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Response:

Bt-cotton: High toxin level in fruiting parts is most critical for bollworm control

Protein expression in leaves is certainly important. I agree. But to say that it is the most critical is incorrect. Fruiting parts are the most favoured feeding sites of the four bollworm species, viz. the cotton bollworm, *Helicoverpa armigera*.; the pink bollworm *Pectinophora gossypiella*; the spotted bollworm, *Earias vittella* and the spiny bollworm, *Earias insulana*. High toxin expression in fruiting parts, and not leaves, is certainly most critical for effective bollworm control.

It is true that the *H. armigera* lays majority (70–80%) of its eggs on leaves of the upper canopy and neonate larvae scrape and feed on the surface of the leaf soon after hatching and get killed. However, rest of the eggs (20–30%) laid directly on squares, flowers and bolls can survive, depending on the levels of toxin expression in these parts. The issue also relates to the efficacy of *Bt*-cotton on the other three major pests of cotton, the pink bollworm, spiny bollworm and spotted bollworm. These insects lay majority of their eggs directly on fruiting parts or in their close vicinity. Neonates that hatch from eggs laid elsewhere go straight to the fruiting parts within a few hours after hatching. Therefore, toxin expression at adequate levels in fruiting parts becomes important. It must be mentioned here that Cry1Ac is at least 3–6 times more toxic to the other three bollworms compared to its toxicity on *H. armigera*. Hence, the current levels of Cry1Ac in fruiting parts are reasonably effective against the pink bollworm, spotted bollworm and spiny bollworm. But higher levels would be more preferable for effective and sustainable control of all the bollworms. More importantly, higher toxin expression in fruiting parts, especially in the boll rind can prevent bollworm larvae from reaching the developing non-*Bt* seeds that constitute about 25% of the total seeds present in each of the bolls on the *Bt*-cotton F-1 hybrid plants.

Manjunath suggests that using neonates in the bioassays would have been closer to reality. In our experience, we did not find any significant difference in Cry1Ac bioassay results of corrected mortality using neonates and one-day-old larvae. However, the major disadvantage with neonates compared to one-day-old larvae is that the former are fragile and show > 10% mortality in controls, which is unacceptable; whereas, mortality of one-day-old larvae rarely exceeds 5% in controls.

As Manjunath pointed out, some NGOs[1] were trying to use our results to show that *Bt*-cotton is ineffective in India. Our data[2] show that *Bt*-cotton can be less effective than is commonly expected, but certainly not ineffective. The NGOs also tried to relate our data to the cases of *Bt*-cotton crop failures in some parts of the country. Clearly, there appears to have been some confusion between failure of the technology itself and failure of the product that was developed incorporating the technology. Failure of a particular *Bt*-cotton hybrid to give higher yields in a particular location can be due to innumerable factors, including genetic, environmental, biotic and abiotic stresses and not necessarily because the *Bt*-technology failed to protect the crop from bollworm damage. There has been hardly any scientific proof anywhere in India thus far to show that low yields in *Bt*-cotton in the locations reported were due to bollworm damage. *Bt*-cotton was introduced in India three years ago, in March 2002. In fact, bollworm infestation over the past three years did not cause cotton crop failures either in *Bt*-cotton or even in non-*Bt*-cotton in any part of the country. Therefore, it would be incorrect to relate poor yields of *Bt*-cotton to the varying levels of Cry1Ac expression in the plant and erroneously conclude that the technology is ineffective.

Our effort has been to present a realistic picture of the true potential of the currently available *Bt*-cotton hybrids with reference to India[2]. We believe that there is room for improvement and much can be done even with the currently available material. Under field conditions, even MECH-162, which is not really the best (in terms of Cry1Ac expression) of available *Bt*-cotton hybrids, has been successful in reducing bollworm populations by at least 70–80%. This is significant in terms of control efficacy and economic returns. However, our data clearly show that Cry1Ac expression could be enhanced in fruiting parts depending on the parents used in hybrid development. We suggested that seed companies should enhance their efforts to develop hybrids that have high expression in fruiting parts and high expression in leaves for the longest possible time. Most importantly, Indian researchers must intensify efforts to develop straight *Bt* varieties at the earliest, incorporating the best possible toxin expression in all parts of the plant.

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