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RISK REGULATION RELATED TO RESISTANCE DEVELOPMENT IN INSECTS

Transgenic pesticide seeds

Farmers have always fought against damage caused by devastating crop pests. Since the 1950s, their favourite weapon has been the chemical pesticide. The progress made in the field of plant biotechnologies has equipped farmers with new arms in his war against crop enemies; transgenic varieties lethal to insects. These varieties allow farmers to decrease the use of chemical pesticides or even avoid them altogether. Until now, all the insect resistant varieties that have been marketed have received a gene isolated from *Bacillus thurigiensis (Bt)*, a soil bacteria, of which the weed-killing proteins have been used in biological farming as a way of defence since the 1970s. In the *Bt* transgenic varieties*,* these proteins are directly synthesized by the plant. Varieties of *Bt* maize and *Bt* cotton have been cultivated in the USA since the end of the 1990s. The first varieties of *Bt* maize were resistant to European corn borers *(ostrinia nubilalis)* and last year a variety resistant to Western corn root worms *(diabrotica virgifera virgifera)* was marketed.

The weapons of mass destruction against crop pests that are transgenic *Bt* seeds have, however, their own limits, just like any chemical pesticides. There is a risk of resistance development to *Bt* toxins in the population of pests, reducing, even nullifying, the efficiency of the pesticide seed in itsfight. This phenomenon has been observed in the past with chemical pesticides. It induced the farmers to increase the proportions of chemical solutions, to use them more frequently or adopt new, more expansive pesticides. This development is quite costly for the agricultural sector and for society as a whole. Regulated introduction of transgenic seeds is, then, a good opportunity for the regulation authorities to intervene in order to avoid such inefficacy.

The strategy of compulsory refuge areas

In order to delay the development of resistance to *Bt*, the North American authorities (United States and Canada) have set out a so-called strategy of compulsory “refuge areas”. In the United States, every producer of *Bt* maize or *Bt* cotton is required by the (EPA) Environmental Protection Agency and through the intervention of seed manufacturers, to grow conventional varieties (non *Bt* seeds) on a proportion of their farm. This proportion is, for example, 20% of the surface area of maize for *Bt* maize, in the US mid-West (Corn Belt). These areas provide a refuge for insects sensitive to *Bt*. The purpose is to maintain a stock of sensitive insects able to limit the proliferation of a gene resistant to *Bt*. Generation after generation, the population of sensitive insects is going to weaken the gene of resistance in the whole population and, thus, limit its expansion (for more details, see Bourguet, D.; Desquilbet, M. et Lemarié, S. 2003a et 2003b).

Besides compulsory refuge areas, other regulation strategies to slow the development of resistance are conceivable. For instance, taxing insecticide transgenic seeds and/or sustaining conventional varieties could encourage more farmers to grow conventional varieties. Their plots then would be used as refuge areas. Tradable permits could also be considered. It would only be a matter of permitting farmers to trade their plots of compulsory refuge areas. A farmer could plant his neighbour’s refuge area and get in return a financial compensation. The purpose of our research is to produce the elements of an answer to the question of the choice of regulation tool. It combines two fields, biology and economy through two methods of analysis.

Simulations from a biological and economic model

The first research work, Vacher & *al*. (2004), relies on a biological and economic dynamic model graded according to field data. The elements of the answer are given by simulated results. It appears that a size of refuge area between 4% and 45% preserves sensitiveness to *Bt* while farmers make a profit over the long term. Below 4%, it is too weak to limit development to resistance. Above 45%, insect sensitiveness to *Bt* is certainly preserved but the costs are too high for farmers who lose out financially. Simulations also take into account opportunist problems on the part of the farmers: in accordance with the regulation of compulsory refuge area, several patterns are tested. Lastly, the first results suggest that any tax on *Bt* seeds must be relatively high in order to incite farmers to adopt conventional seeds.

Refuge area versus tax in a stylized model with mobility

The second research work, Ambec and Desquilbet (currently in progress), analyses the choice of regulatory instrument (refuge area versus tax on *Bt* seeds) in a stylized model. It shows how this choice depends on the localization of the production and the dissemination of insects.

The model takes into account neighbouring farms on which the need for regulation comes from the insect mobility between farms. Indeed, with immobile insects, a rational farmer would himself create a refuge area in order to secure his future profits. Since, in reality, an insect flits from one farm to another, then a farmer does enjoy all the benefits from his refuge area although he must support the entire cost, especially, if his neighbours do not set out a refuge area. As a consequence, in comparison with the optimal size, every farmer under-proportions his refuge area, or does not create any refuge area.

A compulsory refuge area helps to restore efficiency when farmers are identically vulnerable to insects. It is, then, the optimal regulatory instrument whatever the dissemination of insects on the farms. However, if farmers differ in their vulnerability to insects (when faced with various populations of insects because of the climate or the presence of other crops), the refuge area is no longer the optimal tool. Its size being standard, it is not adaptable to the local conditions of each farm. A regulatory instrument such as a tax or a transferable refuge area helps farmers to adapt the size of the refuge area to their farm.

When insects are fully mobile, meaning they spread out evenly over the farms, and when farmers differ as to their vulnerability to crop devastators, a tax on *Bt* seeds and/or a subsidy on conventional seeds may help recover efficiency. Indeed, farmers who meet with few insect problems will be inclined to grow conventional varieties, their farms being considered, then, as a refuge area. The refuge area is, thus, concentrated in the same zone. Its size can be adapted to the amount of the tax or subsidy. When insects are perfectly mobile, the locality of the refuge area is of little importance. The farmers using *Bt* seeds take advantage of this refuge area, in the same way as if it were a neighbouring farm. However, when the insect mobility is limited, the locality is important. Due to its distance from the *Bt* crop fields, the refuge area is, then, limited in its capacity to disseminate the resistant gene, indeed even ineffective.

To sum up, the choice between compulsory refuge areas and *Bt* seed taxation as regulatory instruments to keep development of resistance under control depends on insect mobility. When this mobility is reduced, compulsory refuge areas are the better instruments. Nonetheless, taxation would seem more appropriate when mobility spreads to areas where farmers differ as to their vulnerability to crop devastator.

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More information

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