Seeking sustainability for smallholders: *Bt* cotton in India

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Of the various genetically modified (GM) crops in use today, none is planted by more smallholder farmers than *Bt* cotton. *Bt* crops contain insecticide-producing Cry genes from the bacterium *Bacillus thuringiensis*, expressing proteins deadly to many common cotton insect pests. Small-scale Indian cotton farmers in particular have struggled with pest management, and in 2013 over 90 per cent of Indian cotton farmers planted *Bt* cotton, more than in any other country. A pressing question in agriculture today is how sustainable the benefits of *Bt* cotton will be for these farmers.

Despite universal recognition of the importance of sustainability in agriculture, we often forget this aspect as we point to the short-term impact of GM crops. Sustainability is not simply a property of a technology, but a matter of how that technology is integrated into local agricultural practices. Extensive research has shown that sustainable smallholder farming is highly knowledge-intensive.[1]

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Our research in India focused on the ways in which farmers develop local knowledge about crops and what this means for their sustainability. Research in Warangal District began before *Bt* cotton was released, with fieldwork in a set of villages representing farmers differing in caste, education and prosperity. Four villages were selected for long-term research on trends in cotton farming. We draw on this research to advance our knowledge of sustainability, first by examining patterns in cotton yields in the study villages (and also in the state and nation), and second by examining the long-term trends in seed choice that reflect how technology is or is not being integrated into local knowledge systems. In 2014 Warangal District became part of the new state of Telangana, but since our discussion covers a period when it was still part of Andhra Pradesh we use that name here.

Trends in cotton yields

The sustainability of *Bt* cotton cannot be understood separately from the recent history of the technologies used to grow cotton. Hybrid cotton seeds spread through India in the 1990s, marketed by rapidly proliferating and lightly regulated private seed companies, leading to a flood of seed brands.[2, 3] The hybrid seeds lacked resistance to Asian pests so uptake expanded along with heavy insecticide use. This technology package provided many farmers with quick profits and was rapidly adopted. But the insecticides lost effectiveness as pests developed resistance and beneficial insects were often killed off. During the 1990s and early 2000s, cotton farmers found themselves on a technology treadmill as they went through various types of insecticide, including organochlorines, organophosphates, carbamates, synthetic pyrethroids and spynosins. Seed brands appearing and disappearing from the market by the hundreds further challenged the stable integration of technology into local farm management.

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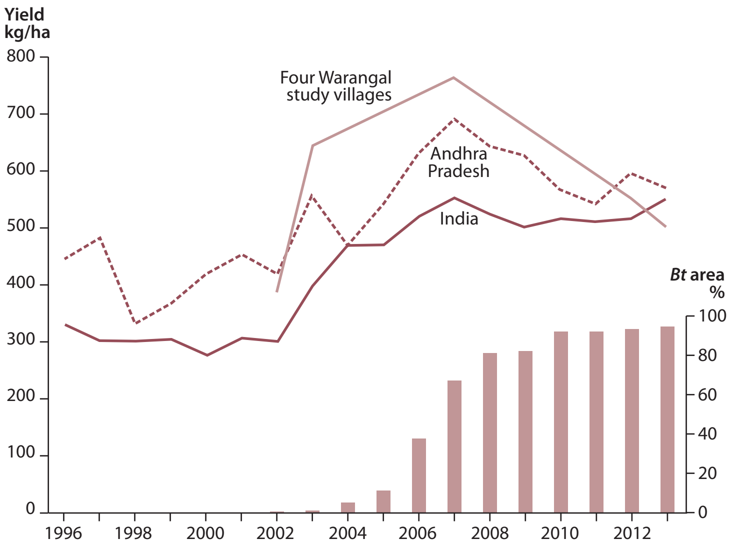
Figure 1. Cotton yields through time for India, Andhra Pradesh and the study villages, and *Bt* adoption as a share of India's cotton area



Notes: *State and country figures pertain to lint. Warangal farmers reported yields as kappas (seed cotton), here converted to lint with a conversion factor of 33 per cent.*

Sources: International Service for the Acquisition of Agri-biotech Applications (*Bt* area 2002–2012); Cotton Corporation of India (*Bt* area 2013, cotton yields).

Such practices were unsustainable; farmer debt rose to alarming levels, and many resorted to suicide.

Approved for sale in 2002, *Bt* cotton offered farmers a different insecticide technology. Cotton is plagued by both bollworms and sucking pests, two major categories of insect pests, and *Bt* genes produce proteins that are

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lethal to bollworms. Initially, farmers in Andhra Pradesh – and in India generally – adopted *Bt* cotton slowly, but these numbers climbed rapidly during 2005–2007 (Figure 1). There have been more than a dozen studies attempting to isolate its impact on yields, most of which focused on the first few years after release, and most credited *Bt* seeds with significant yield increases[4, 5] as well as promising reductions in pesticide use.[6] However, these studies tell us little about sustainability in a cotton sector with a history of unsustained benefits.

A 2012 study estimated that, in sample villages in four states, *Bt* cotton increased yields by 4 per cent per year between 2002 and 2008.[7] And a further study that looked at our four Warangal villages over the period 2003–2007, during which time *Bt* cotton was widely adopted, found a similar average yield rise of 4.5 per cent per year.[3]

To consider yield sustainability, Figure 1 shows long-term yield trends for India as a whole, Andhra Pradesh and our four study villages in Warangal. In Andhra Pradesh, cotton yields had been rising at an average rate of 11 per cent annually for the three years before *Bt* cotton was first approved in 2002. In Warangal District, yields jumped by 66 per cent between 2002 and 2003, but this is apparently unrelated to *Bt* cotton as only 2 per cent of the sample farmers had adopted the new seeds. It was not until 2005–2007 that *Bt* adoptions surged, and since then yields have not risen. Since 2007, yields have stagnated nationally and fallen by 17 per cent in Andhra Pradesh. In our study villages, the decline has been yet sharper: yields have dropped to 34 per cent below the 2007 high.

Reasons for this decline are uncertain. An obvious concern is that, like previous generations of insecticides, *Bt* might lose its effectiveness, causing spraying to go back up and yields to go down. Krishna and Qaim's 2012 study concluded that the early pesticide reductions were sustainable,[8] but their data only went up to 2008 – the same year that *Bt* resistance was reported in one of India's worst bollworm outbreaks.[9] Still, to date there are no indications that *Bt* resistance has spread or that it is causing lowered yields.

However, India does have a problem with sucking pests that are not targeted by *Bt*. This problem has also been reported in China, where rising difficulties with sucking pests eroded the early benefits of *Bt* adoption.[10] In Warangal, farmers report particular problems with aphids, but recent studies show that mirids too have emerged as a key pest throughout much of India.[11] The role of *Bt* plants in driving this trend is debated. Exacerbating the problem is that most of the hybrids that *Bt* technology has been put into are large-boll cotton types that are more susceptible to sucking pests.[12] Overall, pesticide use remains lower than before the adoption of *Bt* cotton, but losses to sucking pests are a likely contributor to the slump in yields.[13]

Let us then turn to the larger question of how sustainably farmers have been able to develop local knowledge of the technology.

Integrating technology into farm management

Cotton farmers always have to deal with insects, but not all end up in a spiral of debt and suicide. We have noted the importance of local knowledge-intensive management in

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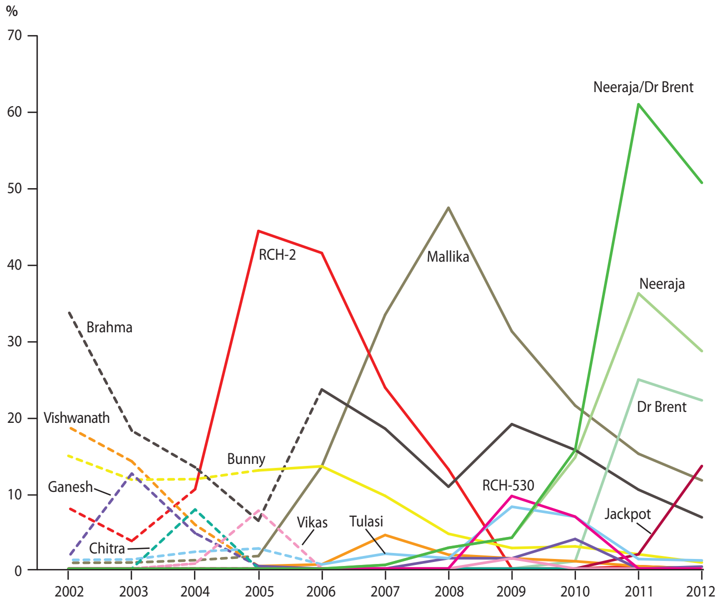
sustainable farming; from this perspective the treadmill that Warangal farmers had been on was not an insect problem so much as a technology management problem. Earlier studies, before the introduction of *Bt* cotton, showed Warangal farmers having severe difficulties integrating new technologies into local agricultural practice. With pest populations, seed brands and pesticides all changing very rapidly, and with seeds and sprays inaccurately or deceptively labelled and marketed, effective trialling of technologies was nearly impossible. Instead of careful assessments, farmers turned to simple emulation of neighbours and followed the herd. Even before *Bt* became popular, the problem was reflected in short-term seed fads, in which one of the many seeds on the market would become wildly popular in a village for a few years. There was no clear agronomic reason for these fads, and farmers were unable to learn the properties of a seed before the next fad took over. Pesticide brands and technologies also changed rapidly, increasing the uncertainty in farmer decision making.[14]

The hope has been that *Bt* technology would provide more reliable insect control so that the new seeds would be more amenable to being sustainably integrated into local management practices. One concern in this regard is that *Bt* technology itself has changed rapidly: from one *Bt* technology (or transformation event) in 2002, there are now six different *Bt* technologies approved and more than 1,500 hybrids. K.R. Kranthi, head of the Central Institute for Cotton Research, sees the proliferation of seed brands as a primary cause of declining cotton yields. The huge number of approvals – more than 1,100 brands as of 2012 – makes judicious trialling of seeds nearly impossible,

Figure 2. Patterns in the cotton seed choices of farmers in the four Warangal study villages



Random samples of farmers in each village were interviewed over the decade, reporting a total of 3,162 seed choices. The y axis shows what proportion of each year's seed choices were for the most popular seeds. Dashed lines before 2006 indicate conventional seeds; solid lines indicate *Bt* versions of the same seeds. Further details on the data and analysis are provided in Stone *et al.* (2014).

Note: *Neeraja and Dr Brent are separate brands but they are almost identical. They are from the same company, released around the same time, contain the same Bollgard II event, were co-marketed in a new marketing strategy that is becoming more popular, and are often treated as interchangeable by local farmers.*

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and also opens the door for unscrupulous marketing.[15]

Since we have found farmer technology assessment to be reflected in patterns of seed buying, we have analysed the history of seed choices spanning the period of *Bt* seed adoption. Figure 2 shows that the pattern of seed fads has not only continued but strengthened, with RCH-2 followed by Mallika, then Neeraja and Dr Brent. Continuing the pattern documented before, these seeds were not superior performers, as yields for Neeraja and Dr Brent were indistinguishable from those of other seeds. Their wild but ephemeral popularity was the result of a herd behaviour that develops when technologies are very difficult for farmers to assess.

Our long-term study of sustainability in cotton cultivation confirms the importance of looking at patterns in technology use rather than technologies in isolation. Taken in isolation, the hybrid seeds that spread in the 1990s should have been beneficial to the farmer, as test plots showed them to be higher-yielding than earlier varieties. Taken in isolation, each generation of insecticide should also have been beneficial to the farmer, as each showed initial effectiveness. And the *Bt* seeds adopted in the mid-2000s, taken in isolation, should have been beneficial as well, since they have shown effectiveness against one major category of pest. It is when we look at the pattern of technology deployment that the appearance of unmitigated benefit begins to fade. Simultaneous rapid change in seeds, pesticides and pests is destructive to the process of trialling that is essential in developing local knowledge of a technology and achieving sustainability.

India offers a sobering lesson for smallholder farmers seeking technological fixes to agricultural problems. Their focus must remain not only on sustained yield increases but on how technology is integrated into local agricultural practices.

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