



Figure 2. (From left to right) M. Alpine, M. Ismael, C. V. Raman, M. Born and E. Metcalfe.

On searching for 'Raman', a number of photographs appear. The one reproduced here (Figure 2) is from *C. V. Raman: A Pictorial Biography* (Ramaseshan, S. and Rao, C. R. (eds), Indian

Academy of Sciences, Bangalore, 1988) and appears slightly different from the photograph on the AIP webpage in that B. Venkatesacher does not feature in it. The preface of the book says: 'What is

unfortunate, however, is that all of the information regarding the original donors was lost' (p. 5).

As far as the AIP record is concerned, in both the above stated cases the credit goes to the AIP Emilio Segrè Visual Archives. Reproduction of images from the archives entails a payment of US\$ 10–52 depending upon the size. Evidently, the material scanned from the Indian journal or appearing in the collection on C. V. Raman is the property of AIP.

I hope that influential scientists, policy makers, historians and maybe even journalists will make an effort to collect photographs and create a central archive to keep a record of Indian heritage and culture.

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***Bt* cotton: refuge in 'mixed bag'**

Under the umbrella of cultivating refuge crops for delaying development of resistance in *Helicoverpa armigera* to *Bt* toxins, a questionable opinion of mixing non-*Bt* with *Bt* seeds in the same bag was recently proposed for adoption in India¹. Insect Resistance Management (IRM) has been strongly emphasized ever since the commercial birth of *Bt* crops about 15 years ago in the US. One of the prominent IRM strategies is to cultivate a certain proportion of refuge crops (non-*Bt* crops of target pests) alongside *Bt* crops. Several theoretical reasons have been elaborated to promote the idea^{2,3}. Nevertheless, just as every approach might not suit every society, Indian farmers, unlike their counterparts in the US, are observed to hesitate from conscious planting of refuge crops¹. Subsequently, for India, an idea of enforcing unconscious planting of refuge crops by mixing non-*Bt* with *Bt* seeds in the same bag has been projected¹. Here, we caution that the idea of 'mixed bag' may not only defeat the purpose of

resistance management, but may also have undesirable socio-economic consequences on the society.

In simple words, functioning of the mixed bag is as follows. When a farmer in India purchases a mixed bag of *Bt* cotton seeds, 20% of the seeds contained in it will be the non-*Bt* version. As he cannot differentiate 'which is which', he will be planting all of them. As a result, non-*Bt* seeds get randomly distributed in his field. Thus, it would be ensured that the stipulated proportion of non-*Bt* plants is available for the pest to complete its life cycle.

While contemplating the idea of mixed bag, it would be important to realize that a caterpillar of *H. armigera* feeds on several bolls to complete its development, and, in the process, may have substantial probability of moving between plants, especially when canopies overlap (Figure 1). This probability increases with increasing impetus for high-density planting these days. Movement from

non-*Bt* to *Bt* plants would be enhanced under the mixed-bag approach, as the probability for every non-*Bt* plant to neighbour a *Bt* plant would approach one. Its consequences on IRM plans can be summarized in two ways – (i) As the effectiveness of the toxin lowers with age of the caterpillars feeding on it, movement of older caterpillars from non-*Bt* to *Bt* will enhance opportunities for exposure to sub-lethal doses of the toxin. This can enhance risks of developing resistance. (ii) Movement of younger caterpillars from non-*Bt* to *Bt* plants may enhance their mortality and reduce density, which might culminate in reduced number of susceptible moths available for mating with the tolerant individuals emerging from *Bt* plants. This may also contribute towards developing resistance. Therefore, the mixed-bag approach can potentially defeat the concept of refuge crops for delaying resistance in *H. armigera*. These issues have been highlighted by others too⁴.



Figure 1. Photograph showing overlap between canopies of *Bt* cotton hybrid plants that could facilitate inter-plant movement of *Helicoverpa armigera* caterpillars. Spacing followed here is 3 ft × 3 ft.

Another projected advantage of the mixed bag is the distribution of susceptible insects across *Bt* cotton fields, which is theorized to enhance mating opportunities between the susceptible and the tolerant⁴. This might suit insects with restricted flight capabilities and farmers with large landholdings like those in the US; distant patches of refuge and main crop may interfere with the desired mating opportunities. However, in the case of *H. armigera*, which is a strong flier, and where both sexes take to flight before mating⁵, this is unlikely to be of any significant gain. The small per capita landholdings of farmers in India may also play against the anticipated benefit.

A disturbing consequence of the mixed bag is for pest management on refuge crops. Here, under the current prescription of 20% structured refuge, farmers undertake pest management on refuge crops to minimize losses. Now, in the mixed-bag situation, how will the farmer take up, say, insecticide sprays on refuge crops to lessen the burden of bollworms? If the two versions of cotton crops are morphologically identical, the farmer will have to spray without any distinction, which could potentially be 80% waste. Or, he will have to visit each plant and assess its damage before deciding to spray it, which is impractical. And, if the two versions of cotton are morphologically dissimilar, the farmer will perhaps remove non-*Bt* plants early in their growth phase, as retention could increase costs of pest management and other cultivation practices. Removal may also be promoted by the fear that insects from the non-*Bt* plants could spread over to

the *Bt* version, causing damage to the latter. Perhaps, it is the fear of cultivating susceptible crops that may have also contributed to the present low compliance of refuge in India. Additionally, there is no provision under the Indian Seed Act for selling two different genotypes in the same bag in the name of one hybrid; it can be tricky if a mixed bag produces morphologically different plants.

There is a subtler, yet critical issue. The mixed bag strategy may take a new dimension of enforcement on the Indian farmer, who has hitherto not been exposed to any policy that advocates compulsory adoption of an agricultural operation. He is not mandated to test the soil before applying fertilizers; he is not forced to implement integrated pest management practices; so on and so forth. Approaches in India have never relied on compulsion, in that, efforts are made to educate the farmer on developments in agriculture, while the decision of adoption has always rested with him. Arguably, the first agricultural operation that has been enforced on the farmer is to grow 20% non-*Bt* cotton along with its *Bt* version. Yet, compliance by the farmer is poor and reasons for non-compliance are not scientifically assessed. Therefore, in the current state of affairs, farmers may feel deceived and resent if the mixed bag is indeed offered to them. This can have delicate social consequences that are to be carefully scrutinized. The farmers' take on this has to be given prime importance; it is beyond proposals of technologists.

Farmers in India could be reluctant to plant refuge crops for varied reasons. For example, logic suggests that small and

marginal farmers whose net returns are generally low may show lower acceptance to cultivate refuge crops, given the fact that the refuge is susceptible to target pests. And, as mentioned earlier, there have been no attempts made to scientifically analyse the issue in India. Instead, we find a publication that categorically suggests that farmers must not be given a choice¹. It calls for strict enforcement in India while pitifully citing compliance data of farmers in the US¹. It is important to know that the mixed bag is also being pushed in the US, where refuge is stringently followed. The reasons are definitely different for the two countries – convenience of planting in the US and convenience of enforcement in India. For a farmer in the US, who strictly plants refuge crops, the mixed bag may assist in planting both versions of the seeds over vast areas. The situation in India is different. Here, majority of farmers have small landholdings and are reluctant to plant refuge crops. Therefore, 'convenience' becomes a non-issue here; it points purely to 'enforcement'. At the end, we urge that the proposed 'mixed bag' should not be given any consideration in India. Instead, the situation demands scientific studies on the reasons for poor compliance of refuge, which, further, may throw light on the appropriateness of refuge in India.

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