The Factish in the Field: An Anthropological Inquiry of Genetically Modified Seeds and Yields as Beings

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Abstract

Research in GM crops is of pressing importance to biotechnologists, development economists, farmers, government officials, and concerned citizens. Each of these stakeholders carries preconceived notions of success and failure that not only influence how data regarding GM crops is shared but also reify the objective reality of GM seeds as a technology that might exist outside the idiosyncrasies of a farmer's field. In this essay, I draw on ethnographic fieldwork conducted among GM cotton planting farmers in Telangana, India to deconstruct the process by which scientific facts surrounding yields and GM seeds are created, leveraged, and then divorced from their subjective contexts in agricultural research. Calling attention to the methods and assumptions involved in constructing scientific facts, Science and Technology Studies (STS) reveals underlying complexities that explain why purportedly objective science, and the seed as its supposedly universal product, produce such ambiguous outcomes for Indian farmers. Specifically, Isabelle Stengers' and Bruno Latour's notion of the factish, the process by which autonomous facts are created and live beyond their experimental and laboratory confines, can help to explore the neocolonial dynamics underlying the construction of success and failure in GM crops.

Keywords: agriculture, biotechnology, anthropology, factish, India

Introduction

"Don't you understand," my research assistant asked after a particularly long and difficult interview. "We're taking a lot of their time, don't you see? If we were not here, they would not be answering any questions and giving any of this information for your study! They're only giving this information because you're asking." I conducted 14 months of ethnographic fieldwork 2012-2016 among farmers in Telangana, India, planting genetically modified (GM) Bt[1] cotton. Through this anthropological inquiry, I sought to understand how farmers made decisions about the seeds they planted. Although I set out to administer surveys and interviews that asked farmers to justify seed choices and report their yields, these data do not exist independently of the specific farmers, conditions of the field, and the space of the interview. Frequently black-boxed in academic literature, yields and seed choices cannot be understood apart from the farmers who grow them, the fields in which they grow, or the scientific processes used to discover this knowledge.

My assistant's question speaks to a deeper concern with the institution of social science.

A social science researcher's questions and respondent answers exist within the occasionally awkward space of the qualitative interview. Aided by a research assistant, I ask questions relating to seed choices, yields, and farmer experiences with agricultural technologies. Such interviews range from twenty minutes to two hours, depending on our shared patience and the meandering route of our conversation. Sitting in plastic lawn chairs drinking sweetened tea we are separated not only by race, class, education, language, culture, and history, but also the assumptions of research that demand that farmers have answers to questions about their decision-making. In practice, farmers often do not remember the names of their seeds, cannot clearly describe their crop yields, and do not express their motivations in clear, linear ways. While frustrating, this breakdown of knowledge and miscommunication between American agricultural companies and Indian farmers is a crucial part of my research in the experience of new seed technologies. My research assistant is correct to observe that my investigations and subsequent database of seeds and yields is determined by the constructed space of the interview. There, farmers, research assistants, anthropologists, and seeds co-create a narrative appropriate for academic research, but that does not exist as a truth external to any of us.

In February 2013 crop scientists observed that GM cotton yields hit a five-year low in India, leading media and activists to declare GM crops a failure (Jha, 2013; Nair, 2013). Six months later, national newspapers cited scientific studies to claim that the same cotton increased yield, increased incomes, and helped to develop the nation (The Economic Times, 2013a; The Hindu, 2013). In this essay, I argue that there is no truth to seeds or the yields they provide that exists apart from the specific people who cultivate GM crops and the farms where they grow. By calling attention to the methods and assumptions involved in constructing scientific facts, Science and Technology Studies (STS) is uniquely positioned to explore the underlying complexities that explain why purportedly objective science, and the seed as its supposedly universal product, produce such ambiguous outcomes for Indian farmers. Specifically, Isabelle Stengers' and Bruno Latour's notion of the *factish*, the process by which autonomous facts are created and live beyond their experimental and laboratory confines (Latour, 2010b; Stengers, 2010, 2011), can help to explore the neocolonial dynamics underlying the construction of success and failure in GM crops.

This paper begins by looking to the actors and processes involved in constructing scientific narratives about agricultural development. Then, I adapt the factish as a heuristic to understand how yield became the yardstick by which agricultural development should be measured and how seeds take on a life of their own in development studies, independent even of the farmers who grow them. This leads me to discuss the politics of measurement, but I stay with the factish as a conceptual framework because it draws attention to the ways that scientific facts, here seeds and yields, come to have independent lives in agricultural scholarship and policy. GM seed debates are currently framed around yields, and understanding how arguments in favor of or critical of the spread of GM crops in the developing world rely on this discourse without questioning its underlying assumptions helps untangle plural lived experiences with this new technology. I draw on debates relating to GM crops in India, including reflections on my own ethnographic fieldwork 2012-2016 and my reading of key authors from agricultural economics, anthropology, public policy, agronomy, and crop sciences. In paying closer attention to the ways that the science of agricultural development has circumscribed the possibilities of farmer experience, this paper addresses Latour's (2010a) call for a compositionist investigation of a shared world slowly assembled by its constituent actors. Because I am analyzing this research within the scope of STS, I will critically examine the methods and assumptions of several researchers and disciplines. However, I myself have employed the same tools and used the same factishes to make arguments about Indian agriculture. In this essay I intend not to criticize these methods or scientists but to illuminate the ways in which we all have described seeds and yields as autonomous beings.

Debates and contested scholarship in GM research in India

All scientific research is contextualized within the paradigms that guide researchers' questions and research design, as well as within subtler biases inherent to the tools used in different disciplines. This is a function of the larger sociology of science that determines which questions are asked, by whom, and how scientists judge the evidence they collect. In agricultural development research, this issue is complicated by the pervasive influence of pro-GM and anti-GM voices that conduct scientific research as members of industry research groups or activist Non-Governmental Organizations (NGOs), respectively.

In India, GM crops have been alternately celebrated as a pro-poor technology raising incomes and yields while decreasing pesticide sprays (Herring, 2007; Kathage and Qaim, 2012; Veettil et al., 2016), or derided as a dangerous incursion into Indian agriculture failing small farmers (Nair, 2013; Shiva et al., 2002). The direct causal relationships between Bt cotton, cotton yields, and farmer well-being remain difficult to parse away from pro- or anti-industry sentiment (Stone, 2002). In India, these relationships are measured by proxy benchmarks for success, such as farmer enthusiasm or the nation's total cotton production. Over 95% of Indian farmers have adopted Bt cotton since its official 2002 release (Cotton Corporation of India Ltd., 2014), a figure that agricultural scientists (Herring and Rao, 2012; Kathage and Qaim, 2012) and government officials creating policy (Cotton Corporation of India Ltd., 2014; The Hindu, 2013) cite as proof that farmers have eagerly chosen Bt cotton. The language of choice posits that farmers make choices in a rational and free market, where they objectively evaluate seeds as yield-producing commodities.

On Telangana farms, free and informed choice is often difficult to achieve. Although economists and policymakers celebrate GM seed adoption as a choice in a free market, locally desired seeds are often unavailable and villages are plagued by periodic shortages of popular brands (Wadke, 2012) or spurious seeds (Herring, 2007). Yet the framing of seeds as a matter of freedom and choice (The Economic Times, 2013b) helps these pro-GM voices explain away other research with more ambiguous results regarding farmer inputs. Longer-term studies on the effects of Bt cotton in India challenge the influence of Bt cotton on higher yields and lower pesticide sprays (Gruère and Sengupta, 2011; Stone, 2013), attributing these to changes in agricultural management strategies like new pesticides, fertilizers, and denser planting (Gruère and Sun, 2012; Stone, 2011). Additionally, while pesticide applications initially fell with the introduction of Bt cotton on Indian farms, a key benefit of Bt cotton (Veettil et al., 2016), insecticide sprays in Indian cotton now exceed pre-GM levels (Kranthi, 2014).

Examining pro- and anti-GM research as texts, Pearson (2006) argues "that there are striking similarities in the narratives utilized by both Monsanto *and* [anti-GM NGO] Deccan Development Society; both seek to deploy 'objective science' in their efforts to govern smallholder farmers, and both purport to represent transparently the views of farmers and their best interests" (Pearson, 2006: 307), emphasis in original). Both GM companies and critical NGOs continue to release studies claiming that Bt or non-Bt cotton, respectively, is more profitable, socially sustainable, productive, or ecological for farmers. Agribusiness companies have an obvious interest in showing that their products are successful, defined through Monsanto India's (2012) and the Cotton Corporation of India's (2014) annual reports that celebrate Indian farmers' aggressive adoption of GM cotton. However, environmentalist groups also benefit from upticks in funding when stakeholders rally behind anti-GMO sentiment (Schmid, 2007; Schurman and Munro, 2010). Schurman and Munro (2010) further argue that pro- and anti-GM activists and institutions inhabit fundamentally different 'lifeworlds', the norms that define values and ideas while structuring interactions, guiding their differing interpretation of the same evidence.

Whether supportive, critical, or agnostic, this body of research focuses on seeds and yields as indicators of success and failure. While not contesting the underlying claim that seeds' yields can be measured independently of the conditions under which they are grown, critics (Crost et al., 2007; Gruère and Sun, 2012; Stone, 2011) attack empirical studies of Indian GM crops as relying on flawed farmer samples. These critiques charge that others irresponsibly generalize from the field trials of seeds planted by the wealthiest, most adventurous, and highest yielding farmers. Empirical trials of GM crops suffer from a selection bias in the farmer sample as a whole, they argue, and are therefore a poor indicator of the broader impacts of GM crops. Social scientists have noted that the earliest adopters of any technology are likely to have more resources and to be more cosmopolitan than others in the community (Rogers, 2003; Ryan and Gross, 1943), because the institutional support given to such early adopters can help to underwrite the costs of using new technology (Stone, 2016). Critical researchers agree that yields can and should be measured, but they disagree on whose yields are most representative.

Agricultural economist Matin Qaim (2012), who has published numerous papers in top journals on the effects of Bt cotton in India, aimed to refute this sampling critique through a 2012 paper that used stratified stratified economic models. These document farmer experiences across a representative swath of socioeconomic variation, countering farmer selection bias 2002-2008. Yet this was too little too late, argued anthropologist Glenn Stone (2012), who observed that success narratives had already been established by initial selection biases and short-term research designs (Stone and Flachs, 2014). Stone argued that these early results allowed pro-GM findings, already exciting and thus attractive to academic journals, to flow through publication pipelines as the studies cited each other and established a circular credibility. Questioning the incentives of academic publishing and the sampling strategies of agricultural economists, Stone (2013) cites his own ethnographic research as proof of his commitment to discovering facts on the ground – a criticism not of the process of scientific inquiry but an argument for better models that account for the complexity of agricultural work.

Stone's appeal to an objective empirical science fueled a 2012-13 debate through the widely read Indian intellectual weekly journal, Economic and Political Weekly (Herring, 2013; Herring and Rao, 2012). While conceding that some early studies may have been biased, Stone's agricultural economist interlocutors argued that each new study continued to build a scientific consensus that Bt cotton itself was responsible for increased crop yields in India. Agricultural economist Ronald Herring (2013: 63) responded wryly that the presumption that such research stems from collusion between GM manufacturers and scientists is a strong claim, "even by the standards of conspiracy theories". Citing Latour's (2003) *Promises of Constructivism* as an example of postmodernism at its most destructive to objective science, Herring asks if critics like Stone would consider facts to be socially constructed fiction (Herring, 2013: 63). Ironically, Latour laments in that essay that constructivism has been misused to present a false equivalency between scientific arguments and personal opinions. This misses his arguments about constructivism, which questions not facts themselves so much as the way that scientists tend to remove themselves from their findings. Latour argues instead that scientific facts are made real through the process of scientific inquiry, not discovered in a state of nature by objective scientists.

Obligations and Responsibilities in Agricultural Development

The authors and institutions above may disagree on the interpretation or collection of yield and farmer livelihood data, but each situates their claims within a scientific process that discovers objective data. Their argumentation presupposes a truth, Bt cotton yields, that waits to be discovered. This is opposed to a Latourian (2010a) compositionist approach that would see scientific facts as mutually composed by different stakeholders and inextricable from that context. The focus on yield and productivity, even by critics challenging the success of GM crops in India (Forster et al., 2013; Gruère and Sun, 2012; Jha, 2013), masks the contingencies of agriculture and the construction of a scientific space in which to measure yields. In effect, both scholarship critical of and in support of GM crops as a form of agricultural development in India employ the same types of abstract reductions when describing yields and seeds. This presents an opportunity for an STS analysis of the underlying assumption in this research: that seeds and yields exist apart from farms, farmers, seed shops, GM regulations, weather, agricultural researchers, and the multitude of other stakeholders involved in rural life.

That a seed cannot have a yield unless it is grown and measured may seem obvious to STS scholars, but it is curiously absent from the dominant discussions by agronomists, policymakers, economists, and even sometimes from ethnographers like myself. The seeds are viewed as if they have the power to create yields and justify policy irrespective of who plants them or how. This is a vision of seed technology and the measurement of yields as an autonomous thing beyond and independent of the people and social institutions that interact with it – a *factish*. Qualitative social scientists problematize the definitions of facts on the ground in their analyses of experience (Herring, 2007; Stone, 2011), calling attention to the diverse and complex ways that farmers make cost-benefit decisions or even how they calculate yields on a plant like cotton that will provide multiple harvests throughout it growing season. Yet when articulating their findings with a broader debate within agricultural development, they more often frame their arguments within the scope of the yield and seed as if those were inherent truths lying in wait to be discovered. In this way, qualitative social scientists simplify some aspects of their work to make it legible to this wider audience.

This simplification is unfortunate, because an empirical and STS-inclined analysis suggests that there is no singular narrative driving neo-colonial relationships in agricultural development. Instead, as I will discuss below, there are several competing definitions of yield and several competing understandings of success and failure discussed by scientists, policymakers, trade analysts, or farmers themselves. During interviews, farmers claimed to be switching seeds in the search for good yields (Telugu: *manci digubadi*), but this measure of 'good' rarely translated into a reliable cost-benefit analysis that one seed would yield more than another or experience a more profitable response to fertilizers or pesticides (Flachs, 2016). Instead, farmers spoke about yields as a way to show off their skill to neighbors, scientists, or other passersby. Noticing a neighbor spraying his fields, one farmer cut an interview short by saying that he had to go spray as well. "Do you have insects in your field," I asked. "No," my interlocutor admitted. Nevertheless, "you should always seek to produce more than your neighbors. If they spray four times, you have to spray five." Yield here is as much a competitive signal as it is a search for an objective profit. Later, when I spoke with a local crop scientist, he reiterated the factish argument that yields are inherent products of the seeds, not complex efforts on the part of farmers and fields. "Here farmers are very intelligent," he said. "If [a seed] performs well they'll keep going with that hybrid. Otherwise they'll throw in the dustbin." By reducing the decisions and farmer experiences with seeds to a question of intelligence or yield calculations, the scientist sidesteps other possible competing understandings of how farmers select seeds or measure yields while simultaneously attributing yield as a product of the seed, not of farmers' efforts.

Latour's (2010b) and Stenger's (2010, 2011) analysis of the factish can help to engage these deeper questions because they illuminate the process by which subject and object are ostensibly separated in scientific inquiry. In calling attention to the ways in which facts are composed as scientists conduct their work, the factish can be a powerful tool to analyze how arguments are conceived in the space of the field test-plot or the farmer interview. Factishes also emerge when farmer yields are considered in aggregate, as when researchers (Cotton Corporation of India Ltd., 2014; Lalitha and Viswanathan, 2015) characterize yields produced not by Indian farmers, but by India itself.

Agricultural economics and anthropology, like all sciences, exist within what Stengers (2010) calls an ecology of practices. Ecology, Stengers argues, is an advantageous metaphor because it has both scientific and political connotations. Ecological science stresses the interdependence of subjects and objects, and helps Stengers to work against a view of facts that exist as naturally occurring objects waiting to be discovered. Politically, ecology also emphasizes that not all environments provide equal opportunities for those subjects and objects. Stengers (2010: 32–34), argues that science as an ecology of practices illuminates unexpected symbioses and unintentional creations of meaning. While she uses this term to mean that what science discovers cannot be separated from how scientists discover it, a key insight of STS itself, she continues that this process also creates requirements and obligations, an ecological link between knowledge and the thing discovered.

This set of obligations and requirements is self-reinforcing in scientific practice, what Stengers (2010) terms a reciprocal capture. Scientists and their objects of discovery come to work together symbiotically when scientists construct research spaces like test fields or farmer interviews, thereby reinforcing the objective of looking for or experimenting on something in the first place. Reciprocal captures also illustrate the potential asymmetry of scientific inquiry. Stengers cites ecological examples like parasites and predators as reciprocal capturers, who create value and knowledge in an ecosystem and who do not exist apart from each other. These interactions need not carry such negative connotations. Stengers (2010) continues to explain that neutrinos and physicists also engage in an asymmetrical reciprocal capture of obligations and requirements. Neutrinos, difficult to stabilize and observe in a laboratory, must be made to exist for the physicists who study them. Through this process, the physicists themselves change, understanding themselves and their work within the questions and speculations made possible by the neutrinos. Ecologically, they are linked even though scientists more directly forge the connection. Thus is the capture reciprocal.

The ecology of seeds and yields from this perspective includes the need for seeds to grow, rain to fall, and soil to bring forth plants, but also for governments to allow GM legislation, seed shops to carry the desired brands, and scientists and farmers to record yields. Seeds and yields do not exist outside of the narrow set of conditions in the political economy that bring them to farmers' fields. Indian cotton farmers, like Stengers' neutrino physicists, come to see themselves with respect to their ability to produce good yields, a reciprocal capture framed within the logics of agricultural development that limits other possible visions of agricultural success. Farmwork, like physics, creates conditions through its ecology of practices that lead farmers to see themselves as protectors of plants (Gupta, 1998), stewards of soil (Stoll, 2002), and otherwise fundamentally moral caretakers (Pandian, 2009) who create landscapes and increase yields. To unpack the factish on the field, I will first clarify the processes used in anthropological, economic, and agronomic inquiries into GM crops.

Latour, Stengers, and Three Types of Factish

In agricultural development science, encompassing social scientists, agricultural economists, and agronomists, yields and seeds have been given lives unencumbered by farms and fields – thus can Bt cotton be credited with increasing yields or changing farmers' lives in India as discussed above. Farmers, scientists, and seeds have been swept up in the factish. Latour began exploring the construction of scientific facts in Laboratory Life (Latour, 1986), an ethnographic study of the way in which scientists and laboratories produce scientific texts. These texts coalesce to reveal universal truths, but through the process of their creation, they are often contested at certain moments. Impossible to attribute to single authors, Latour found that they are created by a wide range of actors seeking consensus throughout the process of scientific inquiry. The resultant actor network theory later helped him investigate how various agents create a mutually composed reality within institutions such as the economy, science, or religion (Latour, 2003).

This ultimately leads Latour (2010b) to describe the construction of *subjects* much as he previously observed the construction of *objects*. Throughout *On the Modern Cult of the Factish Gods,* the titular factish concept emerges as a way to illuminate how beings transition from (1) the state of subjective human action enmeshed in a sociocultural web of meaning to (2) an autonomous being beyond and independent of the human actor. Factish is an etymological play on the term 'fetish', which derives from the Latin *facio*, to make. Portuguese traders living near Africa's Western coast denounced animist religious objects as fetishes, human-made and imbued with false power. This propelled a colonial legacy of distrusting fetishes as constructed from human beliefs and led "moderns", those who ascribe to a nature/culture separation, to distrust the notion that human beliefs creep into scientific facts. To trust facts, Latour (2010b) argues that moderns must both deny that they are constructed and create a space, such as a laboratory or a farmer interview, where facts can be reliably discovered. These spaces sustain the illusion of the separation between discovered object, process, and discoverer subject. By drawing attention to the social work that drives scientific inquiry in this work, Latour describes a factish as a subject in its own right, which facilitates the creation of autonomous facts.

In her second volume of *Cosmpolitics*, Stengers (2011) builds on Latour's factish to shed light on at least sixteen different gradations of the concept. I will collapse these into three broad categories for my analysis below. The <u>theoretical</u> factish is characterized by new ways of thinking that allow us to construct a reality in which researchers can ask different kinds of questions and imagine other paradigms. Theoretical factishes "intervene whenever theories "judge" experimental practices and refer to them as a reality that assigns them one role, that of access to its own – now discovered – theoretical truth" (Stengers, 2011: 78). Although scientific theories circumscribe findings by delineating an experimental process, theoretical factishes help to re-expand the pool of possibilities in scientific practice. Throughout *Cosmopolitics I* and *II*, Stengers (2010, 2011) cites individuals and paradigms that helped to enable a new way of representing real possibilities: new concepts of quantum physics required rethinking older models of Newtonian dynamics, while the equivalency reified by the "=" sign challenged extant ways of knowing. Because GM crop research in India is constrained by efforts to understand seeds and farms in terms of yields, a new theoretical factish would demand a new politics of measurement and analysis beyond a success defined by yields or comparisons of seeds planted.

Stengers' <u>experimental</u> factishes concern the construction of subjects like yields or seeds, which she describes as being at once constructed by humans and living their own existence (Stengers, 2011: 4). Similarly to the Latourian factish, the experimental factish gains power from a false autonomy derived from modernist illusions in scientific practice. An experimental factish interacts with living and nonliving agents in the world and its subsequent "adventures, once stabilized, [can be] "explained" in terms of the properties that have been attributed to it as an "autonomous being" (Stengers, 2011: 58). For moderns, this existence can be accepted because it can be tested (Stengers, 2011: 78). Latour (2010b) calls this a circular argument, used by moderns when they create a superficial divide between belief and empirical knowledge in the laboratory setting. As I will discuss below, seeds and yields are experimental factishes when they are made to exist unencumbered by the means of their cultivation or measurement.

Stenger's third flavor of factish induces a new kind of relationship between the laboratory and the larger world based in the self-interest of the scientist. This is the <u>promise</u> factish, which focuses on the possibilities exposed when the promise of a solution and the problem itself can be articulated and joined (Stengers, 2011: 246–7). The promise factish describes a process by which researchers formulate scientific processes and research questions in such a way that allows science as an institution to work around problematic assumptions. In this way it is similar to the theoretical factish. Unlike that variety, it does not emerge from a generic need for new theoretical possibilities. Rather, Stengers' promise factish makes a concerted effort to create a scientifically viable model capable of solving existing problems. In the current scientific discourse, yields represent such a promise factish in that agrarian development has been framed as referential to crop yields: yield is what development experts are concerned with studying, yields are contested as benchmarks, and the solution of higher yields is itself joined to the problem of underproduction without questioning the value of using that benchmark. No alternative futures are necessary in this promise factish framing – only higher-yielding seeds.

The factish is a useful heuristic to explore GM seeds, although it is only part of this complicated story. Factishes draw attention to the ways in which scientific inquiry creates facts, like crop yields, that appear to have their own, autonomous lives. Latour and Stengers stress that this heuristic focuses on scientific processes, but a focus on the factish itself may distract from the larger politics of measurement (Porter, 1996; Rottenburg and Merry, 2015), which ask why the quantification of data, such as yields, has become so important for states and corporations in the first place. Although there is not space in this manuscript to fully discuss the complex and politicized ways in which yield is measured, the urge to document yields as objective and naturally occurring truths distinct from their particular and socially constructed context in farmers' fields is essential to the larger debate over how GM crops affect the lives of smallholders. Because critics also frame their arguments around yields, either to say they are lower than reported or that the farmers in question have abnormally high yields, they too are participating in creating a factish that keeps yields distinct and separate from the innumerable variables of farm management, farmer and scientist measurement, and politicized reporting. Viewing social science research from a Stengersian, ecological perspective, yields are sustained by a promise factish that defines possible requirements and obligations of working with cotton farmers. The factish, a tool to illuminate assumptions and methods, shows how success and failure have become tied to crop yields as one factor above all others. The experimental factish in particular is useful in describing the material catalyst for the controversy: the GM seed itself.

Facts and Factishes in Agricultural Development

Debates on the merits of GM crops in the WTO, across India's scientific and regulatory bodies, in popular discourse, and in scientific circles maintain that there is such a thing as a GM cotton seed. Yet this is not, strictly speaking, true on farms: Each seed is unique in size and shape; many seeds, as much as 25% of an acre packet, never germinate and leave field gaps filled with home vegetables (Flachs, 2015); each farmer has small variations in their land and resources allowing different seeds to have differential opportunities; the seeds have varying levels of genetically modified Bt gene expression; insect, weather, and weed patterns affect the crop; and several different versions of Bt expressing genetic constructs have been bred into more than 1,200 GM private seed brands. No single GM seed could stand in for all seeds in all situations. Social scientists (Herring, 2007; Stone, 2007) find that farmers are often unclear as to the differences between seed brands, an uncertainty common in studies of new agricultural technology (Busch et al., 1990; Tripp and Pal, 2000).

Law (2004) and Lury and Wakefield (2012) argue that social scientific researchers and their methods address this complexity by helping to create the world that they are meant to explain. While ethnographers may be comfortable with addressing their influence and positionality in reporting yields, scientists seeking more objective measures, including agricultural economists and agronomists, may be less comfortable in accounting for these socially constructed variables. In Stengersian terms, the degree to which the researcher's voice creeps into scientific documents reflects the different obligations that researchers using these distinct disciplinary approaches have to their data. This further muddies reports of yield as success in farm fields in the resulting scholarship. A search of the term "GMO factish" on GoogleScholar suggests the term "GMO facts". This is part of why I argue that the factish has an opportunity as a heuristic on these farms. Despite its usefulness in illuminating the circular logic of the practice of development science and the separation of seeds from farmers and institutions, this concept has yet to be widely incorporated into studies of agricultural development. However, the influence of sociopolitical institutions on what counts as acceptable science is a powerful force in GMO discourse.

States and supranational groups require different forms of evidence to evaluate GMOs through their regulatory structures, reflecting their conception of their relationship between states, scientists, and objective scientific inquiry. Sheila Jasanoff's (2005) study of comparative biotechnology regulation argues that the United States, the United Kingdom, and Germany developed unique regulations for the production and commercialization of GMOs based in their national conceptions of markets and legislation, food safety, and centralized state science, respectively. Similarly, The World Trade Organization (WTO), found that the requirements for scientific proof have led to regulatory difficulty across national borders (Bonneuil and Levidow, 2012). When adjudicating the spread of GM technology, the WTO demanded that scientists be able to produce objective and detached "views from nowhere" that could justify regulatory science without the perceived bias of pro- or anti-GM sentiment. However, WTO member states called for strict, science-based trade law without ever reaching consensus on what it meant to prove or disprove something scientifically, let alone a consensus on what it meant to practice science. The WTO attempted to sidestep state concerns about GM science by demanding that states produce experimental factishes, scientific evidence that would be separated from its human, and thus politically biased, connections. Ultimately, differing national burdens of proof and standards for scientific objectivity derailed GM crop trade policies between the Americas and Europe in the early 2000s (Charles, 2001).

The complex combination of enthusiasm and caution experienced by farmers, consumers, and regulators in the USA and Europe may have had rippling effects in attitudes toward GM crops in nations in Africa and Asia. Paarlberg (2001, 2002) argues that cautious approaches in Europe have led countries in the developing world to hesitate, caught between a suspicion of neocolonialism and the fear of missing out on new technology. Implying that Indian farmers would like to plant GM hybrid seeds but are being held up by burdensome regulation, Paarlberg further argues that seed-saving nations like India have benefitted from new private sector seed varieties bred to solve agricultural problems. India has been particularly Janus-faced with GM regulation, reflecting a desire to grow biotechnological capital, meet the needs of poor farmers, and resist domination by foreign influence (Guha, 2008; Scoones, 2006).

The Promise Factish and Development Imaginaries

The WTO and global regulators presume that science, technology included, can be objective and that politics are separate and interfering in a natural process of economic growth. This is the promise factish, which posits that scientific practices can be reworked to keep old possibilities in place without suggesting new paradigms. In doing so, it maintains the existence of the experimental factish, which separates yields and seeds from scientific or agricultural actors so that they can be objectively judged. Such logic follows that GM seeds are only one thing: yield-improving. Similarly, a yield is only one thing: evidence of a farmer's competence. Within this narrative, all other interpretations of agriculture are political and anti-scientific. Perspectives driven by these larger discussions of agricultural development economics can be seen in pro-GM academic outlets like *AgBioForum*, although it is not out of the mainstream of scientific inquiry as discussed above. The contrary view, espoused by environmentalist authors like Vandana Shiva (Shiva et al., 2002) frames the argument similarly, but reaches a different conclusion. From this perspective, GM seeds are poisonous and dangerous while seed companies promote GM crops through objective corruption in the regulatory process. Much as the economics-driven national and supranational arguments hold that all alternative views are political because they are unscientific, this contrary national and supranational perspective holds that all other interpretations of agriculture are political because they are corrupted by agribusiness interests.

These arguments ignore that farmers are a heterogeneous group and yield is a tricky phenomenon to study. The promise factish common in agricultural development, that technology leads inevitably to a better state of higher production, compels pro-GM researchers to ask "why might it be that low income countries would apply regulatory systems for agricultural biotechnology modeled after European standards, *even though it means their poor farmers and consumers lose any potential gains in agricultural productivity and social welfare*?" (Graff et al., 2009: 1, my emphasis). The authors suggest that biotechnology free from regulation is a necessary precondition of agricultural productivity and its associated social values. This free-market approach celebrates small farmers' potential to earn greater returns through higher yields of a cash crop like Bt cotton, but ignores the longstanding suspicions that Indian farmers and regulators harbor against foreign technologies and influence (Parsai, 2012; Scoones, 2008). Such an argument is also apolitical in that it does not consider the colonial history that has led to India's complex regulatory framework. Instead, in this framing, technology offers gains in yields and incomes, with no discussion of the differences in trade, agriculture, or aspiration between those producing and consuming biotechnology.

Authors who accept this promise factish see development as the technological creation of higher-yielding seeds, where success is judged by the single metric of yield. This is true even of detractors like Shiva, who contest this argument by denying or downplaying measured gains in yields as evidence of GM crops' failure. In reworking agricultural development to fit the proscribed future of higher yields and better outcomes, the promise factish suggests critical and optimistic ways that GM crops affect farmers in developing countries: GM advocates and detractors alike appeal to a sense of justice based on equal access to technology (Graff et al., 2009; Paarlberg, 2002; Shiva et al., 2002); they argue that GMOs are necessary to or incapable of feeding and clothing the world sustainably (Altieri, 2005; Dreifus, 2008; Fedoroff, 2011; Qaim, 2010); and they bemoan the lack of scientific argumentation while suggesting that GM crops will assuage or exacerbate global issues of suicide, climate change, and population (Gutierrez et al., 2015; Harmon, 2014; Plewis, 2014).

Seeds and Yields as Experimental Factishes

The experimental factish is far more pervasive and obvious than the other factishes in studies of GM research: the notion that GM seeds and the measurements of their yields are independent from the political economy and scientific practices in which they are embedded. Throughout regulatory battles over GM cotton in India, success and failure have been structured around questions of yield and agronomic success (Herring, 2015). This argument disembeds seeds from larger social or political connections and considers them to be autonomous beings. By framing legitimate criticism within the space of yields, Herring (2015) argues that Bt cotton advocates sidestepped issues of risk and biosecurity that later dogged Bt brinjal, which was slated to be India's second approved GM crop before national outcry placed a moratorium on all new GM crops in 2010 (Rodrigues, 2010). While agnostic on GM crops themselves, Herring notes that un-scientific concerns around Bt brinjal, based in public fears rather than agricultural science, have led to an un-scientific rejection of the crop. This conclusion is only possible when seeds are viewed as autonomous objects and yields as objective truths waiting to be discovered. Numerous (Fedoroff, 2011; Graff et al., 2009; Harmon, 2014; Paarlberg, 2001; Thaindian News, 2008) pro-GM scientists argue that biotech fear and farmer non-adoption stem from doubt manufactured by anti-GM groups mobilized to affect the risk-perception of uninformed people (Blancke et al., 2015). According to this factish, because crop yields can be objectively measured by scientists, a better informed public should have no such objections. But even the most hardened critics of constructed facticity admit to considerable variation in actual farm fields:

> "Bt produces one trait; it affects only biotic stress from one class of insects. Yields are driven by numerous traits, characteristics of germplasm, and biotic and abiotic stresses that vary continually. There will be variance, field to-field, season-to-season. Variance across studies simply reflects the nature of agriculture." (Herring, 2013: 64)

Yield, Herring shows, is inherently complicated because it results from innumerable variables in the practice of farmwork. And yet to make arguments about yield and the efficacy of seeds, Herring and other agricultural development writers including myself (Flachs, 2016; Gutierrez et al., 2015; Stone, 2011) must accept the experimental factish that they can reliably measure and report those yields in aggregate. Adding considerations like weather and social stratification helps them to maintain belief in the factish, that seeds can be abstracted and studied as external to farmers and fields even when confronted with empirical realities or lived experiences that do not match the expectations of the factish.

The socially constructed conditions under which seeds and yields are measured enable experimental factishes like the neutrinos or microbes studied by other STS scholars. In my own measurements of yields and discussions with agricultural scientists in Telangana, I found that yields and other production analyses are often context dependent. Cotton will fruit several times over the course of a season and is picked, with diminishing returns, two to ten times per season. Scientific arguments over systemic bias in yield measurement have been addressed above, but both sides maintain that there is an interior truth, a true yield that can be discovered.

The search for a composed social reality regarding yields is easier on the scale of anthropology, typically requiring years of language training and long-term fieldwork with relatively small populations, than on the scale of agricultural economics. Qaim and Zilberman (2003) based their initial findings on panel surveys with 157 farmers in 25 districts in three states, and used this to argue that GM crops were a success and should be spread in other countries in the global South. Qaim's team has used this panel data to conduct long-term studies, an innovative mixed-methods approach to agricultural economics data, revealing interesting trends about adoption, risk, and decision-making not usually legible to agricultural economic studies (Kathage and Qaim, 2012; Kouser and Qaim, 2011). Yet other disciplines have different requirements and obligations in the collection of their data.

I personally surveyed Bt cotton-planting farmers in three districts in one region of one state and found ambiguous results for yield, inputs, seed responses, and metrics underlying agricultural decisions on farmer fields (Stone et al., 2014). I used a recent census to identify at least 60 farming households in each of six villages (resulting in nearly 400 households surveyed), stratified into three wealth terciles and selected to represent a range of variation in soil quality, ethnicity, and proximity to cities. Furthermore, I used this survey as the first step in a larger ethnographic interview in which I was able to spend time speaking and sometimes farming alongside farmers to collect richer qualitative data. Ultimately, I spent 14 months collecting this data with farmers, including repeat visits and numerous walks around the field.

This ethnographic approach differs from the short-term visits, structured surveys, and occasional focus groups of the agricultural economics studies above, and thus allowed me to collect different data. While farmers justify their seed choices with the hope for a greater yield over another seed, I found that this hope does not manifest in greater yields with different seeds when I asked farmers to report their yields over four consecutive cotton seasons 2012-2016. I am not comfortable generalizing beyond the region where I worked because anthropologists place a primacy on hyper-local knowledge and practice, while economists likely would be frustrated with my sample because it was limited to only one small region of one state in India. This is a difference in obligations, in what different disciplines feel comfortable reporting. I think it is possible for both of our studies to reveal interesting data given our methods. However, neither is the objective truth on the ground, collected as it was with different teams, methods, and assumptions. I call attention to research design here to emphasize that sciences dealing with human responses must pay special attention to the ways that research interlocutors construct facts than in a way that, say, physicists measuring neutrinos are not often asked to attend, even when national and legal discourse attempt to make them uniform or legible.

Divorced from billions of dollars of research and development, an international network of scientists, global capitalism, and farmers, development science maintains the experimental factish of the seed because it is the anti-political technological fix (Ferguson, 1994) through which development can occur. This discourse naturalizes India's agrarian distress. The problem is an ecological issue of pest attacks or pesticide use (Qaim, 2010), not a political question of clothing supply chains (Brooks, 2015), biotechnology infrastructure (Scoones, 2008), or colonial history (Beckert, 2014). When reduced to a single, scientifically observable benefit, yields, GM seeds allow the rest of the cotton supply chain to continue through this crisis without challenging the underlying inequalities of the cotton trade.

Conclusion: Attending to the Factish in the Field

A re-reading of Latour's concept of constructionism allows us to see how facts are constructed and shaped while simultaneously showing how they are de-politicized to mask intention on the part of the author and avoid questioning researchers' methods. Why would a yield be the most important thing to measure anyway? The discussion around the success and failure of Indian cotton has been framed in this way since GM cotton was legalized in 2002. This pushes other concerns, including risk or public fears expressed by non-experts and framed outside of agronomy, to the side (Herring, 2015).

STS approaches critically examine the methods and assumptions of laboratory and field research. Like the authors discussed in this essay, I have described seeds as autonomous and yield-creating beings to make arguments about Indian cotton agriculture in my own work. It is not my intention to criticize the work of these other scholars but to draw attention to the ways in which all of us use models and create factishes that mask how this data is co-created. Anthropologist Paul Richards (1993), for example, is particularly suspicious of the field trials in which agricultural technology like GM seeds are tested, as these eliminate the variables of farm life and mask the improvisations that define farmwork in practice. From this perspective, it is not GM seeds but the collective work of farmers, landscapes, and measuring scientists who create yields and decide the productivity of a given seed. Agricultural and development models regarding GM seeds are useful and legible to scientists and policymakers as these generalizations can describe abstractions and amalgamations of farmers and seeds. The STS approach in this essay is a critique of the ways in which yields are divorced from farmers and fields in agricultural development discourse, and is not necessarily conducive to directing agricultural or economic policy. At least, I would ask that such policies pay far more attention to social variability and consider the multitude of factors beyond yields that reflect socioeconomic uplifting in areas targeted for agricultural development. Models that present seeds and yields as a fact of nature rather than a socially embedded and contingent factor are not equipped to address underlying rural precarity linked simultaneously to generational poverty brought on by colonialism, contemporary trade inequality, unequal access to irrigation infrastructure, and rural aspirations to land stewardship (Gupta, 2017; Gutierrez et al., 2015; Vasavi, 2012).

While I contest that seed models describe an independent and objective reality, I agree that the combined social work of farmers, seed breeders, agricultural scientists, policymakers, and other stakeholders help to make these yields a shared reality. In the first pages of An Inquiry into Modes of Existence, Latour (2013) notes that climate scientists are beginning to think of themselves as members of institutions with particular ways of evaluating evidence and making claims. Yet his recent work (Vrieze, 2017), and STS in a broader sense argues that this is an opportunity for deeper understanding, not a rejection of inquiry. In his *Compositionist Manifesto*, Latour finds that both proponents and skeptics of climate change cling to modernist scientific reasoning, arguing "if [climate science] is slowly composed, it cannot be true," said the skeptics; "if we reveal how it is composed," said the proponents, "it will be discussed, thus disputable, thus it cannot be true either!" (Latour, 2010a: 478). Both GM seed proponents and skeptics who research the seeds' impacts in the field buy into a similar factish, that seeds are autonomous beings and that crop yields can be measured objectively. By recognizing this experimental factish, as well as the promise and theoretical factishes that undergird it, we can begin to make sense of different stakeholders' reports on the triumphs and failures of GM crops, how they are collectively composed, and what obligations and requirements that process demands.

My assistant's initial objection, that the data would not exist without my collecting it, turns out to be exactly correct when viewed outside the parochial ecology of practices in my discipline of anthropology and my constructed experimental factish of the GM seed. All seeds and yields are born of wildly different environmental circumstances and entangled with different kinds of actors. That factish persists in my own work and in that of other social sciences for the same reason that factishes persist in biology or physics. They are useful abstractions that provide helpful generalizations, they are easily taught and practiced within the current institutions where we work, they are fundable and studyable within the confines of our disciplines, they allow us to remove ourselves from the laboratory and thus give our phenomena their own independent lives, and they require no extra theoretical work in the realm of the possible. But if any researchers can cope with compositionism and think beyond experimental or theoretical factishes, qualitative empirical social scientists should welcome the opportunity. My data cannot exist without my interactions with the farmers, but the farmer's fields, cotton, seeds, income, happiness, ecological management, and all of the hundreds of factors that have led to the process wherein seeds become plants are anything but external to the fields and farmers who grow them. By paying better attention to their interconnectedness, we may have a better chance at documenting the composed reality, not as it exists to be discovered and written on my clipboard, but as seed, farmer, and social scientist create it.

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References

Altieri MA (2005) The Myth of Coexistence: Why Transgenic Crops Are Not Compatible With Agroecologically Based Systems of Production. *Bulletin of Science, Technology & Society* 25(4): 361–371. DOI: 10.1177/0270467605277291.

Beckert S (2014) *Empire of Cotton: A Global History*. New York: Knopf.

Blancke S, Van Breusegem F, De Jaeger G, et al. (2015) Fatal attraction: the intuitive appeal of GMO opposition. *Trends in Plant Science* 20(7): 414–418. DOI: 10.1016/j.tplants.2015.03.011.

Bonneuil C and Levidow L (2012) How does the World Trade Organization know? The mobilization and staging of scientific expertise in the GMO trade dispute. *Social Studies of Science* 42(1): 75–100. DOI: 10.1177/0306312711430151.

Brooks A (2015) *Clothing Poverty: The Hidden World of Fast Fashion and Second-hand Clothes*. London: Zed Books.

Busch L, Burkhardt J and Lacy WB (1990) *Plants, power, and profit: social, economic, and ethical consequences of the new biotechnologies*. Cambridge, Mass., USA: B. Blackwell.

Charles D (2001) *Lords of the Harvest: Biotech, Big Money, and the Future of Food*. New York: Basic Books.

Cotton Corporation of India Ltd. (2014) *44th Annual Report 2013-2014*. 44, Annual Report. Mumbai: Cotton Corporation of India Ltd.

Crost B, Shankar B, Bennett R, et al. (2007) Bias from Farmer Self-Selection in Genetically Modified Crop Productivity Estimates: Evidence from Indian Data. *Journal of Agricultural Economics* 58(1): 24–36. DOI: 10.1111/j.1477-9552.2007.00076.x.

Dreifus C (2008) An Advocate for Science Diplomacy. *The New York Times*, 19 August. Available at: http://www.nytimes.com/2008/08/19/science/19conv.html (accessed 3 April 2012).

Fedoroff NV (2011) Genetically Engineered Food for All. *The New York Times*, 18 August. Available at: http://www.nytimes.com/2011/08/19/opinion/genetically-engineered-food-for-all.html (accessed 3 April 2012).

Ferguson J (1994) *The Anti-Politics Machine: 'Development,' Depoliticization and Bureaucratic Power in Lesotho*. Minneapolis, Minn: University of Minnesota Press.

Flachs A (2015) Persistent Agrobiodiversity on Genetically Modified Cotton Farms in Telangana, India. *Journal of Ethnobiology* 35(2): 406–426. DOI: 10.2993/etbi-35-02-406-426.1.

Flachs A (2016) Redefining success: the political ecology of genetically modified and organic cotton as solutions to agrarian crisis. *Journal of Political Ecology* 23(1): 49–70.

Forster D, Andres C, Verma R, et al. (2013) Yield and Economic Performance of Organic and Conventional Cotton-Based Farming Systems – Results from a Field Trial in India. *PLoS ONE* 8(12): e81039. DOI: 10.1371/journal.pone.0081039.

Graff GD, Hochman G and Zilberman D (2009) The Political Economy of Agricultural Biotechnology Policies. Available at: http://agbioforum.org/v12n1/v12n1a04-graff.htm (accessed 19 March 2014).

Gruère G and Sengupta D (2011) Bt Cotton and Farmer Suicides in India: An Evidence-based Assessment. *Journal of Development Studies* 47(2): 316–337. DOI: 10.1080/00220388.2010.492863.

Gruère G and Sun Y (2012) *Measuring the Contribution of Bt Cotton Adoption to India's Cotton Yields Leap*. Environment and Production Technology Division 01170, IFPRI discussion paper. IFPRI.

Guha R (2008) *India after Gandhi: the history of the world's largest democracy*. New York: Harper Collins Publishers.

Gupta A (1998) *Postcolonial Developments: Agriculture in the Making of Modern India*. Durham: Duke University Press Books.

Gupta A (2017) Farming as speculative activity: the ecological basis of farmers' suicides in India. In: Heise UK, Christensen J, and Niemann M (eds) *The Routledge Companion to the Environmental Humanities*. 1 edition. London ; New York, NY: Routledge, pp. 185–193.

Gutierrez AP, Ponti L, Herren HR, et al. (2015) Deconstructing Indian cotton: weather, yields, and suicides. *Environmental Sciences Europe* 27(1): 12. DOI: 10.1186/s12302-015-0043-8.

Harmon A (2014) A Lonely Quest for Facts on Genetically Modified Crops. *The New York Times*, 4 January. Online. Available at: http://www.nytimes.com/2014/01/05/us/on-hawaii-a-lonely-quest-for-facts-about-gmos.html (accessed 8 April 2014).

Herring RJ (2007) Stealth seeds: Bioproperty, biosafety, biopolitics. *Journal of Development Studies* 43(1): 130–157. DOI: 10.1080/00220380601055601.

Herring RJ (2013) Reconstructing Facts with Bt Cotton: Why Scepticism Fails. *Economic and Political Weekly* 48(33): 63–66.

Herring RJ (2015) State science, risk and agricultural biotechnology: Bt cotton to Bt Brinjal in India. *The Journal of Peasant Studies* 42(1): 159–186. DOI: 10.1080/03066150.2014.951835.

Herring RJ and Rao NC (2012) On the 'Failure of Bt Cotton': Analysing a Decade of Experience. *Economic and Political Weekly* 47(18): 45–53.

Jasanoff S (2005) *Designs on Nature: Science and Democracy in Europe and the United States*. Princeton, N.J: Princeton University Press.

Jha DK (2013) Bt cotton losing steam, productivity at 5-yr low. *Business Standard India*, 7 February. Available at: http://www.business-standard.com/article/markets/bt-cotton-losing-steam-productivity-at-5-yr-low-113020601016_1.html (accessed 6 March 2014).

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* 109(29): 11652–11656. DOI: 10.1073/pnas.1203647109.

Kouser S and Qaim M (2011) Impact of Bt cotton on pesticide poisoning in smallholder agriculture: A panel data analysis. *Ecological Economics* 70(11). Special Section - Earth System Governance: Accountability and Legitimacy: 2105–2113. DOI: 10.1016/j.ecolecon.2011.06.008.

Kranthi K (2014) Cotton Production Systems - Need for a Change in India. *Cotton Statistics & News*, 16 December.

Lalitha N and Viswanathan P (2015) Technology Diffusion and Adoption in Cotton Cultivation: Emerging Scenario in Gujarat. *AgBioForum: The Journal of Agrobiotechnology Management & Economics* 18(2): 209–220.

Latour B (1986) *Laboratory life: the construction of scientific facts*. Princeton, N.J: Princeton University Press.

Latour B (2003) The Promises of Constructivism. In: Ihde D and Selinger E (eds) *Chasing Technoscience: Matrix for Materiality*. Bloomington: Indiana University Press, pp. 27–46.

Latour B (2010a) An Attempt at a "Compositionist Manifesto". *New Literary History* 41(3): 471–490.

Latour B (2010b) *On the modern cult of the factish gods*. Durham [NC]; London: Duke University Press.

Latour B (2013) *An inquiry into modes of existence: an anthropology of the moderns*. Cambridge: Harvard University Press.

Law J (2004) *After Method: Mess in Social Science Research*. New York: Routledge.

Lury C and Wakeford N (2012) Introduction: a perpetual inventory. In: Lury C and Wakeford N (eds) *Inventive Methods: The Happening of the Social*. New York: Routledge, pp. 1–24.

Monsanto Company (2012) *Monsanto India Limited Annual Report*. 2012, Annual Report. St. Louis: Monsanto.

Nair KPP (2013) Failure of Monsanto Bt Cotton. Available at: http://www.newindianexpress.com/opinion/Failure-of-Monsanto-Bt-Cotton/2013/12/06/article1930013.ece (accessed 6 March 2014).

Paarlberg RL (2001) *The Politics of Precaution: Genetically Modified Crops in Developing Countries*. Baltimore: The Johns Hopkins University Press.

Paarlberg RL (2002) The real threat to GM crops in poor countries: consumer and policy resistance to GM foods in rich countries. *Food Policy* 27(3): 247–250.

Pandian A (2009) *Crooked Stalks: Cultivating Virtue in South India*. Durham: Duke University Press Books.

Parsai G (2012) Protests Mark 10th Anniversary of Bt Cotton. *The Hindu*, 27 March. Available at: http://www.thehindu.com/sci-tech/agriculture/article3248530.ece (accessed 4 April 2012).

Pearson M (2006) 'Science', Representation and Resistance: The Bt Cotton Debate in Andhra Pradesh, India. *The Geographical Journal* 172(4): 306–317.

Plewis I (2014) Indian farmer suicides: Is GM cotton to blame? *Significance* 11(1): 14–18. DOI: 10.1111/j.1740-9713.2014.00719.x.

Porter TM (1996) *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life*. Princeton, N.J: Princeton University Press.

Qaim M (2010) Benefits of genetically modified crops for the poor: household income, nutrition, and health. *New Biotechnology* 27(5): 552–557. DOI: 10.1016/j.nbt.2010.07.009.

Qaim M and Zilberman D (2003) Yield Effects of Genetically Modified Crops in Developing Countries. *Science* 299(5608): 900–902. DOI: 10.1126/science.1080609.

Richards P (1993) Cultivation: Knowledge or Performance? In: Hobart M (ed.) *An Anthropological Critique of Development: The Growth of Ignorance*. New York: Routledge, pp. 61–78.

Rodrigues A (2010) Back From the Brink. *Frontline*. Available at: http://www.frontlineonnet.com/fl2705/stories/20100312270501100.htm (accessed 29 March 2012).

Rogers EM (2003) *Diffusion of Innovations*. 5th ed. New York: Free Press.

Rottenburg R and Merry SE (2015) The World of Indicators: The making of governmental knowledge through quantification. In: Rottenburg R, Merry SE, Park S-J, et al. (eds) *The World of Indicators: The Making of Governmental Knowledge through Quantification*. Cambridge University Press.

Ryan B and Gross NC (1943) The Diffusion of Hybrid Seed Corn In Two Iowa Communities. *Rural Sociology* 8(1): 15–24.

Schmid O (2007) Development of Standards for Organic Farming. In: Lockeretz W (ed.) *Organic Farming: An International History*. Cambridge: CABI, pp. 152–174.

Schurman R and Munro WA (2010) *Fighting for the Future of Food: Activists Versus Agribusiness in the Struggle Over Biotechnology*. Minneapolis: University of Minnesota Press.

Scoones I (2006) *Science, agriculture and the politics of policy: the case of biotechnology in India*. New Delhi: Orient Blackswan.

Scoones I (2008) Mobilizing Against GM Crops in India, South Africa, and Brazil. *Journal of Agrarian Change* 8(2 and 3): 315–344.

Shiva V, Jafri AH, Emani A, et al. (2002) *Seeds of Suicide*. 2nd ed. New Delhi: Research Foundation for Science, Technology, and Ecology.

Stengers I (2010) *Cosmopolitics I*. Minneapolis: University of Minnesota Press.

Stengers I (2011) *Cosmopolitics II*. Minneapolis: University of Minnesota Press.

Stoll S (2002) *Larding the Lean Earth: Soil and Society in Nineteenth Century America*. New York: Hill and Wang.

Stone GD (2002) Both Sides Now: Fallacies in the Genetic-Modification Wars, Implications for Developing Countries, and Anthropological Perspectives. *Current Anthropology* 43(4): 611–630.

Stone GD (2007) Agricultural Deskilling and the Spread of Genetically Modified Cotton in Warangal. *Current Anthropology* 48(1): 67–103.

Stone GD (2011) Field versus Farm in Warangal: Bt Cotton, Higher Yields, and Larger Questions. *World Development* 39(3): 387–398.

Stone GD (2012) Constructing Facts: Bt Cotton Narratives in India. *Economic and Political Weekly* 47(38): 62–70.

Stone GD (2013) A Response to Herring and Rao. *Economic and Political Weekly* 48(33): 70–72.

Stone GD (2016) Towards a General Theory of Agricultural Knowledge Production: Environmental, Social, and Didactic Learning. *Culture, Agriculture, Food and Environment* 38(1): 5–17.

Stone GD and Flachs A (2014) The problem with the farmer's voice. *Agriculture and Human Values*: 1–5. DOI: 10.1007/s10460-014-9535-1.

Stone GD, 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.

Thaindian News (2008) Genetic engineering can help solve food crisis: US expert. Available at: http://www.thaindian.com/newsportal/sci-tech/genetic-engineering-can-help-solve-food-crisis-us-expert_10077548.html (accessed 5 March 2014).

The Economic Times (2013a) Bt cotton attracting youngsters to farming in India: Survey. Available at: http://articles.economictimes.indiatimes.com/2013-12-15/news/45216500_1_bt-cotton-cotton-farming-cotton-improvement (accessed 6 March 2014).

The Economic Times (2013b) Farmers prefer growing genetically modified crops: Sharad Pawar. *The Economic Times*, 27 August. Online. Available at: https://economictimes.indiatimes.com/news/economy/agriculture/farmers-prefer-growing-genetically-modified-crops-sharad-pawar/articleshow/22095086.cms (accessed 14 December 2017).

The Hindu (2013) Use of Bt. cotton increased yield, farmers' income: Pawar. *The Hindu*, 29 August. New Delhi. Available at: http://www.thehindu.com/news/national/use-of-bt-cotton-increased-yield-farmers-income-pawar/article5069072.ece (accessed 5 March 2014).

Tripp R and Pal S (2000) Information and agricultural input markets: pearl millet seed in Rajasthan. *Journal of International Development* 12(1): 133–144. DOI: 10.1002/(SICI)1099-1328(200001)12:1<133::AID-JID625>3.0.CO;2-J.

Vasavi AR (2012) *Shadow Space: Suicides And The Predicament Of Rural India*. Gurgaon: Three Essays Collective.

Veettil PC, Krishna VV and Qaim M (2016) Ecosystem impacts of pesticide reductions through Bt cotton adoption. *Australian Journal of Agricultural and Resource Economics*: n/a-n/a. DOI: 10.1111/1467-8489.12171.

Vrieze J (2017) Bruno Latour, a veteran of the 'science wars,' has a new mission. *Science* Online Interview. DOI: 10.1126/science.aaq1805.

Wadke R (2012) Mahyco Denies it Sold its Seeds in Black Market. Available at: http://www.thehindubusinessline.com/industry-and-economy/agri-biz/article3658632.ece?homepage=true&ref=wl_home (accessed 13 September 2012).

Notes

1 Bt refers to *Bacillus thuringiensis*, a naturally occurring soil bacterium containing Cry genes that produce a class of toxins poisonous to certain insects, most notably the order *Lepidoptera*, which contains major agricultural pests. Used as a spray pesticide for decades by American farmers, six different Cry genes have now been inserted into GM cotton in various combinations, allowing the plant to produce its own insecticide.