Chapter 24

Bt RESISTANCE MANAGEMENT:
THE ECONOMICS OF REFUGES

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Abstract: Refuge requirements have been the primary regulatory tool used to delay pest resistance to Bt crops. This chapter presents a simple method to estimate the annual cost of refuges to producers, applying it to Bt cotton. It also examines broader welfare impacts, estimating how Bt cotton acreage restrictions affect producer surplus, consumer surplus, seed supplier profits, and commodity program outlays. The implications of grower adoption behavior—partial adoption, aggregate adoption, and refuge choice—for regulatory costs are examined. Empirical examples illustrate how providing multiple refuge options significantly reduces regulatory costs.

Key words: resistance management, refuges, technology adoption, Bt cotton

1. INTRODUCTION

A growing literature reports that transgenic cotton varieties producing toxins from Bacillus thuringiensis (Bt) have led to significant economic benefits from yield gains, reductions in conventional insecticide sprays, or both throughout the world (Cotton Research and Development Council 2002; Doyle, Reeve, and Barclay 2002; Falck-Zepeda, Traxler, and Nelson 2000a, 2000b; Frisvold and Tronstad 2002; Frisvold, Tronstad, and Reeves 2006; Gianessi et al. 2002; Huang, Hu, Rozelle, Qiao, and Pray 2002; Huang, Hu, and van Tongeren 2002; Huang, Rozelle, Pray, and Wang 2002; Ismael, Bennett, and Morse 2002; Marra 2001; Pray et al. 2001; Pray et al. 2002; Price et al. 2003; Qaim, Cap, and de Janvry 2003; Qaim and Zilberman 2003; Traxler et al. 2002). Estimates of U.S. domestic welfare benefits from Bt cotton adoption have been in the range of $150–$250 million annually (Falck-Zepeda, Traxler, and Nelson 2000a, 2000b; Frisvold and Tronstad 2002: Frisvold, Tronstad, and Reeves 2006; Price et al. 2003).
The benefits of Bt cotton could be short-lived, however, if there were rapid evolution of pest resistance. The main targets of the first generation of Bt cotton are tobacco budworm \((Heliothis virescens)\), cotton bollworm \((Helicoverpa zea)\), and pink bollworm \((Pectinophora gossypiella)\) in the United States, and \(Helicoverpa armigera\) in China. In the United States, resistance evolution in budworm and cotton bollworm to organochlorine, organophosphate, and carbamate insecticides greatly reduced the effectiveness of these compounds by the late 1970s (Livingston, Carlson, and Tackier 2004). Resistance evolution in budworm to pyrethroid insecticides, a replacement for these other compounds, led to field failures and large yield losses (29 percent) in Alabama in 1995 (Williams, various years; Gianessi et al. 2002). Because transgenic Bt crops express the toxin continuously, many entomologists believed that pests would quickly evolve resistance to Bt crops. This belief was based on prior experience with other pesticides, laboratory selected resistance to Bt toxins in insects, and the development of in-field resistance to Bt sprays by diamondback moth (Tabashnik et al. 2003).

Foliar Bt sprays, long used in pest control, are less toxic to non-target insect species, birds, and mammals than broad-spectrum pesticides and are the most widely used insecticides in U.S. organic agriculture (Hutcheson 2003). Environmental and organic farming groups have raised concerns that widespread planting of Bt crops would speed evolution of pest resistance to the Bt toxin and potentially undermine IPM and organic pest control strategies.

The U.S. Environmental Protection Agency (EPA) has authority to manage pesticide resistance under FIFRA (the Federal Insecticide, Fungicide, and Rodenticide Act). To delay the evolution of resistance, EPA requires growers who plant Bt cotton to also plant non-Bt cotton on a minimum percentage of their total cotton acreage. These non-Bt acres serve as a refuge for susceptible pests, allowing them to survive and mate with adults that have become resistant to the Bt toxin and thereby delay the development of resistance in the pest population. Experimental evidence and results from entomological simulation models suggest that refuges can significantly delay the onset of resistance (Carrière and Tabashnik 2001, Tabashnik et al. 2003).

For agricultural producers, refuges imply an intertemporal economic trade-off. Refuge requirements mean that growers must forego the annual, short-run benefits of Bt crops on a portion of their planted acres. Refuges, however, preserve the efficacy of Bt varieties over a longer period of time. Both economic theory and experience with conventional insecticides suggest that individual growers may over-use pest control technologies relative to the social optimum, bringing about resistance prematurely (Carlson and Wetzstein 1993). For growers the trade-off is between receiving annual benefits, \(B\), of the Bt technology for \(T\) years versus the benefits net of the opportunity cost of the refuge \(B - C\) for \(T + N\) years. The overall impact of refuge requirements on the present value of grower returns will depend on \(B\),