near pre-*Bt* levels by 2013, despite an increase of over 90% in *Bt* area.

It is emphasized that thus far modern biotechnology (GE crops) provides no traits for yield enhancement. The introduction of the *Bt* trait in hybrid cotton was in part to prevent our mainly resource-poor, small and marginal farmers from saving seeds for the next sowing season. Coupled with the greater adoption of *Bt* technology because of twin irresistible claims (of high-yielding hybrid *Bt* cotton and no pesticides), *Bt* cotton developers (essentially Monsanto), gained a monopoly in cotton farming in India in a short time-span. Its socio-economic implications have been dreadful: driving poor cotton farmers into a 'debt trap' and even to suicide. Many NGOs, including the M.S. Swaminathan Research Foundation (MSSRF), are providing skill and knowledge empowerment for self-created livelihoods to the widows of farmers who committed suicide, and school education for their children, in Vidarbha (Maharashtra) among other areas. MSSRF is also facilitating the widows and other dependents of deceased cotton farmers to derive benefits from various Government schemes.

I had the opportunity to examine the biosafety dossiers of *Bt* cotton and *Bt* brinjal in my then capacity as a Member of the Technical Expert Committee (TEC) appointed by the Honourable Supreme Court of India. The dossiers revealed several inadequacies in the toxicological evaluation of both *Bt* cotton and *Bt* brinjal. It is, therefore, not surprising that international experts who analysed these data have rightly pointed to the several serious flaws. Indeed, it opened a can of worms. In one case, the TEC was aghast to find that the toxicological data of *Bt* cotton presented to the then GEAC revealed a 'gender equality' in terms of body weights and growth rates of rats from the age of 6–8 weeks onwards to 20–22 weeks. That was a piece of new biology. The aspartate aminotransferase (AST) levels in both male and female rats were significantly higher in the *Bt* transgenic brinjal-fed group. The AST is a marker of organ integrity, and an increase in AST could indicate damage to liver and heart. It would appear that these significant flaws and omissions escaped scrutiny of the Genetic Engineering Appraisal Committee. Fortunately, the then Minister of Environment and Forests, Government of India imposed a moratorium on the commercialization of *Bt* brinjal.

The 'hybrid' mustard DMH-11 has several problems, of which one is that the Barnase–Barstar system in seed production programme requires a *bar* gene. This is an HT crop, the herbicide being Bayer's 'glufosinate', a neurotoxin, currently banned in the EU. Because of DMH-11, Bayer would gain a market in India.

The science is clear: 'Selection pressure' will act to induce the emergence of resistant forms of pests. In combination with socio-economic considerations (including the fact that resource-poor, marginal and small-holder farming does not 'allow' in practical terms, a 'refuge', in the absence of surplus land), hybrid *Bt* cotton should not have been introduced for commercial cultivation in India. What is far worse is to commandeer the use of IPM to resurrect Bollgard II cotton. Instead, the need of the hour is to admit past mistakes and rectify the errors as soon as possible.

There are many interesting examples of seeking support for GE crops by normally reputed science academies, such as National Academy of Agricultural Science (NAAS), which is eroding their reputation. In its 'Policy brief to accelerate utilization of GE technology for food and nutrition security and improving farmer's income' (NAAS, New Delhi, 1 August 2016), NAAS cites 107 Nobel laureates in their letter to the governments of the world stating that GE crops are '......as safe as, if not safer than those derived from any other method of production'. The reproduction of this statement by NAAS would be amusing, if it were not such scientific 'cookery' – it is certainly curious as to how and why, Nobel laureates from different disciplines claim to be knowledgeable enough to make scientific judgements on 'modern biotechnology' – a discipline far removed from their own fields of expertise. It is indeed unfortunate that a science academy is so desperate that it requires using such questionable support. The agenda to promote the *Bt* and Ht transgenic crops obviously lacks science-based support. Claims of the benefits of *Bt* and Ht crops well exemplify 'science in post-truth era'[7].

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Response:

Kesavan's understanding that integrated pest management (IPM) is being sought through the published article on pink bollworm (PBW) management on *Bt* cotton, now that PBW has evolved resistance to Bollgard II *Bt* cotton, is not correct.

Biotechnologists and plant protection experts have always developed products bearing in mind that insect pests on crops can be successfully managed over a long time by not relying on a single mode of insect control. *Bt* cotton is no exception because, globally, it (for that matter, all *Bt* crops) is never positioned as a stand-alone method of insect management. *Bt* cotton is an integral part of IPM packages (at times region-specific) for the management of Lepidopteran pests of cotton and the good fit has been successfully demonstrated in cotton growing ecosystems of India[1–3]. As Kesavan has stated, IPM is preferred for *Bt* cotton for the reason that a multiprong approach to kill bollworms reduces the selection pressure exerted by *Bt* alone (along with the refuge planting)[4]. In the case of PBW, certain specific cultural practices (also integral to IPM) like early termination of crop or cultivation of early-maturing cotton in endemic and heavily infested areas, post-harvest ploughing, sanitation of cotton fields and gins from

PBW pupae and larvae play a vital role in limiting the carry-over of PBW population into the next cotton season. With the introduction of the single *Bt* gene cotton and the *Bt* stack Bollgard II in 2002 and 2006 in India respectively, bollworm management on *Bt* cotton became easy and effective for the cotton farmers[5]. This is because the Indian PBW populations were among the more sensitive bollworms to the *Bt* proteins, Cry1Ac and Cry2Ab, expressed by dual-*Bt* cotton[6]. Thus, PBW was effectively controlled for many years post introduction of both versions of *Bt* cotton.

In view of continued low infestation of *Bt* cotton by PBW for many years, cotton farmers gradually moved away from these cultural components of IPM, so important for breaking the PBW pest cycle, overlooking extension advisories. In the current scenario, *Bt*-resistant PBW population levels appear to be high in the cotton ecosystems of Central and South India. My essay highlights the importance of re-introduction of the cultural components of *Bt* cotton IPM and if adopted in a concerted and as a wide-area activity by the cotton farmers, can suppress the *Bt*-resistant PBW populations in the next couple of years. Reiterating, this is a plea to the cotton stakeholders to revive the cultural practices of PBW control on *Bt* cotton.

Kesavan's statement which tends to convey that cotton farming was sustainable through eco-friendly IPM alone, prior to the introduction of *Bt* cotton in India, is also not correct. In the pre-*Bt* era, especially in the 80s and 90s, cotton cultivation was cost-intensive and not remunerative because >43% of the variable cost of its production was spent on insecticides and 80% of this cost was for bollworm control. In short, ~50% of all the insecticides used on agricultural crops, was sprayed on cotton alone[5]. Widespread resistance to pyrethroids and other insecticides among *Helicoverpa armigera* populations (the 'monster' bollworm then) is said to be the key reason. Thus, cotton cultivation was the least eco-friendly, because the cotton farmer sprayed 10–15 times with a cocktail of insecticides[5] and still, did not get good control over *H. armigera* and it was definitely not sustainable. In this scenario, *Bt* cotton provided good control of all bollworms[5] and proved to be a major control component in IPM for cotton bollworms.

The spend of the cotton farmer on insecticides for control of sucking insects has been on the rise (no way connected to *Bt* cotton) in the last couple of years due to increase in the incidence of jassids, thrips and white flies. Now, since the development of *Bt* resistance in PBW, the farmer undertakes a couple of insecticide sprays for PBW management based on the pest reaching economic threshold level (ETL). I wish to point out that the insecticide spray for bollworm control has never reached the pre-*Bt* levels, as commented by Kesavan. It is still profitable to cultivate cotton, though the benefit margins could have reduced, and that is why we are not seeing any substantial reduction in the farmer's choice for *Bt* cotton technology, even 15 seasons after the introduction of *Bt* cotton.

On the comment that the *Bt* cotton farmers were mislead to believe that *Bt* cotton would not need insecticide sprays, is absolutely wrong. The advisory with *Bt* cotton cultivation has always been to spray Central Institute for Cotton Research or State Agricultural University recommended insecticides for bollworm management, if necessary, based on the bollworm population level reaching ETL. Cultivation of *Bt* cotton has always been in the context of IPM, and need-based insecticide application is integral to IPM.

Evolution of resistance to any external selection pressure is an evolutionary phenomenon, be it *Bt* cotton, chemical insecticides or antibiotics. We have seen innumerable instances in the past when insect pests of crops and some of public health importance have gained resistance to chemicals, bacteria to antibiotics. Can we blame the organizations who developed the technologies, just because resistance has evolved after a few years? It is imperative that R&D efforts towards new technologies need to be continuously evolving to stay ahead of resistance evolution. The single *Bt* gene, followed by stacked *Bt* gene products represent this march of continuous development by the technology generators. In most cases, resistance evolved because of improper use of technology (as examples, indiscriminate use of chemical insecticides and not need-based, neglect of other components of IPM, inadequate refuge planting).

On the comment by Kesavan quoting Tabashnik's publication[7], asymmetric cross-resistance was indeed reported by Tabashnik's team in PBW strains that were laboratory-selected for high levels of resistance to Cry1Ac and Cry2Ab, the *Bt* proteins expressed by Bollgard II. In this study, the PBW strain, resistant to Cry1Ac, exhibited no cross-resistance to Cry2Ab, however, Cry2Ab-resistant PBW strain could tolerate Cry1Ac. Inheritance of Cry1Ac and Cry2Ab resistance (in individual strains) was clearly recessive and the crossed progeny PBW strain which was resistant to both *Bt* proteins did not survive on Bollgard II bolls, thus rendering the resistance to the dual-toxins functionally recessive[7]. Earlier studies by Tabashnik's team had showed that the genes conferring resistance to Cry2Ab in Bollgard II in PBW would evolve independently of those conferring Cry1Ac resistance and susceptibility to Cry2Ab would not be influenced by Cry1Ac resistance[8]. PBW populations in India evolved resistance to Cry1Ac first[9].

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