# Advancing the Understanding of Biosafety

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## Lecture

## Bt-Resistant Target Pests Quick Occurrence in South Africa

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## Session

## Reality Checks

**Nagoya**

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Maize is the staple diet of people in Africa. Lepidopterous stem borers seriously limit potentially attainable maize yields by infesting the crop through out it growth, from seedling stage to maturity. The most important of these species are the spotted stem borer, Chilo partellus (Lepidoptera: Crambidae), and African stem borer, Busseola fusca (Lepidoptera: Noctuidae).

## The advent of Bt maize

Through the use of modern biotechnology some very effective solutions for maize stem borer control has been developed. Bt maize, expressing Cry1Ab protein was initially developed for the control of two stem borer species in North America i.e., Ostrinia nubilalis (Lepidoptera: Crambidae) and Diatraea grandiosella (Lepidoptera: Crambidae). These products also provide effective control of moth larvae such as those in the genus Chilo, and provide partial to very good control of noctuid moths in the genera Sesamia and Busseola (Van den Berg and Van Wyk, 2007).

Since the first deployment of genetically modified (GM) crops with insecticidal properties, there has been concern with regard to resistance development of target pests and possible non-target effects (Tabashnik, 1994; Gould, 1998). When resistance to Bt maize develops farmers will be back to where they were with management strategies 15 years ago and if the Bt protein disrupts beneficial interactions in agro-ecosystems it may lead to increased pest presence and/or development of secondary pests.

Between 1994 and 1997 various Bt-events were evaluated under artificial pest infestation in South Africa. The event MON810 of the Cry1Ab gene provided superior control to all other events tested and subsequently approved for release (Van Rensburg, 1999). Bt maize has been planted in South Africa since 1998 and the country is the 8th biggest producer of GM crops in the world.

## Farmers perceptions of Bt maize in South Africa

A survey conducted by Kruger et al. (2009) showed that the greatest benefit associated with Bt maize was the convenience of target pest management. However, Bt maize is only an advantage when target pests are present. In South Africa farmers have benefited from the adoption of Bt maize since its deployment during 1998 (Gouse et al., 2005). Despite paying more for seed, adopters enjoyed increased income over conventional maize varieties through savings on pesticides and increased yield due to better pest control. Farmers also indicated that they did not need to scout their fields for pests any more since they assumed the technology was effective.

## Resistance development

Two years after that start of planting Bt maize in South Africa stem borer damage was noticed involving various Bt maize hybrids (Van Rensburg, 2001). Van Wyk et al. (2007) also reported the presence of B. fusca larvae on mature Bt-maize plants. Since no leaf feeding damage occurred during the vegetative growth stages of these plants, this damage indicates survival of larvae on plants during the period from tasseling to grain filling (Van Rensburg, 2001). No yield losses could be attributed to these infestations, but the observation caused concern due to the possibility that similar infestations may in future result in significant damage to maize ears. This concern was therefore only of “importance” due to the fact that it may result in yield loss and no alarm seem to have been raised about resistance development at that time.

The 1st official report of resistance of a maize pest to Cry 1Ab maize was made in South Africa during 2007. This report of field resistance of B. fusca to Bt maize (Van Rensburg, 2007) showed that the larvae on Bt maize at certain locations where some larvae were able to survive on Bt maize.

Within one year of the first report of resistance of B. fusca another reportedly resistant population was observed by farmers at the Vaalharts irrigation scheme, approximately 50 km from the initial site. Follow-up studies showed that larvae survived on Bt maize and field-collected larvae were reared for four generations on Bt maize plants in the laboratory. The latter study also indicated that larvae collected from non-Bt maize refugia, could survive on Bt maize. This indicates that the high dose/refuge strategy may be compromised in effectiveness in this geographical area.

Analysis of more than a decade of resistance monitoring data up to 2008 for six Lepidoptera species targeted by Bt maize and cotton suggested that the principles of the refuge strategy may apply in the field to limit resistance development (Tabashnik et al., 2008). To date field evolution of resistance has been detected only in B. fusca in South Africa (Van Rensburg, 2007), Helicoverpa zea (Lepidoptera: Noctuidae) in the south-eastern United States (Tabashnik, 2008) and Spodoptera frugiperda (Lepidoptera: Noctuidae) in Puerto Rico (Gassman et al., 2009). Pink bollworm Pectinophora gossypiella (Lepidoptera: Gelechiidae) resistance to Bt cotton has also recently been reported from India.

The increased appearance of these Bt-resistant pests during the last 4 years indicate that the predicted rate of evolution of resistance was seriously underestimated and casts doubts on the use of this technology in future.

## Refugia

Refugia forms an important part of insect resistance management strategies. Refuges are defined as habitats in which the target pest is not under selection pressure due to the toxin and it therefore provides a sustainable habitat for pest development. The high dose/refuge strategy, employed to limit resistance development, comprises a combination of Bt maize plants producing high doses of toxin and non-Bt plants in close proximity. The principle underlying this strategy is that any resistant insects emerging from Bt crops are more likely to mate with the one of the much larger number of susceptible pest insects emerging from refuges than with each other, thereby decreasing the selection for Bt resistant alleles.

## How did resistance develop so quickly in South Africa?

Although the planting of refugia is compulsory, the level of compliance between 1998 and 2006 was shown to be low in the region where resistance was reported in South Africa (Kruger et al., 2009). Research has also shown that B. fusca moths prefer irrigated maize, which could have contributed to increased selection pressure towards the evolution of resistance to the Bt toxin (Van Rensburg, 2007). Van Wyk et al. (2007) also indicated that the strong linkage of stem borers to the maize ecosystem in irrigation areas and especially the planting of Bt-maize in these systems results in strong selection pressure for evolution of resistance.

The increased levels of resistance recorded for B. fusca was at least in part due to non-compliance by producers with the refuge principle (Kruger et al., 2009). However, in retrospect it appears that the Bt-events currently available for control of B. fusca may not meet the high dosage requirement. Pest resistance to Bt maize most likely resulted from a combination of late planting dates with consequent increased levels of infestation combined with non-compliance with refuge requirements which contributed to selection pressure for Bt-resistance. A lesson that could be learned from this is that in areas were Bt-technology adoption rate is very high, refuge compliance should be followed-up and enforced.

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