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Social and economic drivers shaping the future of biological control: A Canadian perspective on the factors affecting the development and use of microbial biopesticides

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ABSTRACT

Globally, the use of biopesticides is growing annually while the use of traditional pesticides is on the decline. North America uses the largest percentage of the biopesticide market share at 44%, followed by the EU and Oceania with 20% each, South and Latin American countries with 10%, about 6% in Asia and India. Although biopesticide growth is projected at 10% annually, it is highly variable among the regions constrained by factors such as regulatory hurdles, public and political attitudes, and limitations for market expansion. Microbial biopesticides have been registered in Canada for 35 years, but the number of registrations for commercial, restricted-industry and domestic uses has significantly increased over the past 10 years. The early Canadian biopesticides registered by pest control category were *Bacillus thuringiensis* in 1972 as the first bioinsecticide, *Agrobacterium radiobacter* in 1989 as the first biobacteriocide, *Colletotrichum gloeosporioides* f.sp. *malvae* in 1992 as the first bioherbicide, and *Streptomyces griseoviridis* in 1999 as the first biofungicide. Between 1972 and 2008, the Pest Management Regulatory Agency approved registration of 24 microbially active substances with 83 formulations. The majority of the registrations (55/83) occurred since 2000 and at the beginning of 2008 there were 10 new products (a combination of new active substances, strains, formulations, and uses) under regulatory evaluation. This paper examines the evolution of microbial biopesticides in Canada illustrating how the actions of the government, the people, and the industry have led to changes in legislation, policy, and programming that spurred momentum for new microbial pest control products in recent years and created a model system for future microbial biopesticide discovery, development, and implementation that could be adopted throughout the world.

1. Introduction

Biopesticides, by the broadest definition, are living organisms or natural products derived from these organisms that suppress pest populations (Thakore, 2006; Kiewnick, 2007). The organisms can be plants, nematodes, or microorganisms including bacteria, fungi, and viruses. The types of products considered as biopesticides by regulatory agencies can be quite varied. Microbial biopesticides usually have lethal or inhibitory effects resulting from physical or biochemical interruption of the pest's growth and development (parasitism, antagonism, or allelopathy). Biochemical compounds with non-toxic modes of action, and compounds that stimulate the plant's natural defense mechanisms (semio-chemicals, pheromones) are also among the registered products. In Canada and the USA, other products derived from naturally occurring sources, such as by-products from organic processing systems (corn gluten meal, acetic acid), diatomaceous earth, kaolin clay, hydrogen peroxide, potassium bicarbonate, salts, and soaps are considered biopesticides. In this paper the term *biopesticide* relates to the definition used by the Pest Management Regulatory Agency, which encompasses all of the above. But the focus of this paper is primarily on microbial biocontrol products and the term microbial biopesticide will be used for clarification, as appropriate.

1.1. Biopesticides on the World Stage

Global assessments of biocontrol markets show that the percentage of biopesticides has steadily grown since 1997 and the momentum is projected to continue at the rate of 10% per year (Bailey and Mupondwa, 2006). Global sales of biopesticides were estimated at $460 million US in 2000 and have continued to increase annually (Table 1) with projections to reach over $1 billion by 2010. There are approximately 225 microbial biopesticides manufactured in 30 member countries of the Organization for Economic Development and Cooperation (Kabaluk and Gazdik, 2007).

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Table 1
Global biopesticide and synthetic pesticide market. *Source:* BCC Research (2006).

Category	2003 $ millions USD	2004 $ millions USD	2005 $ millions USD	2010 $ millions USD	% Average annual growth
Biopesticides	468	562	672	1075	9.9
Synthetic	27,144	26,600	26,076	24,205	−1.5
Total	27,612	27,162	26,748	25,280	−1.1
Biopesticides as % of total	1.69	2.01	2.57	4.25	

A comprehensive database of the mycoinsecticide and mycoacaracides known to exist throughout the world was composed by de Faria and Wraight (2007).

The NAFTA countries (USA, Canada, Mexico) use 44% of all biocontrol products (biopesticides and macrobials) sold worldwide with *Bacillus thuringiensis* (BT) being the dominant product used on 75% of the crops and forests (Cuddeford, 2008). There are 53 microbial biopesticides registered in the USA (Kiewnick, 2007) which have sales valued at $205 million US and this market is expected to grow to $300 million US by the end of the decade (Thakore, 2006).

The European Union has 21 microbial biopesticides registered in at least one member state (Kiewnick, 2007). The sale of these products accounts for 20% of the global biopesticide market valued at $135 million US with a projection for growth to reach $270 million US (Cuddeford, 2008; Thakore, 2006). However, unlike North America, BT use (based on biopesticide sales) in Europe declined from 95% to 25% of the market share between 1985 and 2004, but the use of other biopesticides like nematodes and entomopathogenic viruses increased to represent 55% of the biopesticide market in 2004 (Cuddeford, 2008). Kiewnick (2007) and Grant (2008) suggest that Europe will remain behind North America in the number of biopesticides available because the regulatory system for microbials in the EU is very onerous. Kristiofferesen et al. (2008) analyzed the differences in public and political interests on the use of herbicides in seven European countries. They found that Denmark, Sweden, the Netherlands, and Germany had strong public and political interests in reducing herbicide use and very strict regulations on the use of herbicides in urban amenity areas. The first three countries commonly employed alternative weed control methods and invested highly in research and technological innovation for development of alternative strategies. Germany used some alternative strategies, but had relatively low investment in research on alternatives. In contrast, the United Kingdom is in a state of change regarding the public and political attitudes towards herbicide use, whereas Finland and Latvia had no interest in instituting change. In these countries, there was low to no investment in developing alternative control measures.

The remainder of the global biopesticide market share is divided among the Oceanic countries at 20%, South and Latin American countries at 10%, and less than 5% each attributed to Asia and India (Thakore, 2006). Future growth in these latter countries is variable. Due to the large amount of land in pasture land within Oceania, the market may be saturated in a few years so limited growth potential is expected, whereas in Asia, especially China, biopesticide growth is poised for expansion.

In contrast to the growth observed with biopesticides, the global crop protection market for conventional products (synthetic pesticides) had negative total growth of 7.4% from 1990 to 2005 (Crop Life International, 2005). The greatest losses were reported from 1999 to 2003 (Fig. 1). Other independent researchers have also indicated declining trends in conventional pesticide markets

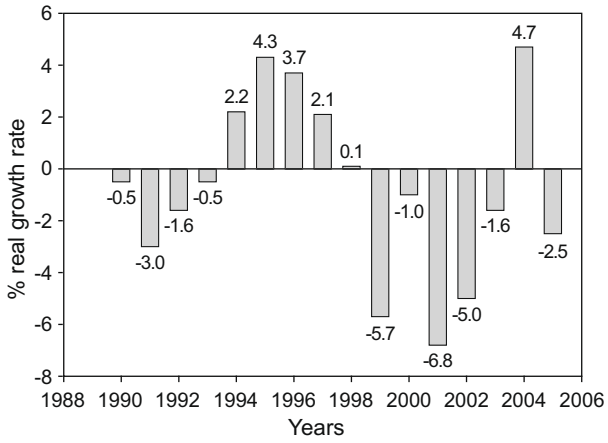

Fig. 1. Real growth rates for global crop protection market. *Source:* modified from Crop Life International Annual Report (2005/2006).

of 1.5% per year (BCC Research, 2006; Thakore, 2006). This trend continued in 2006, with a decrease of 2.5% in sales of herbicides, fungicides, and insecticides from the previous year (Crop Life International, 2007), but in 2007 there was an increase of 9.7% in conventional products due to better commodity prices and weather conditions in Brazil and Europe (Crop Life International, 2008). Very likely there was a concomitant increase in the use of biopesticides for these same reasons.

However, despite the downward trend in conventional pesticide sales in 6 of the past 7 years, the ratio of conventional pesticides to biopesticides remains very high and will likely stay this way for a long time (Table 1).

1.2. Biopesticides on the Canadian stage

The same trends observed in the global markets have also been observed in Canada. The Pest Management Regulatory Agency (PMRA), which oversees pest control product registrations, provides information to the public on new registration activities each year (http://www.hc-sc.gc.ca/cps-spc/pest/index-eng.php). In December 2006, there were 6 new active ingredients registered; 2 were conventional pesticides and 4 were biopesticides. In 2007, there were 9 new active registrations with 2 conventional pesticides, 2 reduced-risk chemicals, and 5 biopesticides. Based on regulatory updates on reduced-risk pesticides in Canada, the proportion of microbial to the total biopesticide product registrations were 15/45 for commercial, 2/21 for domestic, and 5/9 for restricted uses (PMRA, 2008).

The trends in pesticide/biopesticide-use patterns are often attributed to safety considerations, phasing out of toxic pesticides, increased regulation stringency, environmental issues, and emerging developments in new technologies (Thakore, 2006). But these reasons are often based on conjecture and lack supporting evidence. This paper attempts to explain the specific social and economic drivers that have initiated the microbial biopesticide industry in Canada. We will answer the question "Why have biopesticide registrations been increasing in Canada?" by exploring the evolution of microbial products in the country and illustrating the actions of the government, the people, and the industry that have led to changes in policy, management and research initiatives. These events have changed Canadian perspectives on biopesticides and new approaches have evolved to release new products more effectively in the future. Thus, we will describe a model system that could influence the direction of biopesticide development throughout the world in the years to come.