Impact of Bt Cotton on Punjab Soils: Findings of a Survey done by Kheti Virasat Mission

Bt Cotton and Soil Eco-system Impacts

One of the least understood areas in the environmental risk assessment of genetically modified crops is their impact on soil and plant-associated microbial communities. In a review of literature, Dunfield and Germida[1] (2004) found that transgenic plants and plant litter can influence the composition of the plant-associated microbial communities. Their review also points to such effects having been shown in a variety of plants with different transgenes. However, these effects are dependent on field site, seasonal variation, and method of analysis used to assess the community. They conclude by saying that changes in microbial communities associated with growing transgenic crops are relatively variable and transient in comparison with some other well-accepted agricultural practices. Even other scientists who reported that no conclusive research is present to conclude that significant direct effects on soil are present with transgenic crops also reiterate that a comprehensive evaluation of environmental impacts of GM crops grown under a wide range of soil properties is sorely missing.

Other recent studies include those commissioned by the Australian government. A report entitled "Below ground production of Bt by GM Cotton and Bt Cotton impacts on soil biological processes" by Dr Vadakattu V S R Gupta and Dr Stephanie Watson from August 2004 present many new insights about the possible impacts of Bt Cotton on soil. The report acknowledges that soil biota are diverse in terms of their physiology, size and environmental requirements and that the composition and metabolic capabilities of soil biota communities underpin many soil processes. Microbe-fauna interactions also play a critical role in a variety of biological functions in the rhizosphere (the zone directly surrounding the roots) and in the soil near decomposing plant residues. Crop residues play an important role in these interactions and this includes the leaf litter from Bt Cotton and root exudates which could potentially influence the soil eco-systems. It is well known that Bt Cotton plants produce bt-toxin in above-ground parts. Work from the laboratory of G Stotzky has suggested that Bt-toxin is also released from roots, and could bind to clay minerals in soils, raising concerns about the persistence of the toxin.

Changes in the soil eco-systems could include changes in microbial dynamics, soil biodiversity and ecosystem processes such as nutrient mineralisation, disease incidence, carbon turnover, plant growth and biodegradation of agrochemicals.

The Australian study found that detectable levels of Bt-toxin were found in decomposing Bt cotton leaf samples throughout a 8-week field incubation experiment. The study also found that differences in microbial growth indicators, suggesting that microbial population growth on bt cotton leaf litter might be different than for non-Bt varieties. Microscopic examination revealed an apparent increase in fungi and fungal spores on Bt Cotton residues compared to non-Bt residues. This experiment also showed for the first time that Bt toxin is expressed in roots at a similar level to leaves and that fine roots have higher levels of toxin than bulk roots. The study concludes that Bt toxin would

[1] J. Environ. Qual. 33:806-815, May-June 2004

gradually be added to the soil from roots throughout the cotton-growing season through root turnover rather than just at the end of the season.

Data from this study suggest that the majority of Bt-toxin would degrade within 2-4 weeks of plant biomass being incorporated into leaf decomposition in soil, and that a minor amount (<1-10%) could persist longer than 4 weeks, although the proportion of this that is biologically active was not addressed. Therefore, if Bt-toxin enters the soil environment faster than it is degraded by microbes, eaten by invertebrates or inactivated in some other way, it may accumulate in agricultural soils. If accumulation occurred (an issue not addressed by this study), the potential for adverse impacts to non-target organisms and soil ecosystems, both on-site and off-site, would need to be evaluated.

A paper entitled "The Ecological Impacts of Transgenic Crops on Agro-Ecosystem Health" by Dr Miguel Altieri of University of California also is based on literature review on the subject. According to this paper, other earlier studies show that toxins may persist for 2-3 months, resisting degradation by binding to clay and humic acid soil particles while maintaining toxin activity (Palm et al. 1996). Such active Bat toxins that end up and accumulate in the soil and water from transgenic leaf litter may have negative impacts on soil and aquatic invertebrates and nutrient cycling processes (Donnegan et al. 1995). Perturbations have been recorded by several authors with the introduction in the soil of genetically modified micro organisms (such as Pseudomonas fluorescens), including displacement of indigenous populations, suppression of fungal populations, reduced protozoa populations, altered soil enzymatic activity, and increased carbon turnover (Naseby and Lynch 1998).

Other scientists like Charles Benbrook [1999], point out that there has been very little serious and systematic work on the short term and long term impacts of Bt transgenic crops on soil microbial communities, biodiversity and function. Benbrook points out that while Bts engineered into plants are in a more active or cleaved form, the Bt toxins in conventional spray formulations in a more natural, complex and inactive form. The volume of Bt that enters the soil in a Bt transgenic crop field vastly exceeds the natural background levels in the soil plus any form of conventional sprays. Citing other studies by Stotzky et al, Alteiri points that that Bt can be quite persistent and concludes that even if impacts last for only 4-8 weeks, that is ample time to leave a lasting mark on the performance of the cropping system, both in one season and over many years. Even as studies exist to show that Bt toxins enter soils through roots, could accumulate over the cultivation season, could bind to clay particles and could impact microbial activity, the industry would like to deny any such effects.

As part of the biosafety assessment of Bt Cotton in India before approval was accorded for commercial cultivation, studies were conducting on the presence of Bt gene in soil. The findings reported from such studies are given below:

"Bt protein was not detected in soil samples indicating that Bt protein is rapidly degraded in the soil on which Bt cotton is grown. This study showed that the Cry 1AC protein was rapidly degraded in the soil in both the purified form of the protein and as part of the cotton plant tissue. The half life for the purified protein

was less than 20 days. The half-life of the Cry 1AC protein in plant tissue was calculated to 41 days which is comparable to the degradation rates reported for microbial formulations of Bt".

It is reported that studies were also conducted to evaluate the effect of Bt gene on soil micro-flora.

No significant difference was reported in population of microbes and soil invertebrates like earthworm and Gllembola between Bt and non-Bt soil samples as per these studies.

What is interesting to note is that despite the study on the presence of Bt gene in the soil showing that the half-life of the protein in plant tissue was 41 days, and despite the fact that leaf litter and root exudates contribute to the increased presence of the toxin in the soils, no studies were taken up to find out the impact of such a presence on intercrops with cotton or on subsequent crops like wheat, as in the case of Punjab.

There is no evidence of any independent scientific study being done on this subject in India before or after the commercial release of transgenic cotton in the country.

The survey by Kheti Virasat Mission

Many farmers of cotton-growing districts of Punjab had been growing illegal Bt Cotton from 2003 and in 2005 the state received official permission from the Genetic Engineering Approval Committee for the commercial release of six Bollgard Bt Cotton hybrids. Those farmers who had grown Bt Cotton in the earlier years, in meetings organized by Kheti Virasat Mission at the beginning of Kharif 2005 season, shared their perception of adverse soil impacts of Bt Cotton. This was an observation that got repeated again and again in many subsequent meetings too by scores of farmers in the state as in other states like Madhya Pradesh and Andhra Pradesh.

It was in this context of reports from the farmers and existing scientific evidence from elsewhere that Kheti Virasat Mission decided to take up a survey in Punjab for very preliminary findings on the subject, to alert the regulatory authorities for the need to take up systematic studies on the matter.

Methods and tools adopted

100 farmers of Bathinda, Faridkot, Mansa and Muktsar, who had grown Bt Cotton in Kharif 2005, followed by wheat crop were interviewed with the help of a questionnaire in this survey. 27 villages of these 4 districts were visited for the purpose during February 2006 for this purpose.

23 of these farmers had grown GEAC-approved Bt Cotton hybrids like RCH 134 and Ankur 651. The other 77 had grown illegal varieties of Bt Cotton like Arjun, Dollar, Gold, Sarpanch, Mahalaxmi, Prabhat, Kohinoor, Mahagujarat, Manik, Navbharat, Om-3, Tilak, Viraat, Trishul etc.

Study design: The survey used the comparison of wheat yields of Rabi 2004 with those of Rabi 2005 [of wheat grown after harvesting Bt Cotton] as a proxy indicator for any possible effects on soil.

The comparison was made only if the wheat in 2004 and 2005 was grown on the same plot as the Bt Cotton harvested, only if the same variety of wheat was used both in Rabi 2004 and 2005 and if the same management practices were used. In many instances, farmers had to apply more fertilizer on the wheat crop grown after harvesting Bt Cotton.

An annexure has the questionnaire used for the purpose of this end-of-the-season survey.

Selection of the farmers was completely opportunistic as and when farmers agreed to be interviewed for the survey, once the surveyors visited the villages.

FINDINGS

Approved Bt Cotton hybrids:

1. Out of the 23 Bt Cotton farmers who grew approved Bt Cotton hybrids, 5 cases were not considered for analysis since they had changed their seed variety between Rabi 2004 and Rabi 2005. Incidentally, 21 farmers perceived that their soil has been adversely affected by growing Bt Cotton (91.3%).

2. Out of the 18 farmers considered for analysis, it was found that in 14 cases there was a decrease in yields i.e, in 77.8% cases, there was a decrease in yields, with approved Bt Cotton hybrids. In one case, there was an increase reported in the yield – however, it was also a case of seed change.

3. For the 14 cases which reported decrease in yields, the average yield of Rabi 2004 wheat was 20.5 quintals per acre, whereas the average yield of Rabi 2005 wheat was 17.3 quintals per acre. This constitutes a decrease of 15.68% from Rabi 2004 yields.

4. When it comes to fertilizer use for the above 14 cases, the fertilizer consumption has actually gone up by 87.4% in terms of value/cost of fertilizer used.

5. Even for the 4 cases which reported same yields, the average increase in fertilizer use was 95% in terms of value.

Illegal Bt Cotton Hybrids

1. Out of the 77 cases of illegal Bt Cotton growers, 3 of them reported a change in seed variety of wheat between Rabi 2004 and Rabi 2005. Therefore, they were not considered for the analysis.

2. 70 of the illegal Bt Cotton farmers met perceived that there was a negative effect of Bt Cotton on their land [i.e., 91% of the farmers met].

3. 74 cases were used for analysis, of farmers who had used the same variety of wheat both in Rabi 2004 and Rabi 2005. 4 of them reported increases in yields [5.4%] while 19 farmers reported same yields in both Rabi 2004 and Rabi 2005, after harvesting Bt Cotton [25.7%]. 51 farmers reported a decreased yield in Rabi 2005 i.e, 68.9% of the farmers met.

4. The average yield per acre in Rabi 2004 for the 51 farmers who reported decrease in yields was 17.68 quintals per acre, whereas the average yield in Rabi 2005 came down to 15.78 quintals per acre. This is a 10.75% decrease in yields.

5. It is interesting to note that the yield decreases were accompanied by an increase in fertilizer use by 88.5%.

6. In the case of farmers who reported increase in yields, the average yields went up from 15.5 quintals per acre to 18 quintals per acre. The yield increases were accompanied by a 80.4% increase in fertilizer consumption [in terms of value].

7. Even in the case of those farmers who reported the same yields with the same variety of wheat being used, the fertilizer use went by 93.8%.

DISCUSSION

- These findings point to an alarming trend – nearly 91% of the farmers met had perceived that their soil was being adversely impacted by growing Bt Cotton. 65% of the total farmers surveyed had obtained lower yields of their rabi wheat crop after the harvest of Bt Cotton on the same plot. This high percentage of cases where yields were found to have declined could be because Punjab goes in for early sowing of cotton [as opposed to sowing that happens in June/July in the central zone and south zone] so that a second crop can be grown on the same plot. The findings in this survey could reinforce the findings from other studies about the persistence of Bt toxin in the soil and the altered microbial activity discovered after Bt-toxins are released and accumulated into the soil through root exudates and crop residues.

- In the case of approved Bt Cotton hybrids, the decrease in yields in rabi wheat were by around 15.7% while in the case of unapproved Bt Cotton hybrids, it was 10.7%. These decreased yields were incidentally accompanied by increased fertilizer applications in both cases. These findings need further investigation to ascertain the variability of Bt-toxin release into the soil from approved and unapproved Bt Cotton hybrids and any variable impacts because of toxin variability.

Given that wheat from Punjab is an important component of the national food security and given that it is grown right harvesting Bt Cotton in increasing extents of the cotton belts of Punjab, it becomes important to understand the impacts of Bt Cotton on the soil and any possible impacts on yields of subsequent crops. At least in the coming year, Punjab government should collect baseline soil samples from those farmers who have not grown Bt Cotton earlier and are likely to opt for it this year, so that scientific investigations and studies can be taken up to understand possible adverse impacts.