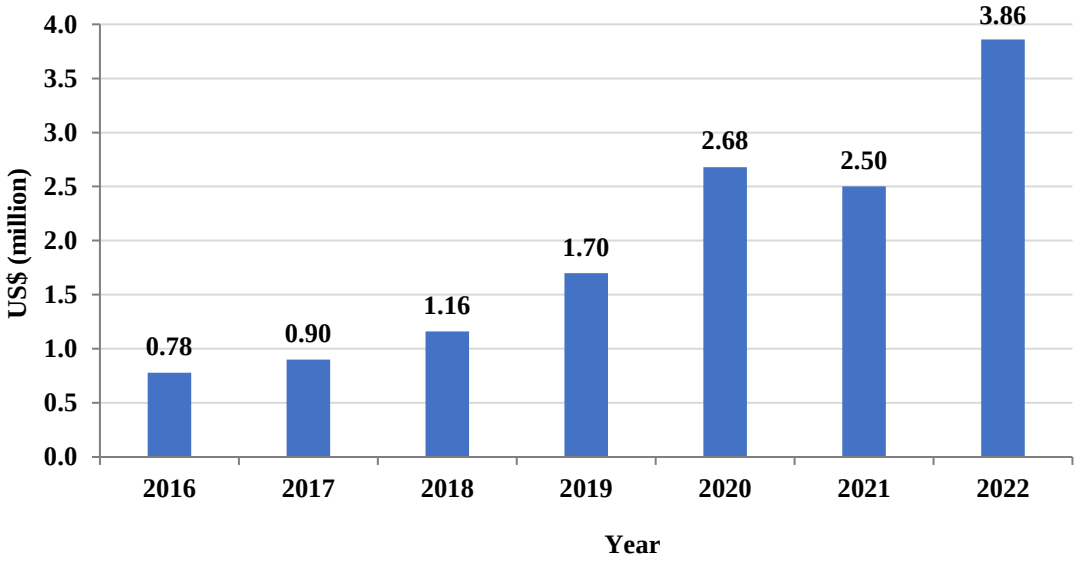

Figure 3. Trends in the biopesticides market in Bangladesh (Source: Personal communication from BCPA)

SWOT ANALYSIS OF THE CURRENT SITUATION

A SWOT (Strengths-Weakness-Opportunities-Threats) analysis involves identifying strengths, weaknesses, opportunities, and threats. It helps develop strategies which can be made into goals and realistic actions to achieve them. SWOT analysis is also useful for planning the future and succession strategies. A comprehensive SWOT status analyzed to understand the overall current situation, as below:

Strengths

- The government has prioritized the innovation and development of biopesticides for the success of IPM.
- Research organizations have the potential for conducting research on biopesticides against major pests and diseases under different conditions.

Weaknesses

- There is a lack of knowledge, interest, and understanding in the private sector of the benefits and methods of biopesticide use (Alam, 2013).
- More infrastructure and expertise are needed for the identification, extraction, isolation, and distribution of suitable bio-derivatives and strains from natural sources.

Opportunities

- There is increasing consumer demand for pesticide residue-free agricultural produce.

- Increased production of safe, organic food products is possible.

Threats

- Chemical pesticides still dominate the market.
- Producers' awareness of the benefits of biopesticides continues to be low.

THE WAY FORWARD

Pest management is a dynamic process, and management tools should be safe, cost-effective, and pose minimum risks or hazards to humans and the overall environment. The following points should be considered in efforts to encourage and facilitate the widespread adoption of biopesticide use.

- Extensive promotional work is needed to disseminate knowledge of biopesticide-based IPM technologies and organic farming practices.
- Develop convenient quality control measures and legal permission systems for commercially available biopesticides.
- The public and private sectors should jointly conduct awareness campaigns among producers and consumers on the benefits of biopesticides for human and environmental health.
- Develop awareness among retailers and farmers of the correct use and safe storage of biopesticides.
- Engage in collaborative biopesticide research at the regional and international levels.
- Conduct research on biopesticide-based pest management systems for different crops.
- Develop cross-country capacity-building programs for researchers, extension officials, and the private sector on the production, quality control, and use of biopesticides.
- Strengthen national research programs to develop and adopt biopesticide and eco-friendly crop protection technologies.
- Inform governments how policies and private-sector support in the form of incentives could significantly increase biopesticide use and impacts on the overall agriculture sector.

REFERENCES

Ahmad, R. 2017. Veg output grows fast. The Daily Star. Retrieved from https://www.thedailystar.net/frontpage/veg-output-grows-fast-1343068.

Alam, S.N. 2013. Extent and potential use of bio-pesticides for crop protection in Bangladesh. SAARC Agriculture Centre. 15–46.

Alam, S.N., Sarkar, D., Dutta, N.K. 2012. Economics of different IPM packages of vegetable crops. Annual Report Year 2, SPGR IPM Project. Division of Entomology, BARI, Joydebpur, Gazipur. 33–36.

Bangladesh Agricultural Research Institute. 2022. Biopesticides-based Technologies for Managing Pests and Diseases of Crops (in Bangla). Bangladesh Agricultural Research Institute, Gazipur.

Brata, A. M., Chereji, A. I., Brata, V. D., Morna, A. A., Tirpe, O. P., Popa, A., & Muresan, I. C. 2022. Consumers' perception towards organic products before and after the COVID-19 pandemic: a case study in Bihor County, Romania. International Journal of Environmental Research and Public Health, 19(19), 12712.

Bangladesh Bureau of Statistics. 2022. Statistical Year Book of Agriculture.

Bangladesh Crop Protection Association. 2023. Pesticide Consumption Report. Dhaka.

Bangladesh Crop Protection Association. 2006. Pesticide Consumption Report. Dhaka.

Business Post. 2021. Biopesticide use, market swell on safe food demand. (https://businesspostbd.com/trade/biopesticide-use-market-swell-on-safe-food-demand-38668, published 2 December 2021)

Gupta, N., Sharma, N., & Ramniwas, S. 2022. Botanical pesticides: use of plants in pest management. CGC Int. J. Contemp. technol. Res: 4,1.

Hazra P. 2008. Upgradation of the vegetable production scenario of Bangladesh: suggested strategy. J. Agrofor. Environ. 2(2):201–204.

Isman, M.B. 2006. Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Annu. Rev. Entomol. 51:45–66.

Isman, M. B. 2008. Botanical insecticides: for richer, for poorer. Pest Management Science: formerly Pesticide Science, 64(1):8-11.

Markets and Markets. 2023. Biopesticides Market. Market Research Report. https://www.marketsandmarkets.com/Market-Reports/biopesticides-267.html. Accessed on 25 March 2024.

Mazed, M.K., Afroz, M., Hossain, M.S., Amin, M.R. 2022. Trends of crop production, land use and pesticide consumption in Bangladesh. Ecology Journal 4(1): 91–99.

Ramjan, M. 2021. Extraction of Plant Based Botanical Pesticides for Management of Vegetable Pests. College of Horticulture and Forestry, Central Agricultural University, Pasighat-791102.

The Business Standard. 2021. Pesticide use sees decline. (https://www.tbsnews.net/economy/pesticide-use-sees-decline-316849,published on 17 October 2021).

The Daily Star. 2021. Organic pesticides catching on. (https://www.thedailystar.net/news/bangladesh/agriculture/news/organic pesticides-catching-2193281, published on October 8, 2021).

U.S. Department of Agriculture. 2024 (https://fas.usda.gov/data/production/commodity/0422110, accessed on 15 September 2024).

ACKNOWLEDGEMENTS

The practices or case studies described in this review paper are supported by a book by the Bangladesh Agricultural Research Institute, Gazipur, titled “Biopesticides-based Technologies for Managing Crop Pests and Diseases, 2022 (in Bangla). The authors would like to thank the Bangladesh Crop Protection Association (BCPA) for their cooperation in collecting data. The mention of commercial products in this article is solely to provide specific information and does not imply recommendation or endorsement by the authors.

AUTHORS’ CONTRIBUTIONS

Shaikh Tanveer Hossain made substantial contribution to overall conceptualization, design of analytical framework, led the data gathering and participated in the writing and finalization of the article. Tonmoy Pandit contributed to the data gathering and information analysis, writing, and editing of the paper. Both authors approved of the final version of the manuscript to be published and have agreed to be accountable for all aspects of the work.

COMPETING INTERESTS

The author declares no conflict of interests.