Biotechnology, Schismogenesis, and the Demise of Uncertainty

Glenn Davis Stone
Washington University in St. Louis

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> "The whole problem with the world is that fools and fanatics are always so certain of themselves, and wiser people so full of doubts."
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> —Bertrand Russell

Crop genetic engineering is hardly the first scientific issue to attract controversy, but it may be unique in the degree of polarization in the arguments it generates. The issue is routinely characterized as a war,[1] and it is one that shows no sign of truce or surrender. Just why the GMO[2] wars have been so divisive and protracted is an interesting question. Political scientists have argued that such conflicts are won by the side that best broadens the scope of controversy to engage external audiences,[3] and GMO technology and its related institutions touch on a remarkable array of controversies ripe for audience engagement. The list includes gene patenting, food labeling, impacts on ecosystems, human health issues, impacts on farmers in the developing world, world food needs and the causes of famine and suicide, corporate control of seed and food, neoliberalism and

* Glenn Davis Stone is an anthropologist much of whose work focuses on ecological, political, and cultural aspects of food and agriculture. He has conducted extensive field research in Nigeria, India, The Philippines, and the rural United States. He has served as president of the Anthropology & Environment Society and on the faculties of Columbia University and Washington University in Saint Louis, where he is currently Professor of Anthropology and Environmental Studies. His blog on food, farming, and biotechnology is FieldQuestions.com.

1. *See* Emily Waltz, *Battlefield*, 461 NATURE 27, 27 (2009).

2. GMO refers to genetically modified organisms. Of the various categories of genetically modified organisms, crop seeds are by far the most controversial because of their wide use in nature and their importance in food products. *See generally* Glenn Davis Stone, *The Anthropology of Genetically Modified Crops*, 39 ANN. REV. OF ANTHROPOLOGY, 381–400 (2010).

3. E. E. SCHATTSCHNEIDER, THE SEMI-SOVEREIGN PEOPLE: A REALISTS VIEW OF DEMOCRACY IN AMERICA 2–3 (The Dryden Press 1960).

international trade, industry-academy relations and control of research agendas, the politics of agrifood regulation, the politics of scientific debate, and various knotty ethical issues.[4] Much is at stake here, as are fights over the hearts and minds of the public and, indirectly, the actions of policy makers.

Watching these fights over the past fifteen years reminds me of Gregory Bateson's concept of *schismogenesis*, which describes the self-amplifying process of divergence: I take an extreme position in reaction to your extreme position, leading you to take a more extreme position, and so on.[5] The polarization feeds on itself as nuanced differences become disagreement, then disapproval, exasperation, and eventually hatred. For example, GMO promoters accuse GMO skeptics of crimes against humanity,[6] in part because the skeptics make the same claim.[7] Schismogenesis benefits the combatants at either pole in the GMO wars by generating enthusiasm for militant positions, but it can have pernicious effects on the processes of creating, legitimating, and acting upon knowledge. A particularly pernicious effect is the damage done to the essential epistemological condition of *uncertainty*.

Uncertainty is central to science and to policy-making.[8] A defining feature of science is the care and transparency with which scientists chip away at uncertainty, and the strict rules by which we do so. Before we claim a relationship exists between X and Y, we ask how often such a relationship would occur randomly; rather than saying X determines Y, we say X explains a specified percentage of the variability in Y; rather than saying X cures a disease, we say a higher percentage of participants were cured than in the control

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4. *See* Stone, *supra* note 2, at 381–400.

5. GREGORY BATESON, STEPS TO AN ECOLOGY OF MIND: COLLECTED ESSAYS IN ANTHROPOLOGY, PSYCHIATRY, EVOLUTION, AND EPISTEMOLOGY 68–69 (University of Chicago Press 1972).

6. *Preventing it is a Crime against Humanity*, GOLDEN RICE NOW, http://www.allowgoldenricenow.org/the-crime-against-humanity (last visited Nov. 1, 2014).

7. Elizabeth Lane, *Charge Monsanto with Crimes Against Humanity*, CHANGE.ORG, https://www.change.org/p/chief-zeid-ra-ad-al-hussein-charge-monsanto-with-crimes-against-humanity (last visited Nov. 1, 2014).

8. *See, e.g.*, Christof Tannert et al., *The Ethics of Uncertainty*, 8 EMBO REPORTS 892 (2007); Carl A. Rubino, *The Politics of Certainty: Conceptions of Science in an Age of Uncertainty*, 6 SCI & ENGINEERING ETHICS 499 (2000); Holger Hoffmann-Reim & Brian Wynne, *In Risk Assessment, One Has to Admit Ignorance*, 416 NATURE 123 (2002).

group. As scientists, we are supposed to be professional experts in dealing with uncertainty, even in highly contentious issues. In 2013, Princeton geoscientist Michael Oppenheimer appeared on PBS NewsHour to discuss an alarming new report on climate change. Climate change is a hotly contested issue, yet Oppenheimer carefully explained that the report found it to be "extremely likely that most of the warming in the past sixty years is due to human activity, and that's very unusual for scientists with a complex problem like this to state something with such a high level of certainty."[9]

In contrast, the GMO wars have created a rapacious demand for certainty, a demand that many interlocutors have eagerly filled. Thanks to the schismogenesis in the GMO wars, readers of scientific and popular media are bombarded with assertions and endorsements of certainty on topics where there is actually much uncertainty, often coming from scientists whose job is to be professionals at dealing with uncertainty. The old saying has it that the first casualty of war is truth; it seems that the casualty of this particular war has been scientific uncertainty.

GMO skeptics have generated plenty of questionable certainty claims. One can find claims that GM corn is highly toxic,[10] that Bt cotton[11] causes thousands of farmer suicides,[12] that increased glyphosate use has contaminated "our food, environment and water,"[13] and that transgene introgression into landraces of corn

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9. *Climate Scientists Warn Opportunity to Prevent Dangerous Warming is Dwindling*, PBS NEWSHOUR (Sept. 27 2013) http://www.pbs.org/newshour/bb/climate-change-july-dec13-climate2.

10. *Study reveals GMO corn to be highly toxic*, RT (Apr. 17, 2013), http://rt.com/usa/toxic-study-gmo-corn-900/.

11. Bt seeds are genetically modified to contain one or more genes from the bacterium *Bacillus thuringiensis*; these express proteins that are fatal to some caterpillars that are major crop pests. Along with herbicide resistance, Bt traits account for over 95 percent of all acres planted to GM seeds worldwide. CLIVE JAMES, ISAAA BRIEF NO. 46, GLOBAL STATUS OF COMMERCIALIZED BIOTECH/GM CROPS: 2013 (International Service for the Acquisition of Agri-Biotech Applications) (2013).

12. Andrew Malone, *The GM genocide: Thousands of Indian farmers are committing suicide after using genetically modified crops*, DAILY MAIL (Nov. 2, 2008), http://www.dailymail.co.uk/news/article-1082559/The-GM-genocide-Thousands-Indian-farmers-committing-suicide-using-genetically-modified-crops.html.

13. ISIS, *Why Glyphosate Should Be Banned*, INST. OF SCI. IN SOC'Y (Oct. 10 2012), http://www.i-sis.org.uk/Why_Glyphosate_Should_be_Banned.php. Resistance to the herbicide glyphosate (©Roundup) is the most common trait in GM crops, and glyphosate use is known to

would "create far-reaching negative impacts."[14] But equally spurious claims come from biotech supporters, including scientists who are supposed to be held to higher standards for determining certainty. Such statements include claims that the world population will exceed 9 billion by 2050;[15] that we will certainly starve without GM crops;[16] that GM crops are not only safer than conventional ones,[17] but simply "not dangerous"[18] or even "risk-free";[19] that Golden Rice will save

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have risen sharply with the spread of these crops. However, the effects on environment and public health are poorly known. *See* Charles M. Benbrook, *Impacts of Genetically Engineered Crops on Pesticide use in the U.S.—The First Sixteen Years*, 24 ENVIRONMENTAL SCIENCES EUROPE (2012).

14. Greenpeace, *Maize Under Threat: GE Maize Contamination in Mexico* (2003), http://www.greenpeace.org/international/PageFiles/24249/maizeunderthreat.pdf. Introgression refers to movement of genes from one population into another. Transgene introgression in Mexican landrace maize is a legitimate cause for concern, but its impacts are very poorly known. *See* A. Piñeyro-Nelson et al., *Transgenes in Mexican maize: Molecular Evidence and Methodological Considerations for GMO Detection in Landrace Populations*, 18 MOLECULAR ECOLOGY (2009); Daniela Soleri et al., *Transgenic Crops and Crop Varietal Diversity: The Case of Maize in Mexico*, 56 BIOSCIENCE (2006).

15. Malcolm Elliot, *People will starve to death because of anti-GM zealotry*, The Telegraph (May 23, 2012), http://bit.ly/1CwRTAV. The claim, used to create a sense of urgency to undercut critiques of GM crops, is clearly at odds with the uncertainty expressed by demographers. *See also* Sergei Scherbov et al., *The Uncertain Timing of Reaching 8 Billion, Peak World Population, and Other Demographic Milestones*, 37 POPULATION AND DEVELOPMENT REV. (2011).

16. Martina McGloughlin, *Without Biotechnology, We'll Starve*, L.A. TIMES (Nov. 1, 1999), http://articles.latimes.com/1999/nov/01/local/me-28638; Malcolm Elliot, *People will starve to death because of anti-GM zealotry*, THE TELEGRAPH (May 23, 2012), http://bit.ly/1CwRTAV. While it is possible that the future could hold famines caused by agricultural underproduction, as theorized by Malthus, this has not been the case throughout history; AMARTYA SEN, POVERTY AND FAMINES: AN ESSAY ON ENTITLEMENT AND DEPRIVATION (Clarendon. 1981). Even the Irish "potato famine" that was cited as proof of Malthusian imbalance between agriculture and population occurred during times of rising food exports from Ireland; ERIC B. ROSS, THE MALTHUS FACTOR: POPULATION, POVERTY, AND POLITICS IN CAPITALIST DEVELOPMENT 47 (Zed Books. 1998). It is not even certain that GM crops will offer any increase in food production over what can be achieved by conventional breeding, let alone enough to avert famine. *See* Natasha Gilbert, *Cross-bred crops get fit faster: Genetic engineering lags behind conventional breeding in efforts to create drought-resistant maize*, 513 Nature (2014) regarding the developing world agriculture and Major M. Goodman & Martin L. Carson, *Reality vs. Myth: Corn breeding, exotics, and genetic engineering*, 55 ANNUAL CORN SORGHUM RESEARCH CONFERENCE PROC. (2000).

17. Henry I. Miller et al., *Is Biotechnology a Victim of Anti-Science Bias in Scientific Journals?*, 26 TRENDS IN BIOTECHNOLOGY 122, 122 (2008).

18. Nina V. Fedoroff, *Engineering Food for All*, N.Y. TIMES, Aug. 18, 2011, at A23, *available at* http://www.nytimes.com/2011/08/19/opinion/genetically-engineered-food-for-all.html.

19. *Biotech Coalition is 10 Years Old*, BUSINESS MIRROR, May 20, 2012, *available at*

thousands of lives;[20] that transgene introgression in landraces is "inconsequential";[21] that growing organic food will cause hunger;[22] and that GM crops can avert agricultural catastrophes.[23] Certainty is even claimed about random processes, like transformation events: "When we put a gene in a plant, we know exactly where it goes, we know what it does and we actually can measure on a whole genome basis if it affects any other gene," explains one molecular biologist.[24]

The certainty in such claims by scientists is almost as dubious as the doubt conjured by industry puppets paid to make ostensibly scientific cases against global warming and for cigarettes.[25] The profusion of such claims cannot be understood as a matter of science alone, but of *civic epistemology*. Civic epistemology refers to

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http://bcp.org.ph/activities/biotech-coalition-is-10-years-old/. However, each plant transformation through genetic modification is unique, with possible novel affects on how genes function in the plant and how the plant functions in an ecosystem. Neither regulatory regimes nor academic reward structures are particularly well aligned with exposing risk; see Glenn Davis Stone, *Biosecurity in the Age of Genetic Engineering*, *in* BIOINESUCRITY AND HUMAN VULNERABILITY (Nancy Chen & Lesley Sharp eds., 2014).

20. Adrian Dubock, *No, Zac Goldsmith, golden rice is not 'evil GM'. It saves people's lives*, THE GUARDIAN (Nov. 4 2013), http://bit.ly/192VOYq. Golden Rice is genetically modified to produce a vitamin A precursor in the grain in hopes of mitigating one of the many nutritional deficiencies afflicting very poor children. But according to the International Rice Research Institute, which is overseeing the breeding and testing of the crop, it is uncertain how much more breeding the rice will require to be sufficiently productive, and moreover "it has not yet been determined whether daily consumption of Golden Rice does improve the vitamin A status of people who are vitamin A deficient." *See* IRRI, *Clarifying recent news about Golden Rice* (2013), http://irri.org/blogs/item/clarifying-recent-news-about-golden-rice.

21. Miller et al., *Is Biotechnology a Victim of Anti-Science Bias*, *supra* note 17.

22. Claudia Dreifus, *An Advocate for Science Diplomacy: A Conversation with Nina V. Fedoroff*, N.Y. TIMES, Aug. 18, 2008, at F2, *available at* http://www.nytimes.com/2008/08/19/science/19conv.html.

23. Pamela Ronald, *The Truth About GMOs*, BOSTON REV. (Sept. 6, 2013), http://www.bostonreview.net/forum/pamela-ronald-gmo-food.

24. David Newland, *Sorry Hipsters, That Organic Kale Is a Genetically Modified Food*, SMITHSONIAN (Sept. 10, 2014), http://www.smithsonianmag.com/ist/?next=/science/sorry-hipsters-organic-kale-genetically-modified-food-180952656/ (quoting Robert Goldberg). In reality, the insertion of genes through genetic modification is a largely random and poorly understood process, as virtually all academic sources agree; see for instance Yoel Shiboleth & Tzvi Tzfira, *Agrobacterium-mediated plant genetic transformation*, *in* PLANT BIOTECHNOLOGY AND AGRICULTURE: PROSPECTS FOR THE 21ST CENTURY 102 (Arie Altman & Paul Michael Hasegawa eds., 2012).

25. NAOMI ORESKES & ERIK CONWAY, MERCHANTS OF DOUBT: HOW A HANDFUL OF SCIENTISTS OBSCURED THE TRUTH ON ISSUES FROM TOBACCO SMOKE TO GLOBAL WARMING (Bloomsbury, 2010).

"institutionalized practices by which members of a given society test . . . knowledge claims used as a basis for making collective choices,"[26] or public knowledge-ways.[27] Given the intense interest in GM crops, and the high stakes for producing knowledge about their impacts, it is not surprising that distinctive civic-epistemological mechanisms have arisen to manage knowledge production. For example, Ronald Herring describes a "reciprocal NGO authentication system" whereby "ex-colonial powers and their press authenticate global narratives for local networks, [and] local reports legitimated by indigeneity provide confirmation for global narratives."[28] This system propagates and authenticates claims critical of GM crops. Certainty is constructed by apparent empirical legitimacy; in that reports are presented from where the GM crops are being planted, and by repetition in widely read forums.[29]

On the other side of the coin is what I have described as the "industry-journal" authentication system.[30] In this dynamic, the biotech industry provides support to researchers (including data, intellectual property access, financial support, and publicity), who improve their chances of high-impact publications by taking short cuts to produce conclusive findings, and are then peer-reviewed by other researchers who take the same short cuts.[31] This system trades in the imprimatur of peer-reviewed publication, but it tends to promote certainty claims over equivocal findings, which are less attractive to journals. It also tends to inflate the advantages of GM crops because all parties in the system benefit by authors taking shortcuts, allowing dubious certainty to be published and valorized. When researchers are not competing for space in peer-reviewed journals, they may be freer to acknowledge uncertainty. For instance,

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26. SHEILA JASANOFF, DESIGNS ON NATURE: SCIENCE AND DEMOCRACY IN EUROPE AND THE UNITED STATES 255 (2005)

27. Clark A. Miller, *Civic Epistemologies: Constituting Knowledge and Order in Political Communities*, 2 SOC. COMPASS 1896, 1897 (2008).

28. Ronald J. Herring, *Persistent Narratives: Why is the "Failure of Bt Cotton in India" Story Still with Us?*, 12 AGBIOFORUM 14, 19 (2009).

29. *Id.*

30. Glenn D. Stone, *Constructing Facts: Bt Cotton Narratives in India*, 47 ECON. & POL. WKLY. 62, 67–69 (2012) [hereinafter Stone, *Constructing Facts*]; Glenn D. Stone, *Response to Herring and Rao*, 48 ECON. & POL. WKLY. 70, 70–72 (2013).

31. Stone, *Constructing Facts*, *supra* note 30.

economists Smale and Zambrano summarized the impact of Bt cotton in developing countries as "inconclusive,"[32] and anthropologist Tripp[33] stressed the great variability in results of Bt cotton in India and China.

Dubious claims of certainty by scientists represent an insidious threat to public understanding because they undermine the credibility and integrity of science. A cornerstone of science is to be held to a high standard of epistemology. Moreover, academic scientists are subsidized by society to be honest brokers and conduct publicly funded research, and are endowed with special protections, like tenure, to allow intellectual honesty.

To take a hard look at uncertainty we will turn to a case study. The problem of unsupportable certainty claims is well illustrated by the case study of the closely watched spread of Bt cotton in India.[34] Attention turned to food and farming in the developing world after the cold reception of GM products in Europe in the mid/late 1990s.[35] India was of particular interest as the world's largest cotton planter, and because it was a country suffering from severe problems with the very pests that Bt seeds were designed to combat.[36] My coworkers and I have studied farming in India's cotton belt since before Bt cotton was approved. We have primarily focused on a diachronic multi-village study of culture and agriculture in Warangal District of Andhra Pradesh state.[37] Observing the changing dynamics of

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32. Melinda Smale et. al., *Bales and Balance: A Review of the Methods Used to Assess Economic Impact of Bt Cotton on Farmers in Developing Economies*, 9 AGBIOFORUM 195, 195 (2006).

33. ROBERT TRIPP, *Transgenic Cotton: Assessing Economic Performance in the Field*, *in* BIOTECHNOLOGY AND AGRICULTURAL DEVELOPMENT: TRANSGENIC COTTON, RURAL INSTITUTIONS AND RESOURCE-POOR RARMERS 72, 73 (Robert Tripp ed., 2009).

34. ROBERT TRIPP, BIOTECHNOLOGY AND AGRICULTURAL DEVELOPMENT: TRANSGENIC COTTON, RURAL INSTITUTIONS AND RESOURCE-POOR FARMERS (Routledge 2009); Melinda Smale, *Rough Terrain for Research: Studying Early Adopters of Biotech Crops* 15 AGBIOFORUM (2012); Bhagirath Choudhary & Kadambini Gaur, *Adoption and Impact of Bt Cotton in India, 2002 to 2010* (ISAAA. 2011).

35. Glenn D. Stone, *Both Sides Now: Fallacies in the Genetic-Modification Wars, Implications for Developing Countries, and Anthropological Perspectives*, 43 CURRENT ANTHROPOLOGY 611, 612 (2002).

36. K. R. Kranthi et al., *Insecticide Resistance in Five Major Insect Pests of Cotton in India*, 21 CROP PROTECTION (2002).

37. Since 2000, my students and I have completed a total of 120 person-weeks of ethnographic field research in India, funded by the National Science Foundation (Grant No.

agriculture over the past fourteen years has left me with deep respect for how much we do not know, indeed for how many of the most pressing questions in global debates on this case will never be possible to answer with certainty.

BT COTTON IN INDIA

After Bt cotton's release in India in 2002, an initially slow adoption quickly accelerated into rapid acceptance. In our research area, adoption took hold in 2005, while across India the period of rapid adoption was between 2006 and 2008.[38] By 2008, the adoption rate reached 81 percent nationally, and I was unable to find any non-transgenic seed in Warangal District.

How this adoption of Bt technology impacted cotton farmers is a key question in the global GMO debates. Within a year of the new seeds' release, there was "a huge explosion of studies, each vying for press attention and demonstrating different 'results.'"[39] These "results" have been contradictory. From the reciprocal-NGO authentication system there have been assured claims that Bt cotton has been an agronomic failure, elevated to the level of certainty by repetition.[40] However this claim is only supported by a small number of questionable surveys showing lower average yields from Bt seeds

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0314404), the Wenner-Gren Foundation for Anthropological Research, and the John Templeton Foundation. Warangal District is in the part of Andhra Pradesh that split off to form Telangana State in Spring 2014. The following observations about Indian agriculture derive, in part, from this ethnographic research.

38. Glenn D. Stone, *Agricultural Deskilling and the Spread of Genetically Modified Cotton in Warangal*, 48 CURRENT ANTHROPOLOGY 67, 68 (2007) [hereinafter Stone, *Agricultural Deskilling*].

39. IAN SCOONES, REGULATORY MANOEUVERS: THE *BT* COTTON CONTROVERSY IN INDIA 9 (2003).

40. *See, e.g.*, K. P. Prabhakaran Nair, *Failure of Monsanto Bt Cotton,* New INDIAN EXPRESS (Dec. 6, 2013), http://www.newindianexpress.com/columns/Failure-of-Monsanto-Bt-Cotton/2013/12/06/article1930013.ece; Vandana Shiva, *The Seeds Of Suicide: How Monsanto Destroys Farming*, CENTRE FOR RES. ON GLOBALIZATION (Apr. 5, 2013), http://www.global research.ca/the-seeds-of-suicide-how-monsanto-destroys-farming/5329947; Najma Sadeque, *After a disastrous track record in 40 countries, Bt cotton is 'welcomed' in Pakistan*, FINANCIAL POST (May 12, 2008), http://www.fbae.org/2009/FBAE/website/false-propaganda_after-a%20 disastrous.html.

over short periods of time.[41] Accounts of agronomic disaster are often dramatized by the plight of the luckless Bt planter who plunged into debt after the crop failed.[42] However, such anecdotes mean little without comparison to cases of conventional cotton—in other words, unless there is a legitimate *counterfactual*.

A larger number of studies emanating from the industry-journal authentication system claim to have isolated major yield advantages and economic benefits from Bt seeds.[43] I have argued elsewhere that these studies are agreeable to agricultural technology developers and professionally rewarding for the researchers and journals, but that they often have their own problems with counterfactuals. In India, conventional and Bt seeds were grown at the same time for only a few years, and comparisons generally do not adequately control for confounds such as selection bias and cultivation bias.[44] Nevertheless, there is no shortage of certainty claims that the technology is a "remarkable success"[45] and apparent certainty that, between 2002 and 2007, Bt cotton "generated economic benefits of US$3.2 billion, halved insecticide requirements, contributed to the doubling of yield

41. *See, e.g.*, Abdul Qayum & Kiran Sakkhari, *Did Bt Cotton Fail AP Again in 2003–2004? A Season Long Study of Bt Cottin in Andhra Pradesh*, Deccan Development Society and Permaculture Association of India. (2004); Suman Sahai & Shakeelur Rahman, *Performance of Bt Cotton: Data from First Commercial Crop*, 38 ECONOMIC AND POLITICAL WEEKLY (2003).

42. Mae-Wan Ho, *Farmer Suicides and Bt Cotton Nightmare Unfolding in India*, INST. OF SCIENCE IN SOCIETY (2010), *available at* http://www.i-sis.org.uk/farmersSuicidesBtCottonIndia.php; Deccan Development Society (2003): *"Why Are Warangal Farmers Angry with Bt Cotton?"* (Hyderabad: Community Media Trust), http://bit.ly/1CA710t.

43. *See, e.g.*, Arjunan Subramanian & Matin Qaim, *Village-wide Effects of Agricultural Biotechnology: The Case of Bt Cotton in India*, 37 WORLD DEVELOPMENT (2009); Matin Qaim, et al., *Adoption of Bt Cotton and Impact Variability: Insights from India*, 28 REV. OF AGRICULTURAL ECONOMICS (2006); Arjunan Subramanian & Matin Qaim, *The Impact of Bt Cotton on Poor Households in Rural India*, 46 J. OF DEVELOPMENT STUDIES (2010).

44. Stone, *Constructing Facts*, *supra* note 30, at 65–67; Glenn D. Stone, *Field versus Farm in Warangal: Bt Cotton, Higher Yields, and Larger Questions*, 39 WORLD DEV. 387, 387 (2011) [hereinafter Stone, *Field versus Farm*]. Confronted with criticism of the selection bias problem, some writers cite an experiment in which farmers grew pre-release Bt seeds alongside conventional seeds. *See, e.g.*, Chandrasekhara Rao, *Bt Cotton Yields and Performance: Data and Methodological Issues* 48 ECON. & POL. WKLY., 66, 66 (2013) [hereinafter *Cotton Yields and Performance*]. However, data in this case was from the seed company itself, and it showed a highly suspicious 80 percent yield advantage. Matin Qaim & David Zilberman, *Yield Effects of Genetically Modified Crops in Developing Countries.* 299 SCI. 900, 900 (2003).

45. *See, e.g.*, BHAGIRATH CHOUDHARY & KADAMBINI GAUR, BT COTTON IN INDIA: A COUNTRY PROFILE, ISAAA SERIES OF BIOTECH CROP PROFILES 1 (2010).

and transformed India from a cotton importer to a major exporter."[46] Such benefits have been pronounced "sustainable."[47] By 2008, according to one Bt cotton enthusiast, India had "an empirical consensus about Bt cotton: the technology works as predicted, with predictable results, increasingly well-understood by farmers, and incorporated into their risk-avoidance strategies."[48]

Over-zealousness in claiming to have isolated technology impacts in agriculture has a deep history,[49] but it has blossomed with GMO schismogenesis. Diametrically opposing claims on impacts of Bt cotton often occur in the same articles, as when Agriculture Minister and GMO enthusiast Sharad Pawar attributed India's yield rises entirely to Bt cotton, while a Greenpeace representative cited scientific evidence of adverse impacts.[50]

Such claims of certainty are dubious because Bt seeds appeared in a highly fraught and rapidly changing cotton sector. Hybrid seeds spread rapidly in the 1990s, marketed by rapidly proliferating and lightly regulated private seed companies, leading to a flood of seed brands.[51] The seeds lacked resistance to Asian pests,[52] so they spread along with insecticides. Many farmers soon found themselves not only on a pesticide treadmill,[53] but on a debt treadmill. Various parties agree that the treadmills are a serious problem, but disagree sharply on how to explain them. While GM seed producers like Monsanto regard bollworms as the real problem, and economists

46. CLIVE JAMES, ISAAA BRIEF NO. 39, THE GLOBAL STATUS OF COMMERCIALIZED BIOTECH/GM CROPS: 2008 43 (2008).

47. Vijesh V. Krishna & Matin Qaim, *Bt Cotton and Sustainability of Pesticide Reductions in India*, 107 AGRICULTURAL SYS. 47, 47 (2012).

48. Herring, *supra* note 28, at 14.

49. Stone, *Constructing Facts*, *supra* note 30, at 67.

50. *Use of Bt. Cotton Increased Yield, Farmers' Income: Pawar*, THE HINDU (Aug. 29, 2013), http://bit.ly/1EydAOA.

51. Milind Murugkar, Bharat Ramaswami & Mahesh Shelar, Competition and Monopoly in the Indian Cotton Seed Market, 42 ECON. & POL. WKLY. 3781, 3782 (2007); N. Lalitha et al., India's experience with Bt Cotton: Case studies from Gujarat and Maharashtra, in BIOTECHNOLOGY AND AGRICULTURAL DEVELOPMENT: TRANSGENIC COTTON, RURAL INSTITUTIONS, AND RESOURCE-POOR FARMERS 135, 139 (Rob Tripp ed., 2009).

52. Venkatesh N. Kulkarni et al., *The Worldwide Gene Pools of Gossypium arboreum L. and G. herbaceum L., and Their Improvement*, 3 PLANT GENETICS & GENOMICS: CROPS & MODELS 69, 90–93 (2009).

53. The pesticide treadmill refers to farmers constantly seeking new pesticides as insect pests develop resistance to pesticides in use.

regard input costs and low yields as the real problem, my research indicates that these maladies are better seen as symptoms of a larger systemic problem: farmers are investing increasingly heavily in a form of cultivation for which they lack reliable locally-adapted management skill.[54] In my analysis of Warangal District, the farmers suffered from agricultural deskilling,[55] which is the result of the inconsistent effects of unrecognizable and rapidly changing technologies. These maladies predated Bt seeds,[56] but Bt seeds spread through an already fraught and evolving situation, and the pattern of spread generally offered no convincing counterfactual cases. This larger context of cotton cultivation makes it exceedingly difficult to isolate the impacts of Bt seed, however strong the demand has been for writers to claim to have done so. This can be illustrated by closer look at the patterns in Warangal and Andhra Pradesh, and then nationwide.

WARANGAL DISTRICT, ANDHRA PRADESH

As noted, Bt seed adoption lagged in our sample villages until 2005, but then spread rapidly over the next few years.[57] Discussions with farmers revealed a general sense of improvement in yields and insect management after Bt adoption. Panel comparison of four villages before and after the virtually complete adoption of Bt seed showed a mean yield rise of 18 percent.[58] Yet little can be inferred from this figure before confronting the counterfactual problem: we do not know how much yields would have risen absent Bt seed. In fact we have good reason to expect they would have risen significantly.

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54. Altieri makes a similar point about agro-ecological diseases as symptoms of systemic failure. Miguel A. Altieri, *Ecological impacts of industrial agriculture and the possibilities for truly sustainable farming*, in *Hungry for Profit: The Agribusiness Threat to Farmers, Food, and the Environment*, 50 MONTHLY REV. 60, 61 (1998).

55. For a more detailed discussion, see Stone, *Agricultural Deskilling*, *supra* note 38, at 84.

56. This is one of several facts of the Bt cotton case garbled by Shiva. Vandana Shiva, *Seeds of Suicide and Slavery Versus Seeds of Life and Freedom*, AL JAZEERA (Mar. 30, 2013), http://www.aljazeera.com/indepth/opinion/2013/201332813553729250.html.

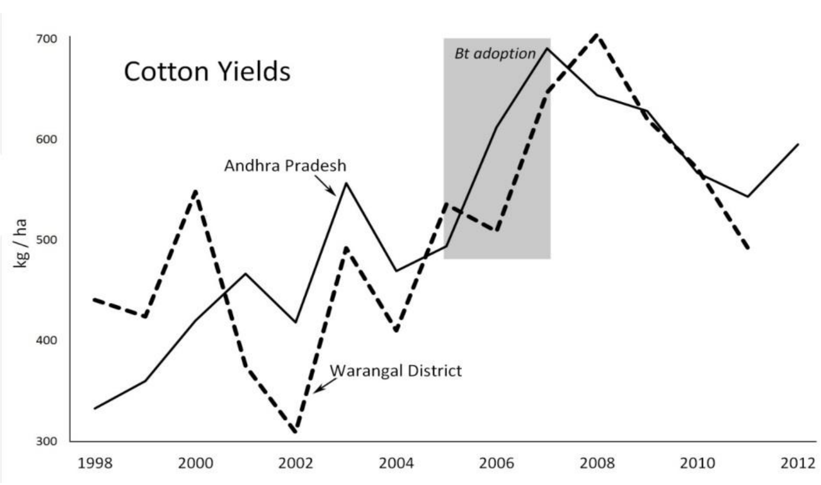
57. Stone, *Agricultural Deskilling*, *supra* note 38, at 67–68; Stone, *Field versus Farm*, *supra* note 44, at 392.

58. Stone, *Field versus Farm*, *supra* note 44, at 387–92.

Figure 1 shows trends in cotton yields for Andhra Pradesh state and Warangal District. The shaded box indicates the adoption period in our study villages. In 2003, a strong surge in cotton yields was observed both statewide and districtwide, but it is difficult to credit Bt seeds for the surge because almost no farmers were planting Bt seeds at that point. In my own random sample of 144 farming households in four villages, Bt seeds accounted for only 2.1 percent of cotton purchases by 2003. Yields had robust upward momentum without Bt seed adoption.

Statewide yields increased from 333 kg/ha in 1998 to 469 kg/ha in 2004, an average rise of just under 6 percent per year. In Warangal district, yields climbed from a low of 309 kg/ha in 2002 to 410 kg/ha in 2004, or a 15 percent increase per year. Not only are Bt adoption figures inconsistent with these yield rises, but yields also seriously slumped after the 2005 to 2007 surge in adoption. In fact, within four years of complete adoption of Bt seeds, yields in Warangal District had lost almost all of the gains enjoyed before Bt adoption. It is impossible to know what yields would have been without Bt seeds, but it is certain that state and district yield rises cannot be credited to Bt seeds under available data.

FIGURE 1



Source: State data are from the CAB (Cotton Advisory Board); district data are from the Indian Directorate of Economics and Statistics.

Even if scientists could unambiguously isolate the yield effect of Bt seeds, we would remain uncertain of the *net* effect of a technology that, like other agricultural technologies before it, impacts society beyond just yields, sprays, and partial budgets. There have been few studies of the broader social impacts of Bt seeds.[59] My own findings point especially to the issue of indigenous knowledge. The low-yields and high-losses were not so much a root problem as they were are a symptom of farmers not knowing how to wield the available technologies dependably. Effective and dependable technology use was prevented by unrecognizable, rapidly changing seed and spray technologies that did not lend themselves to trialing.[60] Bt seeds may have initially been beneficial, as new pesticides often are for farmers on a pesticide treadmill, but they exacerbated these underlying problems by bringing increasingly opaque technologies changing at an even faster pace. In 2002 there was one Bt technology being sold, but by 2013 six Bt technologies were approved for use and over 1200 Bt cotton hybrids were on the market.[61] While it is certain that Bt technologies have made some positive agronomic contribution, it is likely that they have exacerbated the underlying problems of unrecognizability and rapid change.[62]

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59. A.R. VASAVI, SHADOW SPACE: SUICIDES AND THE PREDICAMENT OF RURAL INDIA (Three Essays Collective. 2012); Esha Shah, *What Makes Crop Biotechnology Find its Roots? The Technological Culture of Bt Cotton in Gujarat, India*, 20 THE EUR. J. DEV. RES. 432, 434 (2008).

60. Stone, *Agricultural Deskilling*, *supra* note 38, at 73; Stone, *Field versus Farm*, *supra* note 44, at 394; Glenn Davis Stone, *Biotechnology and the Political Ecology of Information in India*, 63 HUM. ORG. 127, 131 (2004).

61. CLIVE JAMES, ISAAA BRIEF NO. 46, GLOBAL STATUS OF COMMERCIALIZED BIOTECH/GM CROPS: 2013 (International Service for the Acquisition of Agri-Biotech Applications) (2013); Bhagirath Choudhary & Kadambini Gaur, *Bt Cotton Events & Hybrids in India, 2002 TO 2010* (International Service for the Acquisition of Agri-Biotech Applications. 2011).

62. Stone, *Field versus Farm*, *supra* note 44, at 387. Several studies of farmer decision-making show extreme herd behavior in cotton cultivation that is inconsistent with trialing and evaluation. This pattern does not appear in rice farming, where technologies are less opaque and slower to change. *See* Glenn Davis Stone et al., *Rhythms of the herd: Long term dynamics in seed choice by Indian farmers*, 36 TECH. IN SOC'Y (2014); Glenn Davis Stone, *Agricultural Deskilling and the Spread of Genetically Modified Cotton in Warangal*, 48 CURRENT ANTHROPOLOGY (2007).

There is at least some certainty that Indian cotton farmers are on just as much of a treadmill as they were twenty years ago. The Business Standard recently reported that "Bt cotton [is] losing steam, productivity at 5-yr low," citing "lack of innovation."[63] The most salient question for these farmers in the global spotlight carries the most uncertainty: are they really better off on a genetic treadmill than they were on the pesticide treadmill?

NATIONWIDE TRENDS

There is no shortage of certainty claims attributing upward nationwide trends to Bt cotton, but similar problems in isolating impacts from ongoing background changes arise. Herring and Rao's[64] assertion is representative: "It took only five years for lint production per hectare to double . . . after the introduction of Bt technology in cotton in 2002–03 . . . . [I]t seems certain that the new cotton is largely responsible for increased productivity."[65]

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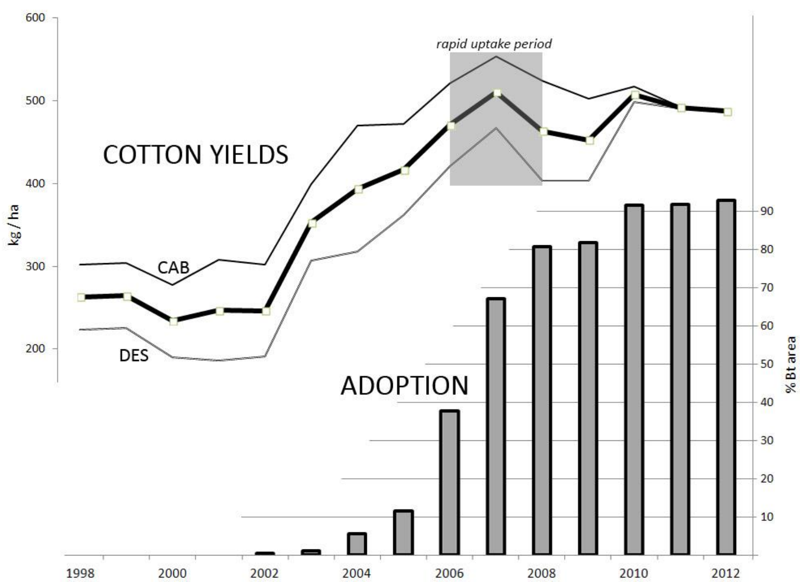
63. Dilip Kumar Jha, *Bt cotton losing steam, productivity at 5-yr low: Falls prey to lack of innovation and pest attacks due to volatile climatic conditions*, BUS. STANDARD (Feb. 7, 2013), http://www.business-standard.com/article/markets/bt-cotton-losing-steam-productivity-at-5-yr-low-113020601016_1.html.

64. Ronald J. Herring & N. Chandrasekhara Rao, *On the 'Failure of Bt Cotton': Analysing a Decade of Experience*, 47 ECON. & POL. WKLY. 45, 50 (2012) [hereinafter *On the 'Failure of Bt Cotton'*].

65. For other examples see P. Ramasundaram, et al., *Welfare Gains from Application of First Generation Biotechnology in Indian Agriculture: The Case of Bt Cotton*, 27 AGRICULTURAL ECONOMICS RESEARCH REV. 74–75 (2014); Camille Gonsalves, *The success of Bt cotton in India*, SCIENCE AND DEVELOPMENT NETWORK (2007).

FIGURE 2



Nationwide trends in cotton yields and Bt adoption. Data on Bt adoption are from the International Service for the Acquisition of Agri-biotech Applications (ISAAA). Data on yields are provided by the Indian Dept. of Economics and Statistics (DES) and the Cotton Advisory Board (CAB). Each dataset has strengths and weaknesses; some researchers prefer the CAB data[66] and some the DES data.[67] The chart provides both as well as a line showing the average.

This national-level claim, however, is poorly supported by a simple comparison of cotton yields and Bt adoption. Similar to the statewide and districtwide data above, the great majority of nationwide yield gains occurred prior to Bt adoption. Figure 2 shows nationwide yields rose from 247 to 488 kg/ha, or 98 percent, from Bt cotton's release in 2002 to 2012. However, 61 percent of this rise occurred in 2003 and 2004 when Bt seeds accounted for 1.2 percent and 5.6 percent of all cotton area. Moreover, during the rapid uptake period between 2006 and 2008, when adoption rates shot up to 81 percent, yields did not climb dramatically; indeed, both datasets show a slight uptick followed by a downtick.

66. *See, e.g.*, Lalitha et al., *supra* note 51, at 146.
67. *See, e.g.*, Rao, *Cotton Yields and Performance*, *supra* note 44, at 66.

The point is not that Bt cotton has made no positive contribution to national yields, of which Shiva seems certain.[68] Instead, we must recognize that Bt cotton cannot account for the entire yield rise, and we cannot know how much credit it deserves. We cannot be certain of the factors behind the yield rise but, as director of the Central Institute for Cotton Research KR Kranthi wrote, "it is probable that the new pesticides, new hybrids, new micro-irrigation systems, new areas, and Bt-cotton together may have been effectively contributing to the enhanced rate of production and productivity."[69]

Confronted with this challenge to the narrative of certain success of Bt seeds, some claim that Bt adoption really did jump between 2002 and 2004, and that the adoption of illegal Bt seeds caused the boost in yields.[70] It is true that illegal Bt seeds had been common in one small part of the cotton belt. The Gujarat company Navbharat Seeds introduced a hybrid seed called 151 around 1999, before any transgenic cotton had been approved for sale. The hybrid sold and performed well—well enough to arouse the suspicion of the Mahyco/Monsanto partnership that was pushing their own Bt seeds to be approved for sale.[71] When Mahyco scientists tested 151 and found that it illegally contained the Bt trait in 2001, the results led to "corporate fury," legal proceedings, and the banishment of 151 seeds from the market before the 2002 season.[72] Some 151 offspring surely remained in the hands of Guajarati farmers, as there had been a cottage industry of home breeding;[73] some small companies also

68. Vandana Shiva, *Seed Monopolies, GMOs and Farmer Suicides in India—A response to Nature*, NAVDANYA'S DIARY (Nov. 12, 2013), http://www.navdanya.org/blog/.

69. K.R. Kranthi, *Part II: 10 Years of Bt in India*, COTTON INTERNATIONAL (May 1, 2011), http://www.cottongrower.com/uncategorized/part-ii-10-years-of-bt-in-india/.

70. Ronald J. Herring, *Reconstructing Facts in Bt Cotton: Why Scepticism Fails*, 48 ECON. & POL. WKLY. 63, 64–65 (2013).

71. Ronald J Herring, *Reconstructing Facts in Bt Cotton: Why Scepticism Fails*, 48 Economic and Political Weekly (2013). Virtually all Bt cotton seeds on the market are hybrid seeds.

72. Ronald J. Herring, *Stealth Seeds: Bioproperty, Biosafety, Biopolitics*, 43 J. DEV. STUD. 130, 132–34 (2007); Glenn Davis Stone, *The Birth and Death of Traditional Knowledge: Paradoxical Effects of Biotechnology in India*, *in* BIODIVERSITY AND THE LAW: INTELLECTUAL PROPERTY, BIOTECHNOLOGY AND TRADITIONAL KNOWLEDGE 207, 226 (Charles R. McManis ed., 2007) [hereinafter Stone, *Birth and Death*].

73. Stone, *Birth and Death*, *supra* note 72, at 227.

produced 151 knock-offs.[74] But the dominant source of illegal Bt seeds were store-bought 151 seeds that would have peaked in 2001; 2002 was the first year 151 was off the market, and the surge in nationwide yields began in 2003. Therefore, the theory that 151 plantings explained the rise in national yields is at best highly uncertain, and at worst a dubious notion patently at odds with the history of cotton seed use.[75]

Lastly, we need to look critically at the claims that adoption of Bt cotton caused sharp drops in pesticide use in India. Figures for the decrease attributed to Bt seeds vary widely, with examples including 20 percent,[76] 30 to 37 percent,[77] 50 percent,[78] 52 percent,[79] and even 83 percent.[80] My own panel study documented a 55 percent drop in pesticide use from the pre-Bt to post-Bt years in four Warangal District villages.[81]

74. Stone, *Birth and Death*, *supra* note 72.

75. Some writers have claimed that illegal 151 seeds were still being planted on a large scale, but one looks in vain for supporting evidence. Shah bases a high estimate of the production of illegal Bt seeds after 2002 on a pamphlet from a farmers group and "personal interview with staff and owners of seed companies." Esha Shah, *Local and Global Elites Join Hands: Development and Diffusion of Bt Cotton Technology in Gujarat*, 40 ECON. & POL. WKLY. 4629, 4631 n.5 (2005). Others offer acreage figures "based on estimates offered by seed industry representatives, industry publications, and newspaper accounts," none of which are dependable sources of information on illegal seed plantings. Bharat Ramaswami et al., *The Spread of Illegal Transgenic Cotton Varieties in India: Biosafety Regulation, Monopoly, and Enforcement*, 40 WORLD DEV. 177, 178 (2012).

76. CHOUDHARY & GAUR, *supra* note 45, at 9.

77. Guillaume Gruère & Debdatta Sengupta, *Bt Cotton and Farmer Suicides in India: An Evidence-based Assessment*, J. DEV. STUD. 316, 323–24 (2010); Ramaswami et al., *supra* note 75.

78. Shahzad Kouser & Matin Qaim, *Impact of Bt Cotton on Pesticide Poisoning in Smallholder Agriculture: A Panel Data Analysis*, 70 ECOLOGICAL ECON. 2105, 2111–12 (2011).

79. Krishna & Qaim, *supra* note 47, at 52–54.

80. C.D. MAYEE & BHAGIRATH CHOUDHARY, ADOPTION AND UPTAKE PATHWAYS OF BT COTTON IN INDIA 5 (2013).

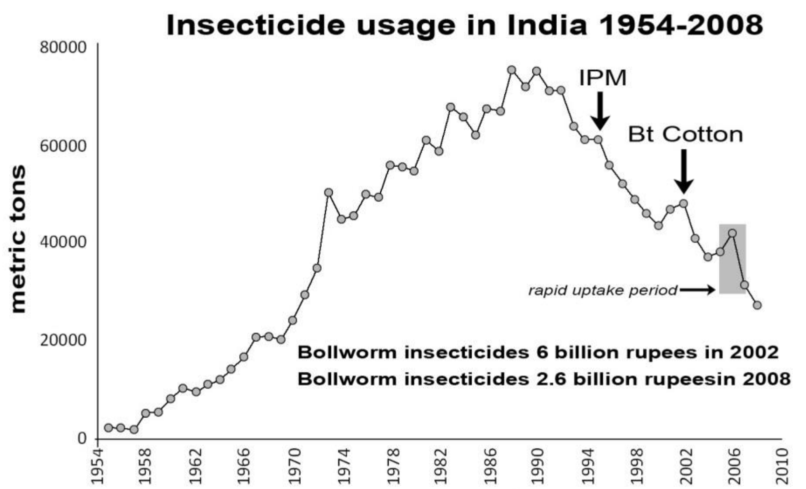
81. Stone, *Field versus Farm*, *supra* note 44, at 391.

There is little doubt that Bt cotton has contributed to decreased pesticide use in several areas of the world.[82] But when we try to isolate the technology's effect, India again shows us how difficult it is to solve the counterfactual problem: the measures of pesticide reductions are not only highly variable, they occurred in a country where pesticide use had been steeply declining for years before Bt cotton was adopted. Nationwide trends for pesticide usage, as displayed on Monsanto's own website,[83] show a sharp drop-off beginning in the early 1990s, a dip upwards between 2005 and 2006 when adoption began to surge, and a subsequent decline back to the fifteen-year-old trend.

82. In Arizona, for example we may even say with some certainty that its use is largely responsible for not only drops in pesticide use but the near-eradication of pink bollworm. Peng Wan et al., *The Halo Effect: Suppression of Pink Bollworm on Non-Bt Cotton by Bt Cotton in China*, 7 PLOS ONE 1, 1–4 (2012) (discussing the effects of Bt seeds on pesticide use in China and Arizona).

83. Monsanto, *India Cotton Success: Partner in Progress: Celebrating the 10th Anniversary of Bollgard Cotton in India* (2012), *available at* http://www.monsanto.com/improvingagriculture/pages/celebrating-bollgard-cotton-india.aspx.

FIGURE 3



Source: Monsanto 2012. This is a reproduction of Monsanto's chart, including the text regarding insecticide expenditures, except for the box indicating the rapid uptake period.

In sum, we may be fairly certain that Bt seeds contributed some to drops in insecticide use, but we can only guess how far insecticide use levels may have dropped absent Bt seeds.

POLITICS OF CERTAINTY

In *Merchants of Doubt*, Naomi Oreskes and Erik Conway recount how a small circle of industry-linked scientists manipulated scientific uncertainty, primarily to combat regulation, during the late twentieth century.[84] Some of the most militant proponents of GM crops believe a like process has been unfolding in the GMO wars, complaining that "bad science is used to justify bad public policies," leading to GM crops being "horrendously, unscientifically . . . over[ ]regulated."[85] In reality, the opposite is true in most key respects. Biotech researchers

84. NAOMI ORESKES & ERIK CONWAY, MERCHANTS OF DOUBT: HOW A HANDFUL OF SCIENTISTS OBSCURED THE TRUTH ON ISSUES FROM TOBACCO SMOKE TO GLOBAL WARMING (Bloomsbury, 2010).
85. Waltz, *supra* note 1, at 30.

themselves are closely linked to, and often funded by, industry, and many scientific publications lauding GM crops are authored by industry employees[86] or based on industry data.[87] A more important difference, however, is reflected in the basic argument in this Article: rather than one side attempting to gin up doubt in the face of scientific certainty, both sides are creating more certainty than the science warrants, as illustrated in the case of Bt cotton in India. I noted above that among the most crucial aspirational qualities of science is the care with which it chips away at uncertainty. It is therefore ironic that the militant scientists described in Waltz's examination of the agri-biotechnology "battlefield" see their work as a "campaign to make academic scientists a little less politically naive and a bit more careful in their scientific work."[88]

But the more carefully one looks at the scientific claims behind the supposed consensus on the "remarkable success" of Bt cotton in India, the more careless the claims appear to be. It is not careful to publish industry data from a contrived one-year test showing a 80 percent yield advantage for Bt seeds, nor to claim those results are indicative of "genetically modified crops in developing countries."[89] It is not careful to entirely credit Bt seeds with upturns in average yields that occurred well before their adoption. It is not careful to entirely attribute downturns in pesticide use to Bt seeds when a major downturn began well before they were even released. And finally, it is not careful to proclaim an opaque, rapidly changing technology is an unmitigated success given its tole in exacerbating systemic problems in farmer decision-making.

These are all questions on which much uncertainty remains. No one wants to admit as much, especially since this is such a key case in the spread of GM crops; it is not only the country with greatest adoption of GM crops by smallholders, but it now has a thirteen-year track record and an extensive body of empirical research on the new

86. *See, e.g.*, R.B. Barwale et al., *Prospects for Bt Cotton Technology in India*, 7 AGBIOFORUM 23 (2004) (receiving funding from the Maharashtra Hybrid Seed Company, India).

87. *See, e.g.*, Qaim & Zilberman, *supra* note 44 (using data from Maharashtra Hybrid Seed Company, India).

88. Waltz, *supra* note 1, at 30.

89. Qaim & Zilberman, *supra* note 44, at 900.

seeds. No one wants uncertainty in this case, and the civic epistemologies at play allow us to avoid it, as distinctive multi-actor mechanisms serve to propagate and authenticate certainty of both success and failure.

But however frustrating it may be—to researchers, activists, and the interested public alike—Bt cotton in India is a case filled with uncertainty, unsettledness, and ignorance of what would have been.