raised on the basis of other studies (referred to in the text) regarding relative susceptibility of pests in the laboratory, field, etc. Since he questions just one of these features (regarding transparency of the regulatory process), it seems that his statement is biased.

- *Resistance management and other technical questions*: Ghosh responds to specific questions under columns II and III with general statements regarding the 'need to evolve a suitable IPM' (exactly, we would like to know details), 'implication of such cross-pollination needs to be understood', (exactly, what information do we have on this?) and so on. Other questions not answered: Are 1 acre tests too small? Are 1–2 seasons of testing too few? Are 2 years sufficient for backcrossing and testing?
- *Transparency of regulatory process*: Ghosh lists the procedural aspects that are open to the public. However, his statement that the process 'is as transparent as it should be', the lack of specific responses to specific questions, and his reading of my paper as belittling and ridiculing the *Bt*-cotton project, suggest that he has missed the spirit in which it was written. Much more discussion on the nature of transparency is required before the public can be confident of obtaining information that it is entitled to. Openness lies in the 'nitty-gritty'.

I hope that there will be more such discussion that would not only clarify misconceptions but also answer some of the questions raised here. Such a discussion would go a long way toward building the basis for a truly democratic process of decision making on this, and future, genetic engineering projects.

GEETA BHARATHAN

## *Bt*-cotton: The view from MAHYCO

While Geeta Bharathan argues in her article that 'It is imperative that assessments of *Bt*-cotton project and future GE projects should be based on considerations in which the biological basis of the technology are clearly distinguished from societal issues', she herself has done precisely so in her article. Further, there are many factual errors in the article, which need to be pointed out. Also, the uncanny way in which issues like the terminator technology and farmer suicides have been mixed up with the technology and regulatory aspects of *Bt*-cotton obfuscates the truth that these are totally unrelated.

I would like to set the record straight on *Bt*-cotton so that readers, who have not had the opportunity to closely follow the developments of *Bt*-cotton in India, get the correct picture.

1. Transgenic cotton today is grown on over 5.3 million hectares (m ha), an increase of 43% over the 1999 area of 3.7 m ha in 6 countries around the world. These countries include USA, Australia, South Africa, Argentina, Mexico and China. China increased its genetically modified (GM) cotton area to more than 10% of its cotton area in 2000. The fact that millions of cotton farmers in both industrial and developing countries opted for *Bt*-cotton speaks volumes of the confidence and trust farmers have in its ability to help them tackle the bollworm problem[1,2]. In fact, the area planted with GM crops worldwide increased to 44.2 m ha; up from 39.9 m ha in 1999, an impressive increase by 11% (ref. 2).
2. India has the largest acreage of cotton in the world[3]. The major pests impacting cotton growers in the country are the bollworms, predominantly *Helicoverpa armigera*, for the control of which insecticides worth around Rs 1200 crores are used annually. In spite of this, farmers are suffering huge losses. Their yields have reduced, incomes have dropped and debts have increased[4].
3. MAHYCO began discussions with Monsanto for licensing *Bt* technology in 1993. An agreement was signed and MAHYCO then received from the Review Committee on Genetic Manipulation (RCGM) in Department of Biotechnology (DBT) permission to import the *Bt*-cottonseed in 1995. It imported 100 g of *Bt*-cotton seeds in 1996. These were used for backcrossing into elite Indian varieties by achieving 3 backcrosses in a calendar year in a glasshouse approved by DBT. Only such lines which were either commercially being used or are likely to be introduced in the near future were considered.

Between 1996 and 1998, according to the direction of RCGM, MAHYCO had carried out extensive tests in India, which included studies on outcrossing, germination, weediness, food/feed safety, allergenicity, toxicity, pollen escape, etc. These studies have established that *Bt*-cotton is safe.

In 1998, following permission by RCGM, the first multi-centric field trials were carried out on 40 locations in nine states in India. The data were submitted in February 1999 and reviewed and accepted by the RCGM.

The data from the 1999 trials were also submitted and reviewed by RCGM in April 2000. In May 2000, after reviewing the data on bio-safety and field trials, RCGM recommended that MAHYCO approach the Genetic Engineering Approval Committee (GEAC) for further action. In July 2000, GEAC permitted MAHYCO to conduct countrywide field trails on 85 ha and seed production on 150 ha. These are now in progress[5].

4. The Government of India has banned the entry of terminator technology (Office Memorandum No. 82-1/98 PQD, dated 25 May 1998 regarding strict watch on any likely import of seeds having terminator gene) and statements to this effect have been made in the Lok Sabha and Rajya Sabha. Monsanto was not involved with this technology. However, since they were unnecessarily implicated, they have made public commitments not to commercialize this technology, even if it becomes available. This was widely publicized and the author does not seem to be aware of it.
5. The choice of genes and resistance development: The author has made a point that *Cry1Ac* gene is not the most appropriate gene for controlling the target pest. We would like to state that the choice of *Cry1Ac* as the most appropriate gene, is based on extensive studies. We wish to inform the author that Australia also has *Cry1Ac* in their commercialized cotton and not *Cry1Ab* as mentioned by her. To date there has been no report of any scientific data to show that *Cry1Ab* is superior to *Cry1Ac* to control *H. armigera* as implied by the author.

Our own in-house studies conducted in India have clearly shown that *Bt*-cotton with *Cry1Ac* is quite effective against the major Indian bollworms, namely *H. armigera*, *Earis vittela* (*Earis insulana*) and *Pectinophora gossypiella*. These have been confirmed by other workers also[6]. The author herself has cited a pub-

lication which states that Cry1Ac protein was found to be the most potent one in a test of 11 different Cry proteins, followed by Cry1Aa and Cry1Ab (ref. 7).

Over the last 5 years, in spite of large-scale introduction of *Bt*-cotton in USA, no incidence of a minor pest becoming a major pest has been reported, not withstanding the keen scientific attention this technology has been receiving during this period.

6. There has been no sign of any bollworm species showing resistance to this transgenic crop. That has also been confirmed in a recent paper by Tabashinik *et al.*[8]. However pro-active measures have been taken in USA, in consultation with experts in academic institutions, to develop resistance management strategies which include deploying *Bt*-cotton as one of the major components of integrated pest management, refugia, gene pyramiding, optimum dosage, etc. These strategies will be appropriately modified to suit local conditions and will be extended in due course in India also, as it has been done in other countries where *Bt*-cotton has been commercialized.

7. Regulatory Process: All the data generated by MAHYCO have been submitted to RCGM and to GEAC. MAHYCO has followed all the guidelines prescribed by DBT over the last six years in developing *Bt*-cotton. The regulatory procedures are very stringent and no responsible agency will seek any short-cut methods as alleged by the author (see ref. 5 in her article).

Obtaining field permit involves obtaining approval from the respective state governments, where the experiments have to be conducted. The copy of the permit is sent to the Chief Secretary, District Collector and District Magistrate of the state where the experiment will be conducted.

8. Use of *Bt* spray vs *Bt*-cotton: *Bt* transgenic technology in cotton helps in overcoming certain limitations of *Bt* sprays such as the need for repeated applications, sensitivity to solar radiation, washoff due to rain, etc. It is an acknowledged scientific fact that transgenic technology is an improvement over conventional spraying[9].

9. The author fears that the non *Bt*-cotton grown in plots adjacent to *Bt*-cotton will act as refugia and suffer more attacks by bollworms. Let it be known that the bollworm moths do not distinguish between *Bt* and non-*Bt* crops while laying eggs. Those laid on *Bt* plants get killed upon hatching owing to inherent insecticidal ability of these plants, while those laid on non-*Bt* plants may survive and cause damage if no control measures are taken. The situation is similar to any two plots grown with protection and without protection against pests. *Bt* crops do not encourage infestation on the adjacent normal crops. On the other hand, they enhance biological control, by allowing natural enemies of pests to survive due to drastic reduction in spraying of chemical pesticides to control bollworms. *Bt*-cotton could thus become a valuable component of integrated pest management[10,11].

10. Geeta Bharathan has also raised certain economic issues. We wish to inform the readers that *Bt*-cotton in USA and other countries has fetched both economical and ecological benefits to the farmers and therefore it is being increasingly grown.

Finally, we wish to mention that insect-resistant *Bt*-cotton introduced in 1996 in USA and thereafter in other countries is improving the comparative advantage through an increase in yield and reduction in costs of cotton production. It is also likely to further reduce the prices by 6%. Comparative advantage of Indian cotton assessed through Domestic Resource Cost Coefficient (DRC) suggests that in recent years, the comparative advantage is eroding due to lower productivity and declining international prices. *Bt*-cotton can provide 20% increase in productivity in India, thereby improving the DRC substantially[12].


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## *Response*:

Barwale's response will enable sober discussion of issues surrounding the *Bt*-cotton project itself. First, a clarification of the phrases '*Bt*-cotton case' and '*Bt*-cotton project'. The former includes the *Bt*-cotton project as well as factors ('terminator technology', socio-economic aspects of cotton farming in India) that led to the controversy. Second, I draw the attention of the readers to a thorough, technical review of issues pertaining to transgenics and pest management (Sharma, H. C. and Oritz, R., *Curr. Sci.*, 2000, **79**, 421–437) that discusses, in general, many points that came up in my account of the *Bt*-cotton project.

Some of the points made by Barwale are matters of detail, not readily available to those not directly involved in this area of research (the reason why the questions originally were raised in my article). Therefore, I am thankful for his view of the history and background of the *Bt*-cotton project (his points 1, 2, 7), and for his corrections and clarifications of some questions raised in my paper (his points 5, 6, 9). Below are some comments on the last, further questions raised

(addressed to both MAHYCO and regulatory agencies), and then some general comments (on his points 4, 5, 10).

It is reassuring to learn that (i) *Cry1Ac* is the best gene for Indian conditions (although Barwale does not give us citations for results from field studies); (ii) no minor pests became major ones in the US over a period of 5 years of *Bt*-cotton growing; (iii) there is no reason to expect that non *Bt*-cotton fields adjacent to *Bt*-cotton fields will suffer greater insect damage than normal; and (iv) extensive studies on pollen escape, outcrossing, germination, weediness, etc. have been conducted in India: Again, citations are not given for results from these studies. Further clarification on time taken for backcrossing is requested: Were the 3 backcrosses done using multiple molecular markers to select the desired genetic background? Unaddressed questions pertaining to the MAHYCO project include: Adequacy of 1 acre plots and 2 seasons at the stage of field trials. General points (not part of the *Bt*-cotton project) not discussed include the need to broaden the pool of genes as emphasized by Sharma and Oritz and, apparently, being pursued by ICAR scientists (*Businessline*, 10 April 1999; 11 February; 2000).

A major point of concern continues to be that of resistance management. It is true that resistance has not arisen as rapidly as anticipated in Arizona (USA), but that might only mean that the models used to predict early evolution of resistance were missing a critical parameter, not that resistance will not evolve in the insect pests in the near future (Tabashnik, B. E., pers. commun.). Therefore, while it is reassuring to hear that strategies for management are being planned '. . . appropriately modified to suit local conditions', it would be even more reassuring to hear some details: What are the elements of the management plan? Would it be essentially the same as those in the US and Australia? Are there enough background data to enable appropriate modification as proposed? Given Barwale's familiarity with difficulties in pest management, I am sure he can understand the anxiety of those who are familiar with the complexities of the issue, but not with the strategies planned to handle these complexities. For instance, Sharma and Oritz (*Curr. Sci.*, 2000, **79**, 421–437) suggest that variability of *CryIAc* gene expression may be the cause, for instance, of *Bt*-cotton failure in Australia. Should we also expect such failures under Indian conditions? How likely is it to occur? At a time when transparency is desirable, so as to separate the technological from the societal factors, it is very important that the former are clearly spelt out.

Since some of the societal issues in the problem of cotton farming in the past apparently come from inadequate pest management, anxiety on this point is not unreasonable. It would also be useful for the public to be informed as to which part of the regulatory process is responsible for overseeing the plans for management. Will it be the GEAC that will evaluate the current field trials? How detailed a management plan does it require? Who will be responsible for implementation?

My paper tried to use the *Bt*-cotton case as a point of reference in order to generate general public discussion on biotechnological applications in agriculture in India. In this context, I would like to clarify two points that appear to have been misunderstood by responses to the paper: One (as mentioned above), the '*Bt*-cotton case' includes the '*Bt*-cotton project'; therefore discussion of the former will necessarily include not only the latter, but also other factors. In trying to understand how public perception was piqued, moulded and distorted, we need to consider all factors that went into the process. If we want to clear up public (mis)understanding, then the technological and other aspects need to be discussed separately. Since I tried very hard to do this, I am puzzled as to how, exactly, my paper 'obfuscates the truth'. Two, the polarization I mention refers to differences in positions taken by the forces that oppose GM technology in the West (where the technology itself is of prime concern), and in countries like India (where intellectual property rights issues tend to be emphasized). Obviously, there is considerable support for the technology in both societies; understanding differences in the factors that move public perception must help in understanding where the overlap, if any, lies (A brief account of these aspects can be found at http://life.bio.sunysb.edu/ee/geeta/Bt-Cotton.htm). Discussion on all these issues needs to be kept alive so that decision making is fully transparent and in the interest of the public at large.

GEETA BHARATHAN

## MEETING REPORTS

# Recent trends in crystallography*

To commemorate the birth centenary of K. Banerjee, one of the pioneer crystallographers of India, a two-day symposium was organized at the Indian Association for the Cultivation of Science (IACS), Calcutta. The inaugural ceremony was attended by more than 200 participants, including J. R. Helliwell, University of Manchester and the Editor-in-Chief of *Acta Crystallographica*, special invitees, past students and family members of Banerjee. S. K. Sikka, Chairman of the Indian National Committee on Crystallography (BARC, Mumbai) inaugurated the symposium. In his Welcome Address, D. Mukherjee (Director, IACS) highlighted the role of crystallography in interdisciplinary research and mentioned the golden heritage of IACS marked by the contributions of C. V. Raman, M. N. Saha, K. S. Krishnan, K. Banerjee, S. Bhagavantam and many others. The Chairman of the Organizing Committee of SRTCRA 2000, and a member of the Commission on Powder Diffraction (CPD) of IUCr, S. P. Sengupta, pointed out the importance of holding the symposium in

*A report on the 'Symposium on recent trends in crystallography and its applications' (SRTCRA 2000) held at the Indian Association for the Cultivation of Science, Calcutta during 15–16 September 2000.