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*Progress in Development Studies* 21, 1 (2021) pp. 68–85

# The Return of Pink Bollworm in India's Bt Cotton Fields: Livelihood Vulnerabilities of Farming Households in Karimnagar District

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10.1177/14649934211003457

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**Abstract:** Since its introduction in India, Bt (*Bacillus thuringiensis*) cotton technology has been the object of controversial scholarly and non-academic debate. The recent return of pink bollworm (*Pectinophora gossypiella*) pests in several Indian states has provided cause for concern about widespread resistances in Lepidopteran pests towards the endotoxins produced in Indian Bt cotton plants as well as about severe setbacks in regard to cotton farmers' livelihood security. This study is the first to provide empirical evidence on the socio-economic consequences of recent bollworm attacks in India based on an exploratory study conducted in Karimnagar district, Telangana, India. It analyses the changed vulnerabilities that smallholders currently face and identifies the reasons why some peasant farmers can only deal with the consequences of this technological failure to a limited extent.

**Key words:** Bt cotton, genetic engineering, India, pink bollworm, rural livelihoods, Telangana

## I. Introduction

Ever since its introduction, Bt (*Bacillus thuringiensis*) cotton technology in India has been accompanied by a controversial scholarly and non-academic debate (Choudhary and Gaur, 2010; Flachs, 2019a; Gutierrez et al., 2015; Kathage and Qaim, 2012; Kranthi, 2015a; Qaim, 2003; Scoones, 2008; Stone, 2007; Veettil et al., 2016). While agricultural economists stress the technology's importance in remedying a proclaimed agrarian crisis in the Indian cotton production through contributions to yield increases, improved revenue, and reductions in pesticide use (Choudhary and Gaur, 2010; Kathage and Qaim, 2012; Qaim, 2003; Sadashivappa and Qaim, 2009; Subramanian and Qaim, 2010; Veettil et al., 2016), other scholars question the technology's success and instead hold a multitude of agricultural factors responsible for improvements in the Indian cotton-producing sector in the early 2000s, such as the introduction of hybrids altogether, the spread of access to irrigation, and the increase in fertilizer application (Flachs, 2019a; Gutierrez et al., 2015; Kranthi, 2014, 2015b; Kranthi and

Stone, 2020). Moreover, the technology's negative ecological side effects, i.e. outbreaks of secondary pests, and upcoming resistances in the target pest have been discussed (Flachs, 2019a; Gutierrez, 2018; Gutierrez and Ponsard, 2005; Kranthi, 2014, 2015b; Tabashnik and Carrière, 2019), its social implications, for example, its role in eroding farmers' knowledge, addressed (Flachs, 2019; Stone 2007), and its contribution to rural poverty reduction questioned (Glover, 2010).

Recent attacks of pink bollworm pests in Gujarat, Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh and Telangana in the cotton season of 2017/2018 and earlier (Fand et al., 2019: 314; Mohan, 2017: 1988; Naik et al., 2018: 2544) have fuelled the debate not only about potential resistances in Lepidopteran pests towards the endotoxins produced in Indian Bt cotton plants, but also about severe setbacks in regard to cotton farmers' livelihood security due to the technology failure. The recurring attacks of Lepidopteran pests throughout Indian states and the sudden decline in yield performance are now overshadowing initial hopes that were placed in Bt cotton technology in its early years of adoption.

In India alone, the lives of an estimated 60 million people are directly dependent on cotton production. Bt cotton technology plays a vital role in the agricultural sector and thus, the effects this industry has on people's livelihoods are of immense significance (Choudhary and Gaur, 2010: 3). This study fills the scientific void that had existed since the return of the pink bollworm in Indian Bt cotton fields was reported, in that it captures the socio-economic impacts of the recent return of the pest on cotton farming households. By following an exploratory livelihood approach, it examines the results of 42 problem-centred interviews conducted in Karimnagar district, Telangana. The study explores the changed vulnerabilities that smallholders currently face and examines the reasons why peasant farmers can only deal with the consequences of this technological failure to a limited extent.

## II. Bt Cotton in India

Cotton production provides livelihoods and income for around 10 million rural households in India. Of these, 7.5 million smallholders have farm sizes of less than 10-15 acres and cotton holdings of 3–4 acres on average (Altenbuchner et al., 2018: 373; International Service for the Acquisition of Agri-Biotech Applications [ISAAA], 2017: 33; Kathage and Qaim, 2012: 1; Subramanian and Qaim, 2010: 296). The major cotton-producing states are grouped into three different zones of production, that is the northern (Punjab, Haryana and Rajasthan), central (Maharashtra, Madhya Pradesh, Gujarat, and Odisha), and southern zone (Andhra Pradesh, Telangana, Karnataka, and Tamil Nadu) (Arora and Bansal, 2012: 7; Choudhary and Gaur, 2010: 3; ISAAA, 2009: 3). While the northern zone is irrigated, accounting for 35% of land under cotton, both the central and the southern cotton cultivation zones are rain-fed, accounting for 65% of land under cotton (Choudhary and Gaur, 2015: 11; Gaurav and Mishra, 2012: 25; ISAAA, 2009: 3; Kaviraju et al., 2018: 1561). The cotton crop is grown in the season of *kharif*. It is sown in the monsoonal period starting in June and harvested in the time from October to January (ISAAA, 2017: 29; Kurmanath, 2018).

Since Lepidopteran insects are considered a major limiting factor in the production of cotton worldwide, genetically engineered (GE) seed technologies were developed to equip cotton plants with built-in protection against these damaging pests (Choudhary and Gaur, 2008: 15; Kathage and Qaim, 2012: 1; Naik et al., 2005: 1514; Subramanian and Qaim, 2008: 1). Bt crops produce endotoxins of the *Bacillus thuringiensis* bacterium, which have lethal effects on Lepidopteran insects (Khan et al., 2018). Following neoliberal economic reforms in the 1990s, the Indian agrarian sector was restructured in that state regulations were eased, seed production commercialized, and the farmer's role changed towards a more capitalist rationality. Alongside these changes, the Indian Genetic Engineering Approval Committee[1] (GEAC) authorized the release of the first generation of Bt cotton seeds for commercial cultivation in 2002 for the Indian market (Flachs, 2019a, 2019b; Kiresur and Ichangi, 2011: 68; Münster, 2012; Ramamurthy, 2000; Scoones, 2008). This first legalized GE crop in India was developed by the Indian seed company Maharashtra Hybrid Seeds Company (Mahyco) in a joint venture with the US-based company Monsanto called Mahyco Monsanto Biotech Limited (MMBL) (Qaim et al., 2006: 49; Sadashivappa and Qaim, 2009: 173). It remains the only legalized GE crop in India to date.

In the first years, MMBL produced three hybrids (MECH 12, MECH 162, MECH 184) with one induced gene (Cry1Ac) based on Monsanto's Bollgard-I technology (event MON-531) (ISAAA, 2009: 16; Kiresur and Ichangi, 2011: 68; Naik et al., 2005: 1514), which soon led to a sharp rise in the development of Bt hybrids and further events (Choudhary and Gaur, 2010: 13; Sadashivappa and Qaim, 2009: 173). One of these additional events, called MON15985, contained two induced genes (Cry1Ac and Cry2Ab) and became later known as Bollgard-II (Choudhary and Gaur, 2015: 10; ISAAA, 2009: 12; Kukanur et al., 2018: 34). Today, Bollgard-I hybrids are almost completely replaced by seeds based on the Bollgard-II technology (Choudhary and Gaur, 2015: 5; see also Hallad et al., 2014: 224; ISAAA, 2016: 29).

The area under Bt cotton drastically increased throughout the country since the GE-technology was introduced (Choudhary and Gaur, 2015: 9; ISAAA, 2017: 28–29). Today, an estimated 93% of the area under cotton are cropped with GE plants (ISAAA, 2017: 28–29), underlining the vital role that Bt technology plays for India's cotton sector. It is grown in such quantities that India is today the world's fourth-biggest producer of GE crops, after the USA, Brazil, and Argentina (Kumar, 2015).

## III. Bt Cotton Farming and Sustainable Livelihoods in India

*Socio-Economic Effects of Bt Cotton Cultivation on Peasant Livelihoods*

In regard to measuring and evaluating the socio-economic effects of Bt cotton cultivation on peasant livelihoods, the technology's effects on yields are controversial. Scholars with backgrounds in economics (e.g., Kathage and Qaim, 2012; Qaim, 2003; Sadashivappa and Qaim, 2009; Veettil et al., 2016) make claims that Bt technology increases effective yields. In these studies, the successes in yield increases of the early 2000s are almost entirely credited to the impact of Bt cotton (Kathage and Qaim, 2012; Plewis, 2014; Qaim, 2003; Qaim et al., 2006; Smale, 2016; Veettil et al., 2016). It is thus argued that Bt has strongly outperformed conventional cotton and yield advantages of up to 40% are ascribed to the impact of Bt technology (Kathage and Qaim, 2012: 2; Sadashivappa and Qaim, 2009: 172). However, other studies take several key trends in the Indian cotton production for overall yield increases into account (Flachs, 2019a; Glover, 2010; Gutierrez et al., 2015; Kranthi, 2014; Kranthi and Stone, 2020) and find lower contributions of the GE technology to increases in yields. Stone (2011: 395), for example, attributes only 18% of the suggested yield increase to the technology as such. In their recent long-term study, Kranthi and Stone (2020: 188) claim that 'yield increases are explained much better by other technological changes' and hence accredit yield increases of the early 2000s to a multitude of agricultural factors, such as the hybridization of cotton seeds, an improved access to irrigation facilities throughout Indian cotton-producing states, and most notably the rising use of fertilizer. Other scholars claim that 'the yield advantage of Bt over non-Bt is not statistically significant' (Gaurav and Mishra, 2012: 12), that it is unrelated to the technology, but rather to different cultivars and agronomic practices, and that yields have been stagnating or even falling during the last years (Stone and Flachs, 2015: 122).

Notwithstanding these differences, some scholars argue that higher effective yields have led to higher profits (Kathage and Qaim, 2012: 2; Maertens, 2017: 991; Plewis, 2014: 15; Sadashivappa and Qaim, 2009: 172; Smale, 2016: 1). Kathage and Qaim (2012: 1) claim a 50% gain in cotton profit among smallholders, which increased household living standards by 18% among Bt adopters and, additionally, increased household consumption (see also Yadav et al., 2018: 66). Hence, the authors conclude 'Bt cotton contributes to positive economic and social development' (Kathage and Qaim, 2012: 1) as most of the adopting peasant households are relatively poor. Sadashivappa and Qaim (2009: 172) furthermore claim that both these benefits (higher yields and an increment of profits) have been sustainable over time.

Also this line of argument, however, is not unchallenged: Several scholars describe the technology as increasing risks for farmers as it is not intrinsically yield-increasing, but instead, its performance depends heavily on local suitability, irrigation and/or rainfall conditions (Flachs, 2019a, 2019b; Gaurav and Mishra, 2012; Glover, 2010). This, in turn, means that 'any effects beyond protection against specific bollworm [...] infestation' are not guaranteed (Gaurav and Mishra, 2012: 3). Moreover, while cotton is generally regarded as a risky crop in terms of yield variability, Gaurav and Mishra (2012: 3) argue that the yield fluctuations of Bt cotton are even higher than the variability of conventional cotton (see also Glover, 2010: 492; More et al., 2017: 161; Ramamurthy, 2011). These circumstances gain further significance when the higher production costs, such as higher seed costs, and recently even higher pesticide costs, associated with Bt cotton are considered (Arora and Bansal, 2012: 102; Gaurav and Mishra, 2012: 13; Glover, 2010; Kathage and Qaim, 2012: 2; Kranthi and Stone, 2020; Morse et al., 2007). Gaurav and Mishra (2012: 25) thus assert that the yield advantage promised by Bt seeds should 'be taken with a pinch of salt' as over the years, the rate of increase in net returns was lower than that of increase in inputs. From this finding, they deduce that the technology is not sustainable from a livelihood perspective and they conclude that there has been an 'increase in riskiness' (Gaurav and Mishra, 2012: 23–25) of cotton production since the introduction of Bt cotton technology.

Concerning pesticides, several short-term studies relying on data obtained before 2008 argue that usage and costs have decreased (Qaim, 2003: 2118; see also Subramanian and Qaim, 2010: 295; Tabashnik et al., 2005; Veettil et al., 2016). In field trials, Qaim (2003: 2118) found pesticide reductions of more than 60%. Kathage and Qaim remark that pesticide costs were significantly higher on conventional plots and claim that a 'widespread adoption of Bt has led to area-wide suppression of bollworm populations' (2012: 2), consequently causing conventional farmers to substantially reduce their pesticide applications. In addition to that, Veettil et al. found that there have been reductions in pesticide usage 'across all toxicity classes over time for both Bt and non-Bt cotton' (2016: 118). Later long-term studies, on the contrary, purport that a decrease in pesticide usage can only be assigned to the initial phase of Bt cotton introduction and that by 2010, when Bt technology diffusion was ubiquitous in India, 'total insecticide applications had largely returned to their pre-GM levels' (Flachs, 2017: 2; see also Flachs, 2019a; Kranthi, 2015b; Kranthi and Stone, 2020). Kranthi and Stone (2020: 188) even claim that farmers are 'now spend[ing] more on insecticides than before they adopted *Bt* seed'.

A further factor pushing pesticide use has been the ecological changes in the incidence of sucking pests. Formerly, these were less problematic and regarded as secondary pests (Kathage and Qaim, 2012). However, Bt technology caused a decline in primary pests leaving an ecological niche that sucking pests have now filled. This increase in sucking pests—which are not susceptible to Bt technology—requires farmers to increase their spending on pesticides (Flachs, 2017, 2019a; Gaurav and Mishra, 2012; Kranthi 2014, 2015b; Kranthi and Stone, 2020; Stone and Flachs, 2015: 123).

### *The Return of Pink Bollworm in India's Bt Cotton Fields*

Recently, a critical turning point has occurred in the production of Bt cotton, as the main target pest, the pink bollworm, has returned to several Indian cotton-producing states. The infestation has spread throughout the central and southern zone of cotton production since the *kharif* season of 2015, affecting fields in Gujarat, Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh and Telangana with anticipated yield losses of up to 30% (Fand et al., 2019: 313; Mohan, 2017; Naik et al., 2018). This incident has caused great concern amongst Bt cotton farmers and other stakeholders in the cotton industry and has reignited the debate regarding the technology's longevity. While Bt cotton technology promised built-in protection against pink bollworm and other Lepidopteran pests, it is now claimed to have 'lost the battle' (Fand et al., 2019: 314). In this context, several potential causes for the pest's reoccurrence are debated, of which we address only those that are directly related to farmers' livelihoods systems, namely the circulation of illicit and spurious seeds, and the requirement of growing refuge crops around Bt plants.

A first potential cause for the pest's recurrence is seen in the prevalence of informal seed markets. Since Bt cotton seeds are associated with higher costs compared to conventional cotton seeds (Gaurav and Mishra, 2012; Kathage and Qaim, 2012) and due to a 'stronger formal intellectual property (IP) status' (Herring and Kandlikar, 2009: 57), there are strong incentives for informal markets to emerge. The traded illicit seeds do have detrimental effects on the fight against bollworm, since low-quality seeds often mean low pest protection. This latter aspect is due to varying levels of Bt toxins to be expressed in transgenic cotton plants. In the case of stealth and counterfeit seeds, it cannot be guaranteed 'that the toxin protein be expressed in adequate quantities' (Bakhsh et al., 2012: 115; see also Khan et al., 2018; Singh et al., 2016) for the technology to maintain its functionality over the entire season. Moreover, the issue of illicit seeds affects market transparency and farmers' capacities to make a choice based on reliable information (Flachs, 2019a; Stone, 2007). As farmers tend to use new seeds each season, because they strive for the most popular brand and type, they 'largely disregard [...] what they know about the previous years' seeds' (Flachs, 2019a: 84; see also Stone, 2007; Stone et al., 2014). Hence, farmers rarely re-plant seeds, and are thus limited in their environmental learning within an increasingly untransparent seed market (Flachs, 2019a; Stone, 2007; Stone et al., 2014).

A second potential cause for the pest's recurrence is seen in the non-compliance of farmers with refuge requirements (ISAAA, 2017, 2018; Mohan, 2017, 2018). For planting GE cotton, refugia consisting of non-GE cotton crops are required to surround each field in the ratio of at least 95:5 (GE:non-GE crops) in order to lower the evolutionary pressure of the pest to adapt to the endotoxins produced by the Bt plants (Carrière et al., 2005: 327; Flachs, 2017: 2; Jayan, 2018; Liu et al., 1999; Zhang et al., 2011: 1). While the ISAAA (2017: 29) blames mismanagement of the technology for the 'erosion of resistance to pink bollworm', it argues that the technology's efficacy could have been prolonged if farmers had followed instructions. Others instead hold the technology itself responsible: As Glover (2010: 502) claims, the technology needs to be evaluated in context as it is not just 'in the seed', but has to 'function in particular socio-technical and institutional settings'.

Given the recently reignited controversy about the return of pink bollworm in India's

Bt cotton fields, in this study we raise the following two questions: (a) How did the adoption of the Bt technology generally affect the livelihoods of farming households in Karimnagar district in the recent past? (b) What immediate livelihood vulnerabilities have the erosion of host resistance, and with it the return of pink bollworm pests, caused among farming households in Karimnagar district and how do they cope with this new situation?

## IV. Methodology

In order to answer these questions, we designed this study after the Sustainable Livelihood Approach (SLA) (Carney, 2003; Scoones, 1998). According to Chambers and Conway, 'a livelihood comprises the capabilities, assets (stores, resources, claims, and access) and activities required for a means of living: a livelihood is sustainable which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and which contributes to net benefits to other livelihoods at the local and global levels and in the short and long term' (1992: 6).

The SLA puts the livelihood system of households centre stage and serves to study the underlying capital (assets), members' strategies of accumulation (activities), influencing social, economic and ecological factors (capabilities), and the respective outcomes of livelihood systems (sustainability) in particular contexts (Carney, 2003; Conway et al., 2002; Krantz, 2001; Kollmair and Gamper, 2002; Moser, 2008). The approach not only refers to households' income, but aims at examining how this income is generated, how the livelihood system is maintained, and how a household's entitlements are enhanced (Chambers and Conway, 1992). Livelihood studies thus aim at revealing a household's means and strategies to deal with certain long-term trends, seasonalities and sudden shocks and intend to identify possible adjustments to help reduce their vulnerability. From a livelihood perspective, households try to manage their livelihood security over both the short and over the longer term and as such risk and resilience are central concepts in livelihood analysis (Chambers and Conway, 1992).

In this study, we followed an exploratory and therefore non-representative, qualitative research design with 42 problem-centred interviews, which we conducted in August and September 2018—and thus during the 2018/2019 cotton season—in three selected locales in Karimnagar district in the Indian state of Telangana (see Figure 1). The exploratory approach was chosen as the recurrence of the target pest urged us to change our focus from general agricultural decision-making processes in cotton-producing households to the particular capacities of cotton farmers to cope with the returned pink bollworm.

The Karimnagar district is located north of Hyderabad in the state of Telangana and belongs to the southern zone of cotton production. We chose this district as study region, because it is one of the state's major cotton-producing districts and neighbouring districts have already been the object of earlier Bt cotton-related studies (Kaviraju et al., 2018; Kukanur et al., 2018; Stone, 2011; Stone and Flachs, 2015). These earlier studies provided a basis for comparison and were hence helpful in identifying recent changes of the impacts of Bt cotton technology on farmers' livelihoods.

Our access to the field was facilitated by colleagues from the University of Hyderabad and the Loyola Academy in Secunderabad. We chose the sample villages according to the criterion of most area under cotton and based on our colleagues' local knowledge of the area. By accompanying some of their students, who were completing their practical training, we were able to establish the first access to the field easily (village 1; see Table 1). The local cotton miller informed us about a neighbouring village involved in cotton production and this became our second study village (village 2; see Table 1). The third village (village 3; see Table 1) was again chosen because a large share

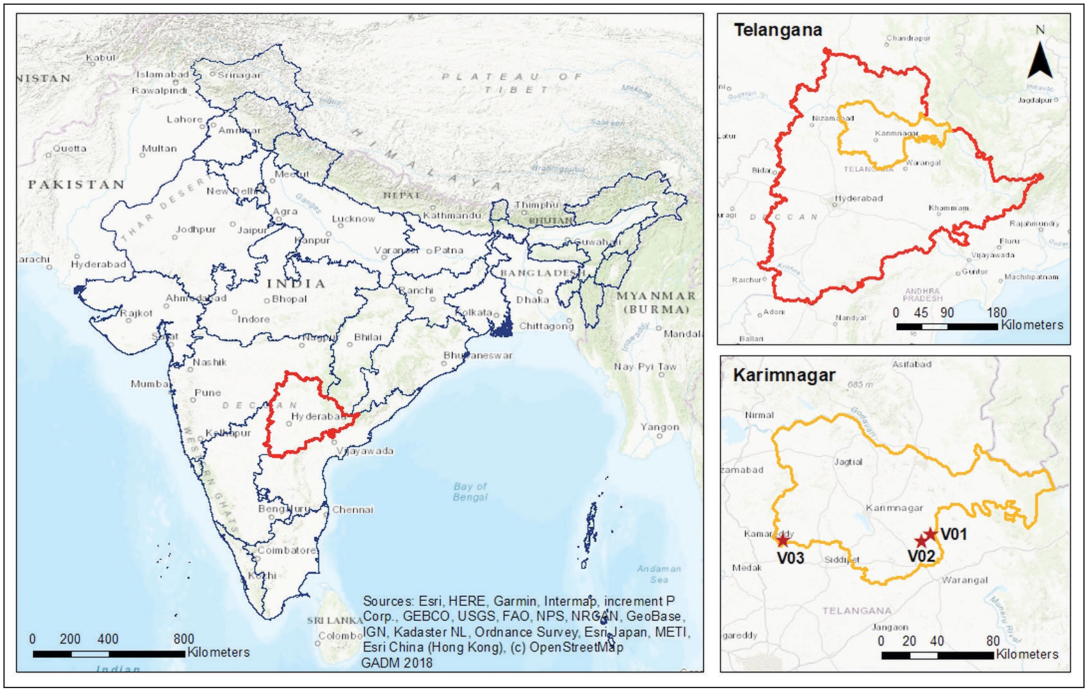


**Figure 1.** Empirical Fieldwork in Karimnagar District in Telangana, India

**Source:** The authors.

**Table 1.** List of Interviews

| No.* | Name | Expertise | Landholding Size | Date |
|---|---|---|---|---|
| V01-I01 | Mari Jagan (m) | Peasant | 11 acres owned: paddy, cotton, chilli | 10.09.18 |
| V01-I02 | Mahendra (m) | Peasant | 7.5 acres owned: paddy, cotton | 11.09.18 |
| V01-I03 | Mamatha (f) | Peasant | 7.5 acres owned: paddy, cotton | 11.09.18 |
| V01-I04 | Karmagala Lakshmi (m) | Peasant | 11 acres owned: paddy, cotton, turmeric | 11.09.18 |
| V01-I05 | Parameshwari (f) | Peasant | 11 acres owned: paddy, cotton, turmeric | 11.09.18 |
| V01-I06 | Mari Jagan (m) | Peasant | 11 acres owned: paddy, cotton, chilli | 11.09.18 |
| V01-I07 | Lavanya (f) | Peasant | 11 acres owned: cotton, maize, turmeric | 11.09.18 |
| T01-I01 | Satish (m) | KVK representative | | 12.09.18 |
| T01-I02 | Mukka (m) | Cotton mill owner | | 12.09.18 |
| V01-I08 | J. Mala (m) | Peasant | No owned land, hired labourers | 12.09.18 |

*(Table 1 continued)*

*(Table 1 continued)*

| No.* | Name | Expertise | Landholding Size | Date |
|---|---|---|---|---|
| V01-I09 | Gujala (f) | Peasant | No owned land, hired labourers | 12.09.18 |
| V01-I10 | Pulajillala (f) | Peasant | No owned land, hired labourers | 12.09.18 |
| T01-I03 | Krishnamurthy Ch. (m) | Inputs shop owner | | 13.09.18 |
| V01-I11 | Jelander (m) | Peasant | 1 acre owned: cotton, paddy | 13.09.18 |
| V01-I12 | Rama (f) | Peasant | 50 guntas owned: cotton, paddy | 13.09.18 |
| T01-I04 | Tirupaddy (m) | Commission agent | | 14.09.18 |
| V02-I01 | P. Ravindar (m) | Peasant | 6.5 acres owned: cotton, paddy, on lease | 17.09.18 |
| V02-I02 | Ram (m) | Peasant | 3 acres owned: cotton, paddy | 18.09.18 |
| V02-I03 | Lakshmi Srinivas (m) | Sarpanch | | 18.09.18 |
| V02-I04 | Mugula (m) | Peasant | 8 acres: 4 acres owned, 4 acres leased: paddy, cotton | 18.09.18 |
| V02-I05 | Thirupati (m) | Peasant | 6 acres owned: cotton, paddy | 18.09.18 |
| V02-I06 | Damodar (m) | Peasant | 1.5 acres owned: cotton | 18.09.18 |
| V02-I07 | Mahindar (m) | Peasant | 4 acres owned: turmeric, chilli, paddy, cotton | 18.09.18 |
| V02-I08 | Tirupati G. (m) | Peasant | 5 acres: 2 acres owned, 3 acres leased: cotton, paddy | 18.09.18 |
| V02-I09 | Parusharam (m) | Model farmer | 10 acres: 5 acres owned, 5 acres leased: cotton, paddy | 19.09.18 |
| V02-I10 | Md. Rahimodhin (m) | Peasant | 4.5 acres: cotton, paddy | 19.09.18 |
| V02-I11 | Kasturi (m) | Peasant | 8 acres: 6 acres owned, 2 acres leased: cotton, paddy | 19.09.18 |
| V02-I12 | N. Venkateshwarlu (m) | Peasant | 24 acres owned: cotton, paddy, on lease | 19.09.18 |
| V02-I13 | Mohamad (m), Jarina (f) | Peasants | 2 acres owned: cotton, paddy | 19.09.18 |
| V02-I14 | Sanjeev (m) | Peasant | 1 acre owned: cotton | 19.09.18 |
| T02-I01 | Vijay Reddy (m) | Inputs shop owner | | 23.09.18 |
| V03-I01 | N. Raju (m) | Peasant | 15 acres: 5 acres owned, 10 acres leased: cotton, maize | 24.09.18 |
| V03-I02 | Kalakonda Narasimha (m) | Peasant | 20 acres owned: cotton, maize, paddy | 24.09.18 |
| V03-I03 | C. H. Narayana (m) | Peasant | 5 acres: 4 acres owned, 1 acre leased: cotton | 24.09.18 |
| V03-I04 | Ramana (m) | Peasant | | 24.09.18 |
| V03-I05 | Karra Srinivas (m) | Peasant | 16 acres: 1 acre owned, 15 acres leased: cotton, maize, paddy | 24.09.18 |
| V03-I06 | Chiluka (m) | Peasant | 8 acres: 6 acres owned, 2 acres leased: cotton, paddy | 24.09.18 |

*(Table 1 continued)*

*(Table 1 continued)*

| No.* | Name | Expertise | Landholding Size | Date |
|---|---|---|---|---|
| V03-I07 | Naran (m) | Peasant | 10.5 acres: 1.5 acres owned, 9 acres leased: cotton, maize | 24.09.18 |
| V03-I08 | Mandhala Linga (m) | Peasant | 18 acres owned: cotton, paddy | 24.09.18 |
| V03-I09 | Raj (m) | Peasant | 9 acres: 6 acres owned, 3 acres leased: cotton, paddy | 25.09.18 |
| V03-I10 | Janardan (m) | Peasant | 6 acres owned: cotton, paddy | 25.09.18 |
| T03-I01 | Tharun (m) | Seed production enterprise | | 26.09.18 |

**Source:** The authors.
**Note:** * 'V' stands for village; 'T' stands for town; and 'I' stands for interview partner.

of its agricultural area was under cotton. Due to its long geographical distance to the first two sample villages, it served as a counterpoise. Here, we established contacts to the peasant community through an inputs shop owner in the nearby district town. Within the three villages, we found interview partners by means of random walks, on which we found volunteering cotton farmers as interview partners. This sampling process allowed for a more diversified group of interviewees in terms of farming characteristics than snowball sampling alone.

Two interpreters, fluent in English, Hindi, and Telugu, assisted us in communicating with the local village councils (*gram panchayat*). With their help, we were able to interview a total sum of 35 peasants (male and female), two owners of shops selling inputs (for fertilizer, pesticides, seeds, and so forth), one owner of a mid-size cotton mill, one coordinator of a local branch of the governmental extension service (*Krishi Vigyan Kendra*, KVK), one commission agent active in cotton trade, one representative of an Indian seed company, and one head of a village council (*sarpanch*) (see Table 1).

The semi-structured interview guide was conceptualized in accordance with the livelihood analysis. Accordingly, in the interviews, emphasis was placed on the assets of the farmer households, that is natural, physical, human, financial, and social capital (Ellis, 2000; Moser, 2008; Scoones, 1998). These assets are modified by the social, economic and ecological factors in which a household is embedded (Ellis, 2000; Moser, 2008; Scoones, 1998). The vulnerability context of livelihoods systems includes trends, seasonalities, and shocks (Ellis, 2000; Scoones, 1998). Livelihood outcomes are mediated by differences in livelihood activities, household assets, the vulnerability context and wider social, economic and ecological factors (Ellis, 2000).

In the following part, we focus on the changes linked to the adoption of Bt technology and on the shock caused by the recurred infestation of pink bollworm pests in the season of 2017/2018 from a livelihood perspective.

## V. Results

*Changes Linked to the Adoption of Bt Seeds*

Most of the farmers we interviewed owned at least some of their cultivated land, while several of them leased large parts. The farm sizes of our respondents varied from one acre to 24 acres and can therefore all be considered as small-scale. The amount of leased land varied between one and 15 acres (see Table 1).

According to our interviewees, all seeds they used for cotton cultivation were Bt II hybrids but varied in brand and type. The most frequently mentioned brands were Rasi

(*659*, *RCH 2*), Mahyco (*Dr Brent*), Bayer (*Surpass First Class*), Nuziveedu (*Bhakti*), and Veda (*Sadanand*) (V01-I02; V01-I04; V02-I01; V02-I04; V02-I11; V03-I02; V03-I09; T02-I01). All farmers claimed to be using more than one variety for reasons of diversification and deficient yield performance (V01-I02; V01-I04; V02-I01; V02-I04; V02-I11; V03-I02; V03-I09; T02-I01).

Illicit seeds were mentioned to be an issue by several interviewees and here, counterfeit seeds, causing negative effects on farmers' yields, were described as more prevalent and problematic than stealth seeds (V01-I04; V02-I08; V02-I12; V02-I13; V02-I14; V03-I01; V03-I04; V03-I10). According to the interviewed farmers, these 'faulty' or 'spurious' seeds started entering the market only with the advent of transgenic seeds (V02-I12; V03-I04) and were not available before. For the farmers, it is impossible to identify them and tell them apart from original seeds as they come in 'fancy packaging and use more or less the same names' (V03-I04; see also V02-I08; V03-I01). In the view of our interviewees, it is the government's responsibility to prevent the entry of faulty seeds into the market (V02-I12; V02-I13; V02-I14; V03-I01; V03-I04).

All interviewed farmers described the trend in yields as a curve which had increased significantly in the first years after Bt cotton adoption, but had recently declined sharply. Our interviewees described the high yields of the early years after adopting the Bt technology as a drastic 'boom' (V02-I07; V02-I08). This initial upturn had improved the economic situation of the vast majority of our respondents, as they had been able to make significant investments. Interviewed farmers claimed that they had been able to construct or renovate their houses or to buy land and machines (such as rickshaws, tractors, and harvesters), which had enabled them to diversify their income sources (V02-I012; V03-I10). Moreover, several of them had used their initial surpluses for covering expenses related to their children's education (V02-I08; V02-I12; V03-I8; V03-I10).

Apart from these positive evaluations, the interviewees also mentioned some drawbacks: Several farmers reported that the yields of non-Bt cotton had been 'not huge, [but] some yield was always ensured' (V02-I06; V02-I12). Altogether, they described them as more constant, whereas those of Bt cotton were termed as more oscillating (V02-I12). One interviewee (V02-I12) claimed that with Bt cotton, 'the yields can be good during one year and not fruitful during the next year' and concluded that Bt cotton was an 'erratic crop'. Similarly, another peasant described Bt cotton as 'very risky' and claimed that cotton farmers, today, will either get a high yield or 'totally lose it' (V02-I06). With non-Bt cotton, in contrast, they had been able to get reliable yields as long as they had worked properly and put enough efforts into it (V02-I12).

Similar to the trend observed in yields, our interviewees described that the quantities of pesticides required had decreased noticeably after the adoption of Bt cotton, but had increased again only a few years later (V02-I07; V02-I08; V02-I12). In terms of pesticides applied, they claimed, quantities required for cultivating Bt cotton are today almost at the same level as the amount needed before for non-Bt cotton. The reason for this, according to the peasants, was a general increase in pest infestation (V02-I07; V02-I08; V02-I12).

According to the interviewed farmers, the most drastic change with the adoption of Bt technology is the alteration of the crop cycle, since crop growth is significantly shorter for Bt cotton than for non-Bt cotton hybrids. While sowing usually takes place in June for Bt as well as non-Bt cotton seeds, the period of harvesting non-Bt cotton had stretched out until January, while harvesting Bt cotton can now be accomplished by November. This shortened growth phase allows farmers to grow a second crop on the same plot, which is mostly maize. The possibility of growing a second crop each year was stated by farmers as being the major benefit of Bt cotton, resulting in additional household income and increased wellbeing (V02-I13; V02-I11; V03-I09).

This privilege is, however, limited to those farmers who are able to provide sufficient amounts of water to the crop (V2-I10; V2-I14). If water supply is insufficient, for example, due to a lack of irrigation systems, the second crop can either not be planted at all or is exposed to new risks. One interviewee described that, after having lost his first crop (Bt cotton) to pink bollworm infestation in the season of 2017/2018, he also lost his second crop (maize) due to a lack of water supply (V2-I13). Hence, instead of balancing his losses, his second crop indebted him even further.

Moreover, some of our interviewees complained that the Bt crop created further negative effects in cropping patterns. The earlier flowering of Bt cotton hybrids exposes them to damage from the rains common during the *kharif* season. One farmer explained that 'the flowering of non-Bt plants started after the rainy season whereas the flowering stage of Bt cotton […] starts during the rainy season' (V02-I07). This is problematic, since 'during the cotton boll's birthing stage, water will drain [now] into the boll and cause it to just fall down' (V02-I12).

In regard to growing so-called refuge or trap crops, all interviewed farmers reported that they did not comply with the instructions given by seed companies for economic reasons (V02-I06; V02-I07; V02-I08; V02-I12). They stated that the non-Bt seeds were of minor quality and the resultant cotton not sellable to the market. In the end, the farmers would experience financial disadvantages, if they planted the non-Bt seeds—a fact that they avoided by planting their entire field with Bt seeds only (V02-I06; V02-I07; V02-I08; V02-I12).

### *Impacts of the Pink Bollworm Pest Infestation in 2017/2018*

The infestation of the pink bollworm pest in Telangana in the season of 2017/2018 has severely impacted cotton farmers' yields with negative effects on peasant livelihoods. The target pest is reported to have returned to central and southern Indian cotton-producing states since the *kharif* season of 2015 (Fand et al., 2019; Mohan, 2017). As our survey, conducted in August and September 2018, captures the ramifications of the 2017/2018 infestation, this is what our analysis focuses on. Although we have no data for subsequent seasons, we can infer that this problem had ramifications for the following seasons in terms of lower and unpredictable cotton yields. All interviewed farmers confirmed these attacks and claimed to have suffered severe financial losses. One farmer's response illustrates the risk associated with this recent collapse in Bt cotton production: He described how he started building his house with the surplus accumulated during the initial years of his adoption of the technology, but then—after the pink bollworm pest had returned—he could not manage to earn enough money to finish the construction (V02-I07). Another respondent, a 70-year-old farmer, claimed that he 'cannot remember a similar shock like this' (V02-I13).

Despite the fact that all interviewed peasants grew Bollgard-II with alleged built-in pest resistance, pink bollworm was claimed to have returned as 'the major problem' of cotton production in all three villages studied (V01-I01; V02-I02; V02-I11; V03-I01; V03-I09). Most of our respondents said that they were taken by surprise by these recurring pest attacks. One farmer explained how a KVK employee informed him of the infestation.

> I could not believe it initially but […] the employee asked me to open one cotton boll and check it. […] So later this day I came to my field and I was very hesitant to open one of the cotton bolls in the beginning, because I thought that if I opened it, it would be wasted. But reluctantly I did and I saw that it was completely infested by pink bollworm. Later I was so desperate that I opened nearly 50 cotton bolls just to make sure that they were not affected, but unfortunately the whole field was infected by pink bollworm (V02-I01).

While secondary pests were mentioned to be problematic in Telangana (V01-I03), most of our interviewees focused on the issue of the recurrence of pink bollworm infestations. This recurrence let some of the peasants assume that pink bollworm had developed a resistance against the Bollgard-II technology. One peasant, for example, argued that 'at first, Bt I (Bollgard-I) lost its resistance to the pest and Bt II (Bollgard-II) is now following' (V02-I14).

In order to cope with this unexpected situation, the vast majority of our respondents had to take loans to buffer this economic shock (V01-I10; V02-I06; V02-I07; V02-I13; V02-I14; V03-I05; V03-I06). For these loans, they preferred the formal bank system. Yet, access was restricted to either land-owning farmers, or to those farmers who could offer another kind of deposit, such as gold or jewellery (V01-I10; V02-I06; V02-I08; V02-I13). Interviewees who did not own enough land had to take loans from informal sources such as money lenders or commission agents (V02-I13; V02-I14; V03-I05; V03-I06). Since these informal sources demanded higher interest rates than formal banks, some farmers were not able to pay off their loans, so that many were still indebted at the time we conducted the interviews (for example V02-I14). One farmer, ironically one who had once won an award for his distinguished agricultural expertise and performance, said that he had needed to borrow money from several moneylenders one after another. In this way, he managed to pay back the interest to one of them, allowing him to delay full repayment (V02-I14). As last resort to cope with the incurred losses, several interviewed farmers explained that they had been forced to sell some of their land (V02-I14; V03-I05; V03-I07; V03-I10).

## VI. Discussion

As our findings show, the implementation of Bt cotton technology has had varying impacts on cotton farmers' livelihoods. While initial uplifts, such as improvements in yield performance, were reported by our interviewees, our findings revealed new vulnerabilities for cotton farmers' livelihoods related to the implementation of Bt cotton and the recent return of pink bollworm to Bt cotton fields.

Our findings confirm the initial socio-economic improvements among Indian cotton-producing households in the early 2000s. Initial increases in yields were experienced by our interviewees as an economic boom (V02-I07; V02-I08), which benefitted farming households with varying landholding sizes and backgrounds alike, and which enabled many of them to make significant investments (V02-I08; V02-I12; V03-I07; V03-I10). These were mostly of a long-term character (building or renovating houses, purchase of machines, investments in children's education) and thus enhanced rural wellbeing. Moreover, they allowed some farmers to pursue diversified strategies of income generation (lending machines, rickshaw services) (V02-I012; V03-I10). As a result, the initial increase of farmers' income and the enhancement of rural households' wellbeing, as reported by some studies (Kathage and Qaim, 2012: 3; Plewis, 2014: 15; Sadashivappa and Qaim, 2009: 172; Yadav et al., 2018: 66), can be substantiated. Yet, while these improvements are attributed by some academics to the Bt technology (Kathage and Qaim, 2012; Qaim, 2003; Smale, 2016; Veettil et al., 2016), our findings cannot provide evidence for or against an isolated effect of the technology.

In contrast, our findings provide clear evidence of a return of pink bollworm in Telangana and confirm that this has caused severe impacts on farmers' livelihoods. As all interviewed farmers reported to have suffered from pink bollworm infestation in the cotton season of 2017/2018, we suggest that Bollgard-II seeds have lost their effectiveness in this particular area. As the Bt technology is claimed to provide protection against this pest, its long-term performance, and with that its impacts on cotton farmers' livelihoods, require a critical re-evaluation.

All farmers reported a severe collapse in yields and therefore an increase in the riskiness of Bt cotton cultivation. This collapse in yields in 2017/2018 forced farmers to pursue strongly responsive livelihood strategies. The most common strategy to buffer the economic shock caused by pink bollworm pests was to take up loans (V01-I10; V02-I06; V02-I07; V02-I13; V02-I14; V03-I05; V03-I06). In this respect, landowning farmers, especially those with larger landholding sizes, were able to cope with the situation more easily, as they benefitted from access to the formal bank system (V01-I06; V02-I02; V02-I04) or had enough savings to cover their losses (V01-I04; V02-I12; V03-I05; V03-I08). Farmers with smaller landholding sizes, in contrast, were facing clear disadvantages, as they were excluded from the formal bank system and thus had to rely on moneylenders (V02-I13; V02-I14; V03-I05; V03-I06). These informal sources generally demand higher interest rates and can lead asset-weak farmers into debt traps: already vulnerable households had to deal with an additional financial risk from the shock of the unexpected pest infestations experienced in the season of 2017/2018. Several interviewed farmers explained that they had to sell some of their land as last resort to cope with the incurred losses and to pay off their debt (V02-I14; V03-I05; V03-I07; V03-I10). The selling of land corrodes the foundations of their agriculture-based livelihoods and needs to be seen by policymakers as clear alarm signal.

According to our interviewees, the collapse in yields is the peak of an increasing unreliability of the cotton crop. The yield performance was described as more 'erratic' or 'oscillating' compared to non-Bt cotton (V02-I06; V02-I12) and is thus creating new vulnerabilities for cotton farmers' livelihoods. This confirms Gaurav and Mishra's (2012) findings of higher production risks associated with Bt cotton cultivation (see also Glover, 2010: 492; More et al., 2017: 161).

The increased unreliability is met by farmers by diversifying their production. While all interviewed farmers diversified their cotton production in terms of the brands and varieties of seeds sown, some even diversified their agricultural production altogether (V01-I02; V02-I12; V02-I14; V03-I05; V03-I06; V03-I10). Some farmers claimed to have already shifted part of their production towards other crops such as turmeric, chilli, maize, or paddy (V03-I04; V03-I05) or were planning to do so if the cotton yield failed again the following season (V02-I05; T02-I01; V03-I06; V03-I08). In regard to the diversification of agricultural production, economically underequipped farmers face severe disadvantages. Firstly, due to smaller landholding sizes, they are unable to dedicate much land to an experimental diversification. As a result, the safety net created through a diversified cultivation is disproportionally smaller than that of farming households with larger landholdings. Secondly, the strategy of crop diversification is limited to those farmers who have sufficient water supplies at their disposal, since most other locally cultivated crops are more water intensive (V01-I02; V01-I11; V02-I12; V02-I14; T02-I01; V03-I10). Access to sufficient water resources is thus a crucial risk-diminishing factor, especially in the mostly rain-fed areas of Telangana. In sum, the risk of yield setbacks due to returned pest infestations is more likely to affect already vulnerable livelihoods more severely.

All interviewed farmers varied their seeds in brand and type and cultivated more than one variety per season. They did so to distribute the risk regarding the performance of each seed type (V01-I02; V01-I04; V02-I01; V02-I04; V02-I11; V03-I02; V03-I09; T02-I01). This diversification of Bt II-hybrids is seen as preventive strategy in response to 'faulty' or 'spurious' seeds in the market, as farmers cannot tell counterfeit and original seeds apart (V01-I04; V02-I08; V02-I12; V02-I13; V02-I14; V03-I01; V03-I04; V03-I10). However, a high degree of switching between seed brands, types or varieties can undermine the process of building up farmer's knowledge about what works best in their environment (Flachs, 2019a, 2019b; see also Stone et al., 2014). Thus, if the Indian government has an interest in building up farmer's knowledge and ability to make discerning seed choices, it needs to get rid of the country's highly opaque and uncontrolled seed market, which evolved with neoliberal reforms in India's agricultural sector preceding GE technology (Flachs, 2019a; Stone, 2007; Stone et al., 2014).

In regard to the altered growth cycle of Bt cotton it needs to be seen that farmers with access to irrigation systems benefitted from the shortened growth period, as they were able to plant a second season of maize in their cotton fields (V02-I07; V02-I11; V02-I12; V02-I13; V03-I09). This group clearly profited from adopting the GE crops. At the same time, however, farmers without sufficient water were either not able to grow a second crop or were exposed to new risks by relying on unruly weather conditions (V2-I10; V2-I13; V2-I14). The benefits associated with the shortened growth duration of Bt cotton are thus limited only to those farmers who are economically better off - even though economically weaker farmers also adopted double cropping. Given India's non-transparent seed markets outlined above, small-scale farmers are more than ever orienting themselves towards the successes of larger landowners and emulate their capitalist rationalities, even if these are associated with an increased personal risk exposure (Keck, 2019: 110).

The last point we want to make is concerned with the required refuge crops for growing Bt cotton. All interviewed farmers reported that they did not comply with the instructions given by the seed companies (V02-I06; V02-I07; V02-I08; V02-I12) despite the fact that this strategy threatens the longevity of the technology and thus stands in direct opposition to farmers' long-term economic goals. And yet, we argue, blaming farmers for mismanaging the technology is at best short-sighted. From their perspective, they follow a capitalist logic, seeking to maximize short-term profits, while refugia imply lower yields and income. It is therefore up to political decision-makers, administrations and the seed companies themselves to take responsibility and provide incentives for farmers to grow refuge crops and help prolong the technology's functionality.

## VII. Conclusion

This study shows that the impacts of the Bt cotton technology on farmers' livelihoods in Karimnagar are diverse and have altered over time. The initial years of Bt cotton adoption were characterized by perceptible increases in yields, noticeable reductions in pesticide use, and improved economic wellbeing. In the season of 2017/2018, however, all interviewed farmers stated that they suffered great yield losses due to pink bollworm infestation—a Lepidopteran pest that Bt technology is claimed to provide protection against. This pest infestation had tremendous negative effects on farmers' livelihoods and the resultant new vulnerabilities disproportionately affected asset-weak households. The failure of Bt technology has therefore put predominantly those farmers with marginal assets at great risk.

Given the return of pink bollworm in Indian cotton fields, we see cause for concern that the built-in pest control in the second generation Bt cotton technology (Bollgard-II) is no longer functional. This represents a threat to the livelihoods of cotton farmers in India. Against this background, we call for the establishment of an independent body to conduct area-wide testing to determine the level and duration of transgene expression in commercialized Bt cotton plants in India. We suggest such a testing is urgently needed to combat the sale of counterfeit seeds, which might be of low quality or do not show any Bt-related traits at all. We furthermore call for an inquiry to examine the levels of resistance of Lepidopteran moths to the endotoxins produced by the GE cotton plants in India. Such an inquiry will provide a more clear-cut picture about the risks for farmers and the longevity of this technology. Last but not least, a representative survey is needed to determine the geographical extent of the return of pink bollworm and the socio-economic costs that it is imposing on farming households in India. Equipped with these numbers, farmers' groups will have the evidence with which to formulate claims for compensation from large seed corporations and to address the government to provide them with support.

## Acknowledgments

The authors are grateful to the anonymous reviewer and the editor for their critical comments which contributed to the manuscript's outcome.

## Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## Funding

The authors disclosed receipt of the following financial support for the research, authorship and/or publication of this article: This work was supported by the German Research Foundation (DFG) (KE1983/3-1).

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## Note

1. In 2010, the GEAC was renamed into Genetic Engineering Appraisal Committee (GEAC). At that time, the GEAC was deprived of the mandate to approve transgenic organisms and downgraded to a national appraisal committee without executive legal functions (Herring, 2015: 159).

## References

**Altenbuchner, C.**, **Vogel, S.** and **Larcher, M.** 2018: Social, economic and environmental impacts of organic cotton production on the livelihood of smallholder farmers in Odisha, India. *Renewable Agriculture and Food Systems* 33(4), 373–85.

**Arora, A.** and **Bansal, S.** 2012: Diffusion of Bt Cotton in India: Impact of seed prices and varietal approval. *Applied Economic Perspectives and Policy* 34(1), 102–18.

**Bakhsh, A.**, **Rao, A.Q.**, **Shahid, A.A.** and **Husnain, T.** 2012: Spatio temporal expression pattern of an Insecticidal Gene (*cry2A*) in Transgenic Cotton Lines. *Notulae Scientia Biologicae* 4(4), 115–19.

**Carney, D.** 2003: *Sustainable livelihoods approaches: Progress and possibilities for change*. Department for International Development.

**Carrière, Y.**, **Ellers-Kirk, C.**, **Kumar, K.**, **Heuberger, S.**, **Whitlow, M.**, **Antilla, L.**, **Dennehy, T.J.** and **Tabashnik, B.** 2005: Long-term evaluation of compliance with refuge requirements for Bt cotton. *Pest Management Science: Formerly Pesticide Science* 61(4), 327–30.

**Chambers, R.** and **Conway, G.** 1992: *Sustainable rural livelihoods: Practical concepts for the 21st century* (Discussion Paper). Institute of Development Studies.

**Choudhary, B.** and **Gaur, K.** 2008: *Trust in the seed*. ISAAA Publication, ISAAA.

**Choudhary, B.** and **Gaur, K.** 2010: *Bt Cotton in India: A country profile*. ISAAA Series of Biotech Crop Profiles. ISAAA.

**Choudhary, B.** and **Gaur, K.** 2015: *Biotech Cotton in India, 2002 to 2014: Adoption, impact, progress & future*. Series of Biotech Crop Profiles. ISAAA.

**Conway, T.**, **Moser, C.**, **Norton, A.** and **Farrington, J.** 2002: Rights and livelihoods approaches: Exploring policy dimensions. *Natural Resource Perspectives* 78, 1–6.

**Ellis, F.** 2000: *Rural livelihoods and diversity in developing countries*. Oxford University Press.

**Fand, B.B.**, **Nagrare, V.S.**, **Gawande, S.P.**, **Nagrale, D.T.**, **Naikwadi, B.V.**, **Deshmukh, V.**, **Gokte-Narkhedkar, N.** and **Waghmare, V.N.** 2019: Widespread infestation of pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechidae) on Bt cotton in Central India: A new threat and concerns for cotton production. *Phytoparasitica* 47, 313–25.

**Flachs, A.** 2017: Transgenic cotton: High hopes and farming reality. *Nature Plants* 3, 1–2.

**Flachs, A.** 2019a: *Cultivating knowledge. Biotechnology, sustainability, and the human cost of cotton capitalism in India*. University of Arizona Press.

**Flachs, A.** 2019b: Planting and performing: Anxiety, aspiration, and 'scripts' in Telangana Cotton Farming. *American Anthropologist* 121(1), 48–61.

**Gaurav, S.** and **Mishra, S.** 2012: To Bt or not to Bt? Risk and uncertainty considerations in technology assessment. In Narayanan, L. and Viswanathan, P., editors, *India's tryst with Bt Cotton: Learning from the first decade*. Indira Gandhi Institute of Development Research, 1–34.

**Glover, D.** 2010: Is Bt Cotton a pro-poor technology? A review and critique of the empirical record. *Journal of Agrarian Change* 10(4), 482–509.

**Gutierrez, A.P.** 2018: Hybrid *Bt* cotton: A stranglehold on subsistence farmers in India. *Current Science* 115(12), 2206–10.

**Gutierrez, A.P.** and **Ponsard, S.** 2005: Physiologically based demographics of Bt cotton–pest interactions: I. Pink bollworm resistance, refuge and risk. *Ecological Modelling* 191(3–4), 346–59.

**Gutierrez, A.P., Ponti, L., Herren, H.R., Baumgärtner, J.** and **Kenmore, P.E.** 2015: Deconstructing Indian cotton: Weather, yields, and suicides. *Environmental Sciences Europe* 27(12), 1–17.

**Hallad, A., Udikeri, S., Patil, S.** and **Bhat, A.** 2014: Field performance of first and second generation Bt cotton events for bollworm resistance in rainfed ecosystem. *International Journal of Current Microbiology and Applied Sciences* 3(2), 223–38.

**Herring, R.J.** and **Kandlikar, M.** 2009: Illicit seeds: Intellectual property and the underground proliferation of agricultural biotechnologies. In Haunss, S. and Shadlen, K., editors, *Politics of intellectual property: Contestation over the ownership, use, and control of knowledge and information*. Edward Elgar Publishing, 56–79.

**Herring, R.J.** 2015: State science, risk and agricultural biotechnology: Bt cotton to Bt Brinjal in India. *Journal of Peasant Studies* 42(1), 159–86.

**International Service for the Acquisition of Agri-Biotech Applications (ISAAA).** 2009: *Biotech crops in India: The Dawn of a New Era, excerpted from The Global Status of Commercialized Biotech/GM Crops: 2008*. ISAAA Brief No. 39. ISAAA South Asia Office.

**International Service for the Acquisition of Agri-Biotech Applications (ISAAA).** 2016: *Global status of commercialized Biotech/GM Crops: 2016*. ISAAA Brief No. 52. ISAAA.

**International Service for the Acquisition of Agri-Biotech Applications (ISAAA).** 2017: *Global status of commercialized Biotech/GM crops in 2017: Biotech crop adoption surges as economic benefits accumulate in 22 years*. ISAAA Brief No. 53. ISAAA.

**International Service for the Acquisition of Agri-Biotech Applications (ISAAA).** 2018: *Pocket K No. 4: GM crops and the environment*. ISAAA.

**Jayan, T.** 2018: Refuge planting needed to slow pest resistance to Bt cotton. *The Hindu*, 7 February, p. 18.

**Kathage, J.** and **Qaim, M.** 2012: Economic impacts and impact dynamics of Bt (*Bacillus thuringiensis*) cotton in India. *Proceedings of the National Academy of Sciences of the United States of America* 109(29), 1–5.

**Kaviraju, S., Kumar, D., Singh, N.** and **Kumar, S.** 2018: A comparative study on socio-economic impact of Bt cotton and Non-Bt cotton farm households in Warangal District of Telangana State. *International Journal of Current Microbiology and Applied Sciences* 7(5), 1561–67.

**Keck, M.** 2019: Worlding countrysides: Das Globale in der Auseinandersetzung um genetisch veränderte Baumwolle in Indien [Worlding countrysides: the "global" in the controversy over genetically engineered cotton in India]. In Mießner, M. and Naumann, M., editors. *Kritische Geographien ländlicher Entwicklung. Globale Transformationen und lokale Herausforderungen*. Münster, 100–15.

**Khan, M.I., Khan, A.A., Cheema, H.M.N.** and **Khan, R.S.A.** 2018: Spatio-temporal and intra-plant expression variability of Insecticidal Gene (*Cry1Ac*) in upland cotton. *International Journal of Agriculture & Biology* 20(4), 715–22.

**Kiresur, V.** and **Ichangi, M.** 2011: Socio-economic impact of Bt Cotton—a case study of Karnataka. *Agricultural Economics Research Review* 24(1), 67–81.

**Kollmair, M.** and **Gamper, S.** 2002: *The sustainable livelihoods approach*. Input Paper for the Integrated Training Course of NCCR North-South.

**Kranthi, K.R.** 2014: Cotton production systems—Need for a change in India. *Cotton Statistics & News* 38, 4–7.

**Kranthi, K.R.** 2015a: Technologies are breaking down—what next? *Cotton Statistics & News* 19, 1–6.

**Kranthi, K.R.** 2015b: Pink bollworm strikes Bt cotton. *Cotton Statistics & News* 35, 1–6.

**Kranthi, K.R.** and **Stone, G.D.** 2020: Long-term impacts of *Bt* cotton in India. *Nature Plants* 6(3), 188–96.

**Krantz, L.** 2001: The sustainable livelihood approach to poverty reduction. Swedish International Development Cooperation Agency. Division for Policy and Socio-Economic Analysis, 1–44.

**Kukanur, V.S., Singh, T.V.K., Kranthi, K.R.** and **Andow, D.A.** 2018: Cry1Ac resistance allele frequency in field populations of *Helicoverpa armigera* (Hübner) collected in Telangana and Andhra Pradesh, India. *Crop Protection* 107, 34–40.

**Kumar, S.** 2015: India eases stance on GM crop trials. States begin to permit field tests of transgenic plants. *Nature* 521(7551), 138–39.

**Kurmanath, K.** 2018: Early onset of pink bollworm in cotton triggers alarm in Telangana. *The Hindu*, 14 September, p. 18.

**Liu, Y., Tabashnik, B., Dennehy, T.J., Patin, A.** and **Bartlett, A.** 1999: Development time and resistance to Bt crops. *Nature* 400, 519.

**Maertens, A.** 2017: Who cares what others think (or Do)? Social learning and social pressures in cotton farming in India. *American Journal of Agricultural Economics* 99(4), 988–1007.

**Mohan, K.S.** 2017: An area-wide approach to pink bollworm management on Bt cotton in India—a dire necessity with community participation. *Current Science* 112(10), 1988–89.

**Mohan, K.S.** 2018: Refuge-in-bag for *Bt* cotton. *Current Science* 114(4), 726–27.

**More, S., Singh, N.** and **Leua, A.** 2017: Performance of cotton in Gujarat: A long term critical analysis. *Journal of Cotton Research and Development* 31(1), 157–63.

**Morse, S., Bennett, R.** and **Ismael, Y.** 2007: Inequality and GM Crops: A case–study of Bt Cotton in India.

*The Journal of Agrobiotechnology Management & Economics* 10(1), 44–50.

**Moser, C.** 2008: Assets and livelihoods: A framework for asset-based social policy. In Moser, C. and Dani, A., editors, *Assets, livelihoods, and social policy*. World Bank, 43–81.

**Münster, D.** 2012: Farmers' suicides and the state in India: Conceptual and ethnographic notes from Wayanad, Kerala. *Contributions to Indian Sociology* 46(1–2), 181–208.

**Naik, G., Qaim, M., Subramanian, A.** and **Zilberman, D.** 2005: Bt Cotton controversy: Some paradoxes explained. *Economic and Political Weekly* 40(15), 1514–17.

**Naik, V.C.B., Kumbhare, S., Kranthi, S., Satijaa, U.** and **Kranthi, K.** 2018: Field-evolved resistance of pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae), to transgenic *Bacillus thuringiensis* (Bt) cotton expressing crystal 1Ac (Cry1Ac) and Cry2Ab in India. *Pest Management Science* 74, 2544–54.

**Plewis, I.** 2014: Indian farmer suicides. Is GM to blame? *Significance* 11(1), 14–18.

**Qaim, M.** 2003: Bt Cotton in India: Field trial results and economic projections. *World Development* 31(12), 2115–27.

**Qaim, M., Subramanian, A., Naik, G.** and **Zilberman, D.** 2006: Adoption of Bt cotton and impact variability: Insights from India. *Review of Agricultural Economics* 28(1), 48–58.

**Ramamurthy, P.** 2000: The cotton commodity chain, women, work and agency in India and Japan: The case of feminist Agro-Food Systems Research. *World Development* 28(3), 551–78.

**Ramamurthy, P.** 2011: Rearticulating caste: The global cottonseed commodity chain and the paradox of smallholder capitalism in South India. *Environment and Planning A* 43(5), 1035–56.

**Sadashivappa, P.** and **Qaim, M.** 2009: Bt Cotton in India: Development of benefits and the role of government seed price interventions. *AgBioForum* 12(2), 172–83.

**Scoones, I.** 1998: *Sustainable rural livelihoods: A framework for analysis*. IDS Working Paper 72.

**Scoones, I.** 2008: Mobilizing against GM Crops in India, South Africa and Brazil. *Journal of Agrarian Change* 8(2–3), 315–44.

**Singh, B.P., Sandhu, S.S., Kalia, V.K., Gujar, G.T.** and **Dhillon, M.K.** 2016: Assessment of Bt trait purity in different generations of transgenic cottons. *Indian Journal of Experimental Biology* 54, 237–44.

**Smale, M.** 2016: GMOs and poverty: The relationship between improved seeds and rural transformations. *Canadian Journal of Development Studies* 38(1), 1–10.

**Stone, G.D.** 2007: Agricultural deskilling and the spread of genetically modified cotton in Warangal. *Current Anthropology* 48(1), 67–103.

**Stone, G.D.** 2011: Field versus farm in Warangal: Bt Cotton, higher yields, and larger questions. *World Development* 39(3), 387–98.

**Stone, G.D.** and **Flachs, A.** 2015: Seeking sustainability for smallholders: Bt cotton in India. In Mitton, P. and Bennett, D., editors, *Analyses: Africa's future … can biosciences contribute?* Cambridge, 119–28.

**Stone, G.D., Flachs, A.** and **Diepenbrock, C.** 2014: Rhythms of the Herd: Long term dynamics in seed choice by Indian Farmers. *Technology in Society* 36(1), 26–38.

**Subramanian, A.** and **Qaim, M.** 2008: Village-wide effects of agricultural biotechnology: The case of Bt Cotton in India. *World Development* 37(1), 1–18.

**Subramanian, A.** and **Qaim, M.** 2010: The impact of Bt cotton on poor households in rural India. *Journal of Development Studies* 46(2), 295–311.

**Tabashnik, B.** and **Carrière, Y.** 2019: Global patterns of resistance to Bt Crops highlighting Pink Bollworm in the United States, China, and India. *Journal of Economic Entomology* 112(6), 2513–23.

**Tabashnik, B.E., Dennehy, T.J.** and **Carrière, Y.** 2005: Delayed resistance to transgenic cotton in pink bollworm. *Proceedings of the National Academy of Sciences of the United States of America* 102(43), 15389–93.

**Veettil, P., Krishna, V.** and **Qaim, M.** 2016: Ecosystem impacts of pesticide reductions through Bt cotton adoption. *Australian Journal of Agricultural and Resource Economics* 61, 115–34.

**Wang, S., Just, D.R.** and **Pinstrup-Andersen, P.** 2008: Bt-Cotton and secondary pests. *International Journal of Biotechnology* 10(2/3), 113–21.

**Yadav, S., Godara, A.K.** and **Yadav, V.** 2018: Impact of Bt Cotton Production Technology in Haryana. *Indian Research Journal of Extension Education* 18(2), 66–71.

**Zhang, H., Yin, W., Zhao, J., Jin, L., Yang, Y., Wu, S., et al.** 2011: Early warning of Cotton Bollworm resistance associated with intensive planting of Bt Cotton in China. *PLoS One* 6(8), 1–8.