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Current status and prospects on microbial control in Japan

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Abstract

Historically in Japan, studies on the diseases of the silkworm, *Bombyx mori*, as a factor affecting the well-being of the silk industry, have dominated insect pathology. However, work by Hidaka in 1933 demonstrated the possibility of controlling the pine moth, *Dendrolimus spectabilis,* with the fungus *Beauveria bassiana* and since then, various attempts have been made to develop a method to control insect pests using insect pathogens. The cypovirus product, Matsukemin, was the first microbial control product to be registered in 1974, and inactive and live *Bacillus thuringiensis* products were also registered and put on the market as pesticides in 1981 and 1982, respectively. Currently, there are 25 microbial insecticides on the market that constitute slightly less than 2% of all insecticides used in Japan. Adoption of biopesticides is likely to increase in the near future due to scientific advances and several new government policies that encourage the use of alternative pest control products.

Keywords: Microbial control; Insect pathogens; Sustainable agriculture; Microbial insecticide; IPM

1. Introduction

Insects comprise the most diverse group of animals on earth, with approximately 1.5 million species described. There are some species among these organisms that cause serious damage to the crops, which can severely limit the production of agricultural products. These insects, which interfere with human health, activity or property, or reduce quality or yield of agricultural products, are termed insect pests, and since ancient times, we humans have developed various methods to control these insects. In particular, synthetic chemical pesticides, first developed in the 1940s, contributed significantly to the increase in the production of agricultural products. At the time, the development of synthetic chemical pesticides was considered revolutionary. Currently, synthetic chemical insecticides are the primary pest control strategy, with annual worldwide sales reaching 7.7 billion US dollars (Hunter-Fujita et al., 1998). Despite their usefulness, the use of synthetic chemical insecticides is also a major social issue due to their toxic effects on the non-target organisms (e.g., humans and livestock) and their ability to generate insecticide-resistant pests.

The Japanese Basic Law on Food, Agriculture, and Rural Areas (revision of the Japanese Basic Law on Agriculture), established in July 1999 (Ministry of Agriculture, Forestry and Fisheries, 2000) firmly states that we must switch over to an agricultural system that is environmentally friendly and sustainable. Public sentiment about the use of environmentally compatible pest control agents is also very strong. And Japanese research on the discovery, characterization, and use of insect pathogens has resulted in the identification of several new pathogens, delivery systems, and formulations. Despite these advances, sales of microbial insecticides remains quite low—less than 2% of all insecticides sold in Japan. This is due to the existence of several barriers that have stood in the way of adoption of microbial control. These include a historical concern about the negative effects of insect pathogens on the health of silkworm (*Bombyx mori*) colonies that are used to produce silk. In addition, farmers have a heavy reliance on

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broad spectrum products, and are not familiar with the use patterns and expectations for more specific, slower acting microbial insecticides. As described below, a coordination of efforts in science, policy and farmer education will be necessary to insure increased use of microbial insecticides in the future.

2. Sericulture and insect pathology in Japan

Insect pathology has two chief aims from an applied perspective. One is to control diseases of beneficial insects, such as the honeybee (*Apis mellifera*) and the silkworm (*Bombyx mori*). The other is to utilize entomopathogens as agents for controlling insect pests. Sericulture has long been one of the main branches of agriculture in Japan. Because of this, Japan has played a very important historic role in the development of insect pathology. Many of the earliest insect pathology publications comes from Japanese descriptions of silkworm diseases that were published in the 1800s and early 1990s (Steinhaus, 1975).

Two significant factors play a key role in commercial sericulture: breeding high-productivity silkworm strains and preventing silkworm diseases. The most prevalent silkworm diseases are flacherie disease (caused by densoviruses and picornaviruses), followed by muscardine disease (caused by *Beauveria bassiana*, *Metarhizium anisopliae*, *Nomuraea rileyi,* and *Paecilomyces fumosoroseus*), and then nucleopolyhedrosis. When flacherie was found to be causing serious losses in silkworm cocoon production during the 1970s (Japanese Society of Sericultural Science, 1992), the government focused increased effort on research for control of silkworm diseases. It was discovered that the viruses involved in flacherie are readily inactivated under the conditions found in sericulture farms and are unable to retain their infectivity for more than several weeks. Therefore, silkworm pathologists were curious about why these viruses were so frequently transmitted to silkworms, starting during the fall rearing season, and continuing through the following summer. Watanabe et al. (1988) found that the mulberry leaves that are harvested from the field and used as food for silkworms were also infested with the mulberry pyralid, *Glyphodes pyloalis*, which was an alternate host of *Bombyx* densovirus and picornavirus and therefore played an epizootiological role in the horizontal transmission of these viruses to silkworms. In a similar finding, it was discovered that the source of silkworm muscardine disease was also mulberry leaves that were contaminated with several species of entomopathogenic fungi that can infect silkworms (Aoki, 1957).

The effects of entomopathogens on the silkworm and sericulture have been an important problem in microbial control in Japan. Since the Sericulture Department in the Ministry of Agriculture, Forestry, and Fisheries of Japan has strong administrative powers concerning the registration of microbial pesticides, the Department of Plant Protection (which is housed in the same Ministry) delayed registering microbial insecticides in Japan during the 1970s, for fear that use of insect pathogens as control agents would have a negative effect on the health of silkworm colonies. The registration process for *Bacillus thuringiensis* (*Bt*) was a typical case (Aizawa, 2001; Asano, 2001). *Bt* was developed for commercial pest control and registered in the United States as a microbial insecticide in 1961. Subsequently, several Japanese chemical companies wanted to import *Bt* products from the US, but the Japanese authorities did not approve this until 1971, when foreign *Bt* products were exempted from plant quarantine in Japan. Despite this exemption, sale of *Bt* products was still not permitted. In 1972, the Study Committee on *Bt* Products was established, which studied the effects of *Bt* products on silkworm rearing in sericulture (Aizawa and Fujiyoshi, 1973). After 7 years, the committee concluded that *Bt* products would not pose a threat to silkworm rearing if farmers were prevented from spraying *Bt* products on mulberry fields (Study Committee on *Bacillus thuringiensis* Products, 1984). Simultaneously, the power of sericulture administrative officials weakened as silkworm cocoon production decreased (Fig. 1) for economic and social reasons including increased labor costs and declining silk prices. Finally, in 1981, *Bt* products were registered in Japan, though there was still an emphasis on the use of products in which the spores had been inactivated (such as Toarow; see Table 1). Even after the registration of *Bt* products was permitted, the lack of regulatory guidelines that were written specifically for microbial pesticides made it very difficult for companies to register their products. Finally, in 1997, the Ministry of Agriculture, Forestry and Fisheries of Japan released guidelines for the registration of microbial pesticides. This was a major turning point in microbial control in Japan, and since then, many other microbial insecticides have been registered (Table 1).

3. History and current status of microbial control in Japan

To date, 168 viruses (1663 host-virus associations), 411 fungi, 1504 protozoa, 51 bacteria, and 146 nematodes have

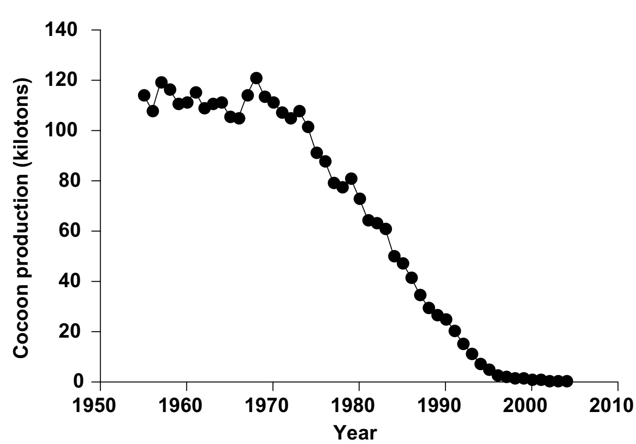

Fig. 1. Trends in silkworm cocoon production in Japan (Ministry of Agriculture, Forestry and Fisheries, 2003).