Indian *Bt* gene monoculture, potential time bomb

In March, this year, an unprecedented number of hybrids of *Bacillus thuringiensis* (*Bt*)-resistant cotton will be planted in India. A recent model simulating the development of insect resistance to *Bt* cotton predicts that such monoculture could lead to resistance within a few years. The risk of resistance as a consequence of gene monoculture is higher in India where *Bt* crops are planted illegally than in other countries producing transgenic crops.

Next month 12 new *Bt* cotton hybrids will enter the Indian market—all carrying the same *cry1Ac* gene licensed from US seed giant Monsanto. Four of the six Indian companies that have licensed the gene—including Mahyco in Jalna, Raasi Seeds in Attur, Ankur Seeds Limited in Nagpur and Nuzhiveedu Seeds in Hyderabad—will each release three *Bt* hybrids. *Bt* cotton carrying *cry1Ac* to confer resistance against bollworms (*Helicoverpa armigera*) was initially exclusively licensed to Jalna-based Maharashtra Hybrid Company—also known as Mahyco—the Indian partner of Monsanto of St. Louis, Missouri, in 2002 *(Nat. Biotechnol.* **20**, 415, 2002).

Keshav Kranthi, a senior scientist at the Central Institute for Cotton Research in Nagpur in the Indian province of Maharashtra and colleagues, warned of the risk of pest resistance to *Bt* varieties currently used in India in a paper published in the Indian Academy of Science publication *Current Science* **87**, 1593–1597 (2004) last December. The authors established a theoretical model to predict resistance development in bollworms due to overuse of the *cry1Ac* gene. The '*Bt*-Adapt model' simulates the bollworm's adaptation to the toxin, depending on the number of generations of the insect exposed to *Bt* every year and on the number of different *Bt* crops the insects encounter.

The first estimate is based on two to three generations of insects exposed each year to a single *Bt* crop. "If the area under *Bt* cotton gets to 70–80% in a 100–200 kilometer radius, our model estimates resistance development [in] 3–4 years," Kranthi said. "So, it wouldn't be surprising to find *Bt*-cotton crop failures in some parts of India, starting with [in the province of] Gujarat in a couple of years from now," he adds.

But the *Bt*-Adapt model can also predict the consequences of exposing bollworms to more than one *Bt* crop (e.g. cotton and potato). If the number of generations of insects exposed to *Bt* crops increases to five or six—a likely scenario when another *Bt* crop is included—the rate of resistance development, according to the model, would be accelerated to half the time it now takes with only *Bt* cotton.

The main gene used in the first hybrids of *Bt* cotton could soon be used in many more crops in India, thus increasing the risk of resistance breakdown.

This scenario is not so unlikely given the increasing reliance on *cry1Ac* in other crops in India. "Over 42% of the projects in biotechnology research use this *Bt* gene," says Suman Sahai, convener of Delhi-based Gene Campaign, a nongovernmental organization, and visiting professor of genetics at Hamburg University. "We are going to face a situation when a wide range of crops, from cotton to potato, rice, maize, brinjal [eggplant], tomato, cauliflower, cabbage, even tobacco, carrying the *Bt* gene will be growing next to each other," warns Sahai.

By contrast, other countries have made limited use of the gene, and have refugia and monitoring strategies. Commercial crops with the *cry1Ac* gene in the US are limited to cotton and corn, and the gene has been used in research on potatoes. China is using *cry1Ac* in at least one of the three GM rice crops for which approval has been sought for commercial release (*Nat. Biotechnol.* **22**, 642, 2004) and in its commercialized cotton, which was individually developed both by Monsanto and by its own scientists. Meanwhile, Argentina, Columbia and Mexico grow the Monsanto *Bt* cotton commercially and Uruguay and Brazil carry out field trials. Currently, the potential for illegal planting and associated resistance outbreak is the strongest in Brazil.

Though no resistance breakdown has been observed in fields in India yet, "it is important to remain guarded," warns Kottaram Krishnadas Narayanan, managing director of MetaHelix, in Bangalore, a crop biotechnology company. "Genetic uniformity is really dangerous," adds Says Ebrahimali Siddiq, board member of the International Rice Research Institute in Manila, the Philippines. "Resistance can break down any day."

"This kind of a situation is unique to India," explains Kranthi. Until now, a refugia strategy, not strictly implemented and widely undermined by illegal planting of *Bt* cotton, was the only strategy to avoid resistance in India (*Nat. Biotechnol.* **22**, 1333–1334 (2004)). "Unlike the US, non-*Bt* cotton refuges are not required in India," explains Bruce Tabashnik Professor at the Department of Entomology at the University of Arizona in Tucson. "If all or most of the other crops eaten by *Helicoverpa armigera* produce *cry1Ac* and cotton produces *cry1Ac*, refuge production of susceptibles might not be adequate to stem resistance."

Fears of early resistance development due to gene monoculture is already forcing Monsanto to develop stacked genes thus shifting the focus to other genes. And Syngenta India, in Pune, started to develop cotton with an unrelated type of *Bt* toxin (*vip3*). "We need other genes not only to delay resistance but to bring seed price down through competition," concludes Prabhakara Rao managing director of Nuzhiveedu Seeds.

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