Rhythms of the herd: Long term dynamics in seed choice by Indian farmers

Glenn Davis Stonea,*, Andrew Flachsa, Christine Diepenbrockb

a Dept. of Anthropology, Washington University, St. Louis, MO 63130, USA
b Dept. of Plant Breeding and Genetics, Cornell University, Ithaca, NY 14853, USA

Abstract

Scholars in many disciplines have approached the question of how humans combine environmental learning (or empirical assessments) and social learning (or emulation) in choosing technologies. As both a consumer item and the subject of local indigenous knowledge, commercial crop seeds provide a valuable window into these processes. Previous research on seed choices by cotton farmers in Andhra Pradesh, India, uncovered short-term seed fads, or herding, indicating agricultural deskilling in which environmental learning had broken down. Unknown was if the faddism (and the underlying deskilling) would continue or even be exacerbated by the spread of genetically modified seeds. Data covering 11 years of seed choices in the same sample villages are now available; we combine analysis of this unusual data set with ethnographic observation. We find that herding has continued and intensified. We also find an unexpected emergent pattern of cyclical fads; these resemble classic models of successive innovation adoption where periodicity is introduced from outside the system, but we argue that it periodicity is actually generated by an internal dynamic.

1. Introduction

For farmers, says a recent book on the wisdom of crowds, “choosing the right variety... is the most important decision they can make, so it’s perhaps not surprising that they would make those decisions on their own, rather than simply mimicking those who came before them” [1]. On the importance of seed choice there can be no argument, but the relationship between individual decision-making and mimicry is not so simple. Seeds naturally pose special challenges to the farmer as experimenter, particularly because they have vital qualities that become apparent only over time or under special circumstances [2].

India’s cotton farmers provide a particularly interesting – if also troubled – case study in decision making on seeds. India is the world’s biggest cotton planter and has some of the world’s lowest yields; debt and crop failure have been linked to cotton farmer suicides [3,4]. Although the most lucrative cash crop for many, cotton is also a notoriously unreliable earner because it is input-intensive, vulnerable to numerous pests, and sensitive to market fluctuation. Seed is usually repurchased on the market every year since most Indian cotton is hybrid, and the cotton seed market is unreliable, offering hundreds of rapidly-changing and often deceptively-labeled seed brands [5]. Seed choice has been further complicated by successive introductions of transformative technologies since the 1990’s: the spread of hybrid seeds, followed by several waves of insecticide technologies, followed by genetically modified (GM) Bt
more crop, the computer maker sees that the microprocessor runs faster, the physician sees that the antibiotic cures more bacterial infections. However in practice, technologies vary enormously in trialability – how well they lend themselves to empirical evaluation through use. Literal mousetraps are on the “trialable” end of the continuum; on the other hand, many agricultural technologies are very difficult to trial under actual farming systems. Breeding of crop seeds relies heavily on field trials, but these are conducted under highly artificial conditions [15].

The copycat dynamic refers to the common practice of basing technology use decisions on others’ decisions. Copycat decisions are based on who is (or how many are) using the technology, rather than how well the technology is working for them. Humans copy each other in matters both grave and frivolous, often picking our models on social criteria that may have nothing to do with how well the technology works. Terms for emulation, including copycat and the verb to ape [17], have negative connotations, but emulation is a fundamental and indispensable practice in a species adapted to such a wide range of practices and habitats [14]. Patterning in copycat decisions may lead to the emergent phenomenon of herding, defined here as widespread conformity that is not obviously adaptive. Wearing warm clothes in winter would not be considered herding because it is clearly adaptive; young people specifically wearing Ugg boots would [cf. 18].

Our long-term investigation of decision-making among farmers in Warangal District, Andhra Pradesh, has generated an unusual dataset on seed choices. Previous publications on the early years of the study showed a striking pattern of herding or seed faddism. Defying social science dogma (and biotech industry rhetoric) about farmer technology adoption being based on careful experimentation, Warangal farmers were found to routinely plant seeds about which they knew very little, often abandoning a seed before planting it long enough to learn much about its performance. Ethnographic investigations showed the underlying cause to be hyper-reliance on copycat emulation due to severe impediments to better mousetrap trialing. Stone [5,19] used the case to theorize agricultural skilling and to identify the three causes of agricultural deskilling as inconsistency, unrecognizability, and accelerated technological change. Genetically modified seeds were adopted during the early years of this study, with the promise of alleviating the severe attacks of Lepidopteran (caterpillar) pests. But seeing the pest-induced losses as a symptom of larger problems, Stone asked if the new round of technological change could alleviate symptoms at the expense of exacerbating the underlying cause. Since deskilling had earlier been revealed in seed choice patterns, further data on seed choices have been collected as Bt seeds have spread.

We report here on a unique dataset on seed choices spanning 11 years, along with extensive ethnographic detail on the dynamics of decision-making. This body of

---

1 GM plants are made by exposing target cells to a vector containing DNA from disparate sources. After exposure, target cells are screened to isolate the cases in which the DNA has been integrated into the target cell’s genome. Each case is termed a transformation event; or simply an event. Each event is unique, sensitive to where and how the introduced DNA is integrated. Once an event has been isolated and evaluated, the cells are cultured and grown into plants so that it can be introduced into various crop varieties by conventional breeding. Bt is Bacillus thuringiensis, a soil bacterium. Proteins expressed by its “Cry” genes are toxic to some Lepidopterans that are common cotton pests.

2 This list of considerations is far from complete. For instance, some seeds have systemic problems such as failure to germinate, and farmers are sometimes given government-mandated rebates. Some brands turn out to be non-viable “spurious seed,” which can be ruinous, and some seeds are available only through the black market, which leaves the farmer without a receipt needed for recompensation.

3 Agriculture minister Sharad Pawar asserts that the Indian farmer has adopted GM seeds and that “The farmer is wiser than me” [8]. On the other hand, biotechnologist Martina McClooughlin claims “for years, people have tried to change cultural practices of these farmers, and it just hasn’t worked. It has been a complete failure, because … you have to re-educate them as to how to modify their farming practices themselves. But with biotech, the technology is in a seed. All you have to do is give them the seed” [9].
information allows for an unprecedented view of some longitudinal dynamics of decision-making and technology adoption. In this analysis we show that predictions of exacerbated deskilling are borne out, but in an unexpected form: seed fads over the past 11 years have peaked with a remarkably regular periodicity. The patterns of seed adoption and disadoption bear striking similarities to classic marketing science models of adoption and substitution for successive high-technology products such as computer microprocessors. However we offer a different explanation of the dynamics of seed herding, including recognition that herding may in some cases be intentional rather than a by-product of the copycat dynamic.

2. Divergent perspectives on technology adoption

Research on technology adoption has a long history in which agricultural seeds have played a key role [20,21]. Pioneering work by sociologists Bryce Ryan and Neal Gross focused on the diffusion of hybrid maize seed in Iowa [22,23]. Hired by breeders to investigate farmers’ apparently irrational reluctance to adopt the new hybrid seeds, they focused on the social aspects of adoption, such as who adopted early versus late and how farmers influenced each other. Iowa seed data provided a classic S-curve of adoption which is the cumulative plot of a normal curve (Fig. 1). This would later be seen in other technologies, from air-conditioners to antibiotics [10].

Sociologist Everett Rogers drew on the hybrid seed research to devise a generalized model of the sociology of technology adoption [25]. It posited five categories of adopters, ordered by when they adopt, as depicted in Fig. 2. The first 2.5% to adopt were termed innovators, with the subsequent stages forming a normal distribution through time. Rogers did not explicitly distinguish innovation from imitation, and he left open the issue of what drove initial adoptions; but to rural sociologists the fundamentals of adoption seemed to have been largely figured out, and their interests tended to move on in the 1960s. The social approach to adoption was, as Rogers later said [10], a victim of its own success.

But adoption studies were already being led into two separate, and more quantitative, directions. One trajectory, which quickly became dominant [21], was led by economists who replaced the social questions with an emphasis on profitability of specific technologies. The new direction was signaled in studies of hybrid corn adoption by Zvi Griliches [26,27], which pointed to the agronomic superiority of hybrid corn and then modeled adoption not as a social process but as a function of the spatial aspects of yield advantage. This was a pure better mousetrap analysis that essentially ignored social learning, and implicitly assumed that environmental payoff information drove adoption patterns.

Citing Ryan and Gross’s data, sociologists Havens and Rogers retorted that “rate of adoption is not related to profitability but is related to cumulative percentage of adoption” [11] – a clear copycat explanation. Yet such utility-based mousetrap models have dominated adoption studies since the 1960s. Indeed there has been a surge in such studies as GM crops have worked their way through the agricultural systems in many countries (e.g., [31]). These studies have

---

5 Rogers did not specify what led to their adoption, but simply alluded to earlier research on “informal leaders” in farm communities. Interestingly, these “informal leaders” (defined by how frequently their advice was sought) were not early adopters at all, but rather traditionalists; the early adopters tended to be wealthy large farmers.

---

6 The technology Rogers used as his empirical case study was the herbicide 2,4-D, developed by wartime research on chemical weapons and introduced to farmers in 1946. It is interesting that the next generation of GM crops is resistant to 2,4-D and dicamba. If and when these are approved, adoption rates of the same herbicide are likely to be closely analyzed again.

7 In recent years, a few economists have returned to consideration on the role of social interaction in technology adoption; see Bandiera and Rasul [28], Brock and Durlauf [29], and Munshi [30].
Our aim is not to privilege mousetrap or copycat models – we are more interested in their interplay – but it is important to recognize a pervasive problem with utility-based explanations of seeds. Griliches attributed the mid-century rise in corn productivity entirely to hybrid seed; his data on spatial patterning of hybrid adoption came from geographer Andreas Grotewold’s (1955) study of corn production. But while claiming to analyze the impact of hybrid corn, Griliches actually did nothing of the kind, as is clear in Grotewold’s actual study. Grotewold does write that hybrid seed was an important factor in the rise in corn productivity between 1935 and 55, but that numerous other key technologies were being adopted simultaneously. This established a pattern that has persisted: attributing adoption and performance advantages to technologies that have not been truly isolated from the confounding factors that are ubiquitous in agriculture [for a recent example from Indian cotton, see [32,34].

The second trajectory was pioneered by marketing researchers, led by Frank Bass who translated Rogers’ scheme into a mathematical model of adoption. The resulting paper, “A New Product Growth for Model Consumer Durables” [36] with a famous typo in its title, explicitly identified and combined the better mousetrap and copycat dynamics under the terms innovators and imitators. Innovators are implied to be trialing technologies, initiating an adoption curve determined by a coefficient of imitation. The new technology that instigates an adoption curve is external to the model, represented by a coefficient of innovation term that does not interact with other terms.

Norton and Bass [13] went a step further in modeling adoption and disadoption of successive generations of products (Fig. 3). In this influential model, the dropoff on the adoption curve represents not saturation (fewer adoptions because more have already adopted) but substitution (fewer buying because more are buying something else). The key driver of the rhythms of adoption is technological improvement external to the dynamics being modeled; it is assumed that new technologies are commercialized as they are invented, and that “each generation is introduced to the market before its predecessor has been fully diffused to its potential population” [13]. In other words, the periodicity in the predicted curves is external to the model: consistent with Bass’s earlier use of an external coefficient of invention, each successive peak occurs when a company invents and chooses to introduce a new product. This is important because in our analysis of cotton seed choices the periodicity appears to be an internal dynamic. (See also Foster and Rosenzweig [38] for a model of technology substitution that depicts changes in market share.)

3. Theorizing environmental and social learning

This selective sketch of technology adoption research shows that the better mousetrap and copycat dynamics may be conceptualized separately, which allows for the construction of more elegant models suited to the pre-dilections of different disciplines. Yet in terms of the actual behavior of decision-makers, the relationship between the two dynamics may be more important than either alone. A classic early work on social learning that defined matched-dependent behavior as when “the leader is able to read the relevant environmental cue, but the follower is not; the latter must depend upon the leader for the signal as to what act is to be performed” [39]. Stone [5] has noted that from an ethnographic standpoint the distinction often strained. “Even a direct environmental observation made on one’s own crop (“Brahma cotton yielded 6 quintals/acre for me last year”) is likely to be interpreted or contextualized through a form of social learning (“which was much more than my neighbor said he got with the same seed”). Even a classic case of conformist adoption (“I am planting Brahma because my neighbors are”) assumes at least an indirect environmental basis (“and they wouldn’t all be planting it unless someone had an indication it would do well”). The Bass models recognize the importance of this relationship but treat it mechanistically. Bass wrote that “Adoptions of the product are made by “innovators” and

---

8 Bass later wrote [37], “The correct title should be: ‘A New Product Growth Model for Consumer Durables.’ I suppose that I was so excited about having the paper accepted for publication that I failed to carefully proofread the galley proofs.”
“imitators”, and “the importance of innovators will be greater at first but will diminish monotonically with time, while the imitation effect will increase with time” [13].

Using a different terminology, Henrich [12] shows that adoptions based purely on environmental learning would produce not the common s-curve but the much rarer r-curves. S-curves must result from environmental learning combined with social learning, with choices of who to learn from being strongly shaped by various intrinsic categories of bias. One is prestige bias, in which a farmer chooses a model to emulate on the basis of prestige – which is not the same as observing the model’s actual results with the technology. Another is conformist bias, in which a farmer adopts a practice when (and because) it has been adopted by many others. Some have also stressed what might be called social proximity bias, referring to the reliance on information from friends and family [28,38].

But despite the conceptual convenience of the distinction, in practice environmental learning is entangled with all of these cultural biases. Consider prestige bias: there certainly are cases where exemplars are emulated on behavior clearly unrelated to what makes them “exemplary.” But more commonly, prestige is equated with general success which cannot be disconnected from decision-making. When I follow a prestigious farmer’s seed choice, I am in part assuming to be harvesting some environmental knowledge, even if he isn’t specifically known as an astute judge of seeds. (The point becomes important in the following case study, as low-caste farmers follow the lead of high-caste farmers even though caste is an inherited status that in itself reflects nothing about insights into seeds.)

Therefore rather than privileging one type of learning it is instructive to view the relative contribution of the types of learning as situational. We can posit that reliance on social learning should increase where environmental learning is costly and/or inaccurate [14,40,41]. This is particularly relevant to agriculture because of the great variation in the cost/accuracy of environmental payoff information available to farmers. Accurate, locally-generated information on seed performance may be readily available for true-breeding (non-hybrid) seeds with an extensive history of local use; farmers would have a sound basis for evaluating and comparing a new seed (or input or practice). On the other hand, with deceptively labeled, annually-repurchased, rapidly-changing seed brands containing a procession of poorly understood genetic technologies, being grown under the challenging conditions of Indian cotton, farmers may have access to very little reliable local payoff information. We should expect them to rely very heavily on emulation to choose cotton seeds, although not necessarily for rice seeds. Such over-reliance on emulation may lead to maladaptive beliefs and practices, especially when the environment changes very rapidly [41].

Parallel ideas have been developed in economics in the model of the information cascade [18,42,43]. Similar to the above concept of conformist bias, these writers point out that each time an individual weights emulation over their own signal (i.e., environmental payoff information), they create a negative externality by raising the chances the next individual will do the same, thus increasingly eroding the weight of payoff information. Eventually even very positive payoff information may be overridden. When payoff information is expensive, unreliable, and/or overridden by cascades, increasingly emulative decisions may have a snowball effect producing herding. While herding is
sometimes defined simply as convergence on a similar behavior, it is used here to refer more specifically to convergence on a behavior that is less attributable to direct utility than to social emulation.

Diverse literatures exist on herd behavior, ranging from cognitive psychologists and marketing scholars’ work on “heuristics” dealing with social aspects of information–environment interactions (e.g., [44]) to popular writing [1,45]; for a summary of other approaches to herding, see Orléan [46]. Our case study in Warangal provides a particularly striking case of herding in seed adoptions and a window into the intersection of the better mousetrap and copycat dynamics.

4. Cotton seed herds in Warangal

In the key cotton-growing district of Warangal, Andhra Pradesh, Stone [5] investigated farmer decision-making and the information environment in which it occurs. He defined *agricultural skilling* as the process of farmers developing the ability to perform with a technology under variable conditions. Skilling had been severely impeded by inconsistency, unrecognizability, and accelerated brand and technology change (especially in seeds but also in pesticides). Of course farmers commonly deal with inconsistency in weather, pests, and/or market conditions, but Warangal cotton farmers are bedeviled by particularly rapid, complex and unpredictable variation in insect attacks [5]. Unrecognizability plagues farmers in several ways, including the deceptive branding of seeds exemplified in Fig. 4. The rapidity of seed change is reflected in input vendor surveys showing a 69.2% turnover in seed brands between 2003 and 5 [5].

Stone theorized the phenomenon of *agricultural deskilling* as the result of impeded flow of environmental payoff information, leading here to a crippling of environmental learning and thus an overwhelming reliance on social learning. This led to a striking pattern of highly localized seed fads with little agroecological basis. For instance, Kalleda and Ravuru are adjacent villages with the same growing conditions. In 2004 the top seed in Kalleda was Gemini, which almost no one in Ravuru planted; in 2005 the leading seed in Ravuru was Vikas, which virtually no one in Kalleda planted. Both seeds disappeared after 2 years of sales. In the five growing seasons between 2003 and 2007, Ravuru had five different top seeds: Brahma, Bunny, Vikas, RCH-2, and Mallika.

The skilling process was further complicated in 2002 by the arrival of Bt seeds. These were little planted in Warangal until the 2005 season, when they caught on suddenly. The adoption of Bt seeds coincided with a change in, and intensification of, seed herding; village-specific fads gave way to a district-wide fad as villages converged on a single Bt seed called RCH-2. Although the Bt version of this seed was new, its properties were not well known, and there was no clear evidence of agronomic superiority (Stone 2007:82–83), it rocketed to wild popularity across the district; in one village, 96% of all cotton-buying households bought at least one box of this seed, out of over 60 available seeds.

The interpretation of Indian farmers’ adoption of Bt seeds is itself quite politicized [47], but Stone’s argument is that the spread of Bt seeds would exacerbate agricultural deskilling and herding [6]. There are concrete reasons to expect the spread of Bt seeds to have such an effect, and also sound reasons to expect this to result in intensified herding. Bt cotton was predicted to have this effect because it brought a new category of accelerated technological change: not only a flood of new seeds containing the original Bt gene, but then a procession of new Bt genes and events. Each event behaves differently, and its behavior also varies with the genetic background into which it is bred [48]. By 2009, Bt seeds had totally replaced conventional seeds in Warangal, and technological change had been further accelerated by the incorporation of six different events in 522 different hybrids [49]. By 2012, 1128 Bt hybrids had been approved nationwide and a plethora of new constructs were being tested [50,51]. The profusion of constructs greatly exacerbated the problem of unrecognizability: the farmers had little inkling of what to expect from the different combinations of genes and regulatory sequences, and advice from input vendors was sketchy and unreliable.12 Indeed, many farmers in Warangal do not even know that they are planting Bt seeds.13 Meanwhile the problem of inconsistency has in some ways worsened as the fluctuations in pest populations have been changed, but not mitigated, by Bt seeds. During the first few years of widespread Bt seed use, predation by Lepidopterans did

---

11 See note 1 for explanation of transformation events.
12 Stone also predicted that deskilling would be exacerbated by the “unprecedented wave of wildly contradictory advertising, campaigning, and lobbying aimed at farmers, with false information being spread by its backers and detractors alike” (Stone 2011:394).
13 In 2013 interviews in Warangal villages, numerous farmers responded that they did not know if they were growing Bt, or that they were not, although all seed sold in the area are Bt. Flachs attributes some of the confusion to uncertainty over whether Bt refers to a company or a brand.
decrease, but aphid attacks surged [6]; in recent years, despite the procession of Bt constructs, predation by Lepidopterans has returned. (In the sample of farmers described in note 13 over half reported Lepidopterans such as Helicoverpa sp. and Spodoptera sp. as the most serious insect pest.) In sum, all three causes of agricultural deskilling have worsened.

Since deskilling had been indexed in previous research by herding, we set out to collect a longer run of seed choice data to look at what diachronic patterns would emerge in farmer decision-making, with particular interest in increased herding. We can now report on long-term herding and also draw on additional ethnographic findings to further illuminate the social dynamics of emulation.

5. Longitudinal analysis

Data on agricultural decision-making and production in Warangal have been collected from 2002 through 2012. Stone’s initial analyses [5,19] used data from nine villages between 2002 and 2005, and he later [6] used data on a subset of four villages to analyze impacts of Bt seed adoption between 2003 and 2007. The villages – Kalleda, Ravaruru, Saireddypally and Gudeppad (Fig. 5) – were selected to provide a cross-section of growing conditions, ethnic groups, wealth, caste, and information connectivity [6].

Farmers were randomly sampled. Surveys obtained seed choice data from these villages through 2012, with a gap in 2009–10 in Saireddypally and Gudeppad. Farmers often buy two or sometimes more brands each year (primarily in an attempt to generate comparative payoff information, although such experiments are often in vain as noted in Fig. 4). Each brand bought each year is recorded as a choice. Comprising data on 3162 cotton choices over 11 years, this dataset provides a picture of the longitudinal dynamics of decision-making (see Table 1).

In this analysis the variable % OF CHOICES gives the percentage of all cotton choices in a given year accounted for by a given seed. The variable % OF HOUSEHOLDS gives the percentage of all cotton-buying households that bought at least one box of a given seed. For example, if every household bought one box of Brand X and one box of some other seed, % OF CHOICES would be 50% and % OF HOUSEHOLDS would be 100% for Brand X.

5.1. Village-level patterning

Let us first consider patterning at the village level. Fig. 6 shows % OF CHOICES for each village over the 11-year study, excluding rarely bought seeds. Four features warrant attention.

1. The 2005 stampede to RCH-2, assumed to be a short-term fad by Stone (2007), was just that: after accounting for 44% of all seed choices in 2005 (and with % OF HOUSEHOLDS rising to 96% in one village, as discussed below), this seed had dropped to 12% by 2007 and 0% the next year.15

2. The RCH-2 fad was preceded by a fad for Brahma and was followed by comparable fads for Mallika and then for Neeraja and Dr. Brent. Neeraja and Dr. Brent are separate brands, but for some purposes they may be lumped in the analysis. They are from the same company, released around the same time, contain the same Bollgard II event, and are often treated as interchangeable by local farmers. For instance, when one village commissioned a buyer to smuggle in seeds from a neighboring state (described below) many farmers put in an order for “Neeraja or Dr. Brent”.

3. Seed fads have continued to be consolidated since 2005. Between 2002 and 2004 there were many instances of localized fads: Gemini in Kalleda, Bunny in Ravaruru, Brahma in SRP, and Chitra in Gudeppad [5]. But from 2005 on, all villages usually had the same favorite seed. This is one sense in which herding has increased with the spread of Bt seed.

4. Also striking is the trajectory followed by most fads, with low adoption being followed by a sharp 1-year peak and then a drop-off. The shape of fads is discussed further below.

5.2. District-level patterning

Fig. 7 shows district wide figures (all 4 villages combined) for % OF CHOICES for the most popular seeds, and Fig. 8 shows % OF HOUSEHOLDS for top fad seeds in specific villages as well as for the entire sample. Four points are of particular interest.

1. Herding has indeed continued and intensified as per predictions, as seen in fads and measured both by % OF CHOICES and % OF HOUSEHOLDS at the district level. The lack of agroecological rationale for seed popularity, documented in previous studies, has persisted. Asked what desirable properties Neeraja or Dr. Brent offered in 2012, farmers gave highly contradictory answers (see Stone (2007:81) for more on farmer knowledge of seeds).

2. The increasing consolidation of fads across villages is especially striking at the district level. This appears to indicate erosion of the local nature of indigenous

---

14 Gudeppad is a village of around 1100 in an area with a relatively high percentage of “black cotton soil” that is generally regarded as best suited to cotton cultivation. This area also has the highest percentage of land planted to cotton in Warangal; indeed the heavy reliance on cotton has left the area vulnerable to downturns in the cotton market, which may help explain why it has been plagued with Warangal’s highest rate of farmer suicide [52]. Gudeppad has a largely indigenous non-tribal population with a range of castes represented. In a measure of information connectivity, it measured medium–high [6]. Kalleda and Ravaruru are in a generally poorer area, with little black cotton soil and a lower commitment to cotton cultivation. Kalleda, with a population of around 3,000, is similar to Gudeppad in ethnic and caste composition but information connectivity is Medium-Low. In Ravaruru, with a population around 800, the population is mostly tribal (Lambadi or Ghor), with very low levels of education and low information connectivity. Saireddypally has a population of around 1500 and a moderate percentage of black cotton soils. Its population is dominated by Andhra (mostly Kamma caste) farmers who immigrated from coastal areas several decades ago. These groups tend to be prosperous, educated, and with high information connectivity.

15 RCH-2 was first introduced in 1992; its Bt variant was introduced in 2004. It was still on the market as of summer 2013.
knowledge that various writers have identified as key to smallholder production [53,54]. Word on the hot seed travels across the district, driving adoptions regardless of local conditions. Fad peaks tend to be times of optimism, as the large numbers of farmers using the same seed builds confidence that the season will be profitable. When the seed inevitably fails to deliver widespread prosperity, villages tend to turn inward, often developing local mini-fads (Fig. 6), until a major fad begins anew.

3. The longitudinal data reveal fads remarkable in their periodic regularity, peaking every 3 years. Fig. 7 provides a composite picture of fads by selecting the top 10 seed fads for each village, aligning their peaks, and averaging their village-specific market shares. Fads on average rise rapidly to a sharp 1-year peak after which they decline at approximately the same rate. The herd does not return to previous fed seeds with the notable exception of Brahma, which appears to have a special role as the fallback seed after its fad had run its course (note 2006 and 2009 in Fig. 7).

4. The intensity of the herd effect is better indicated by the % OF HOUSEHOLDS patterns in Fig. 8. Note the several instances in which over ¾ of village households bought the fad seed, and the case of Gudeppad in 2005 when a full 96% of farms bought RCH-2. In many cases these numbers would have been even higher had shops not run out of fad seeds.

6. Adoption and disadoption

One of the most robust findings in innovation adoption research is the s-curve noted above. Mathematically, this is the cumulative frequency distribution of a normal curve; in terms of underlying dynamics it reflects the generalized sequence described by Rogers, Bass and others in which a small group of innovators is followed by a rapid acceleration of adoptions and then a proportionate dropoff due to saturation. As noted above, the slope of the adoption curve results from environmental learning combined with social learning [12]. This is a model of actors choosing between two states: old mousetrap vs. new mousetrap, in the terms used above. But when there are successive generations of technology, as modeled by Norton and Bass [13], the underlying dynamic is assumed to be driven by a procession of better mousetraps. For instance, the pattern of curves in Fig. 3 depicts adoption of DRAM chips that are released as the engineers produce greater power and more speed.

Table 1
Numbers of farmers surveyed and cotton seed choices for four villages, 2002-2012.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Kalleda</td>
<td>Farms</td>
<td>40</td>
<td>29</td>
<td>34</td>
<td>27</td>
<td>11</td>
<td>22</td>
<td>23</td>
<td>12</td>
<td>12</td>
<td>32</td>
<td>24</td>
<td>428</td>
</tr>
<tr>
<td></td>
<td>Choices</td>
<td>53</td>
<td>37</td>
<td>50</td>
<td>37</td>
<td>16</td>
<td>37</td>
<td>49</td>
<td>22</td>
<td>23</td>
<td>53</td>
<td>51</td>
<td>428</td>
</tr>
<tr>
<td>Ravuru</td>
<td>Farms</td>
<td>36</td>
<td>30</td>
<td>63</td>
<td>71</td>
<td>30</td>
<td>62</td>
<td>63</td>
<td>31</td>
<td>32</td>
<td>42</td>
<td>41</td>
<td>841</td>
</tr>
<tr>
<td></td>
<td>Choices</td>
<td>39</td>
<td>31</td>
<td>73</td>
<td>95</td>
<td>39</td>
<td>113</td>
<td>125</td>
<td>52</td>
<td>80</td>
<td>92</td>
<td>102</td>
<td>841</td>
</tr>
<tr>
<td>SRP</td>
<td>Farms</td>
<td>17</td>
<td>20</td>
<td>80</td>
<td>66</td>
<td>36</td>
<td>57</td>
<td>58</td>
<td>0</td>
<td>0</td>
<td>39</td>
<td>39</td>
<td>887</td>
</tr>
<tr>
<td></td>
<td>Choices</td>
<td>29</td>
<td>31</td>
<td>140</td>
<td>93</td>
<td>65</td>
<td>132</td>
<td>136</td>
<td>0</td>
<td>0</td>
<td>116</td>
<td>145</td>
<td>887</td>
</tr>
<tr>
<td>Gudeppad</td>
<td>Farms</td>
<td>67</td>
<td>66</td>
<td>90</td>
<td>68</td>
<td>44</td>
<td>60</td>
<td>61</td>
<td>0</td>
<td>0</td>
<td>31</td>
<td>35</td>
<td>1006</td>
</tr>
<tr>
<td></td>
<td>Choices</td>
<td>143</td>
<td>150</td>
<td>189</td>
<td>78</td>
<td>59</td>
<td>127</td>
<td>128</td>
<td>0</td>
<td>0</td>
<td>58</td>
<td>74</td>
<td>1006</td>
</tr>
</tbody>
</table>

Fig. 5. Map of Warangal District and study villages.
These are highly trialable performance traits; accurate payoff information is readily obtainable and users have no problems with inconsistency, unrecognizability, or rate of change.

Despite its resemblance to the Norton-Bass adoption curves, several lines of evidence indicate that the underlying dynamic in Warangal seed choices is fundamentally different. The model of successively “better mousetraps,” each with advantages discernible to users, fits cotton seed choices only weakly. While there may be improvements in seeds that are statistically discernible under controlled conditions, it is virtually never the case that a new seed offers a consistent and recognizable benefit to the farmer. In the much-discussed case of illegal Navbharat-151 seeds in Gujarat [55,56], one seed apparently did offer a readily discernible advantage, but its uniqueness makes it an exception that proves the rule. This locally-adapted hybrid, bred by a Gujarat seed company, contained an unapproved transgenic Bt trait. In 2001, as a severe outbreak of bollworms decimated many farmers’ fields, the seed was said to visibly outperform others; this was probably due to some combination of superior germplasm and the Bt trait to which the pests had not yet developed resistance. But we know of no other cases where a single seed had given a consistent and demonstrably greater yield than others. Normally, yields and profits from any given seed are highly variable, as seen in Stone’s ([5] Fig. 9) analysis of yields for 17 top seeds.

Rollouts of new transgenic traits have corresponded poorly with Warangal seed fads. The 2005 rush to the Bt version of RCH-2 can be linked to Bt seeds having been on the market for four years, but the Mallika seed that replaced RCH-2 in 2007 contained the same technology (event 531), and moreover Mallika was only one of dozens of seeds in local shops containing event 531. More importantly, 2007 was the same year seeds containing the new event 15985 appeared in stores. The 2011 fad seeds do contain the 15985 event, but so do the fad seeds that were rising in 2012.

Aggregate trends in seed performance also are inconsistent with progressively better mousetraps: trends in cotton yields do not correlate well with the spread of Bt seeds in general or with adoptions of specific Bt events [32,34,57].

Finally, ethnographic evidence shows a strong and consistent pattern of farmers conforming to seed fads with scant environmental payoff information, as in information cascades, rather than responding to signals that an improved seed has arrived. Asked what characteristics the year’s fad seed has, farmers give wildly contradictory answers. Even if a seed performs well one year, a farmer may readily drop it after hearing about the popularity of another seed. (In one extreme case, nine years of success with one seed were disregarded in favor of untested seeds seen to do well in other fields.) Farmers’ commentaries on seed trends also are inconsistent with the recognition of better mousetraps; for instance, there was no consensus on RCH-2’s and Mallika’s dramatic falls from grace, with farmers citing a wide range of cases or more commonly saying they just felt like trying something new.
In sum, while seed choices are obviously not completely unrelated to field performance, the assumption of agroecologically better mousetraps that recognizably outperform competitors is unsatisfactory. A seed may become locally faddish for reasons that had little to do with payoff information, and it may drop out of favor in the absence of any consensus on its limitations.

Some surprising social dynamics of seed choice are revealed by ethnography. Stone reported seed fads being instigated by factors such as advertising campaigns or a...
new seed being pushed by a local vendor who got a higher profit margin on it [5]. But there are also cases of overt group decision-making that defy classic models of decision-making. As Orléan (1995) points out, the assumption of sequential decision-making (as in information cascade theory) is unrealistic, and this is exemplified in Warangal. One Warangal thanda (small tribal village) held a group meeting in 2008 in which the farmers decided as a group to all plant the same seed (eventually all but a few did buy the seed – Mallika). While their own explanations of the group decision were inconsistent, it seems plausible as an attempt to improve the quality of local environmental payoff information: by holding constant the seed being planted, the villagers turned that season’s farming into a more instructive experiment.

A different form of group decision-making was also evident in one of our sample villages in 2012. Anticipating a shortage of popular seeds produced by the Mahyco company, district authorities in Warangal issued permits that guaranteed individual seed packets to specific farmers at specific shops. Naively designed to curb a black market, the permit system effectively created one, with permits acting as tacit endorsements of the seed’s supposed virtues. The ‘prestige’ of the state involvement helped to exacerbate the fad, and seeds sold by brokers and unscrupulous shop owners commonly fetched more than double the guaranteed state price of Rs 930. Lacking permits or otherwise unable to purchase their favorite seeds due to the shortage, members of this village pooled resources between relatives, friends, and neighbors to send delegates to the neighboring state of Maharashtra to buy seeds on the black market and smuggle them across the border. Lower caste neighbors looked to high caste, larger farmers, usually following their choice of Neeraja/Dr. Brent. The community paid for their smuggler’s transportation and expenses as well as a markup for the seeds in exchange for a guarantee of their favorite brands. However, seed brokers were warned that police from Andhra Pradesh had established checkpoints on the border to Maharashtra, leading entrepreneurial smugglers to hide seeds in containers for non-permit brands, bribe border guards, or even hide seed packets in their headscarves and turbans. All of this increases uncertainty and risk, both introducing potentially fake seeds and denying the official receipts that insure farmers against widespread seed failure. Such wild popularity was fleeting: planting of the four permitted Mahyco seeds crashed from 61% of all seeds planted in 2012 (with Neeraja and Dr. Brent accounting for 48% by themselves) to 45% in 2013 (with Dr. Brent and Neeraja accounting for 34%).

Given these underlying dynamics, it is interesting to look at the generalized pattern of the seed fad. Fig. 9 shows the curve produced by averaging the top 39 village seed fads; the variable % OF CHOICES within each village was plotted for each popular seed, the peak years were aligned, and the values were averaged for 3 years on either side of the peak. The adoption curve clearly approximates a normal distribution, if somewhat more peaked (leptokurtic) than the curves in the Rogers and Norton-Bass models.

7. Conclusions

Analysis of this unusual dataset has generated three sets of findings that merit highlighting. The first concerns the continuing impacts of GM seed technology. Previous studies theorized and documented evidence for agricultural deskilling in Warangal. While the deskilling preceded the arrival of GM seeds, those seeds were predicted to exacerbate its underlying causes of unrecognizability, inconsistency, and rapid technological change. Our general expectation is that farmers should rely increasingly on emulation as environmental payoff information is decreasingly reliable [40], and our specific expectation was that the rapid spread of poorly-understood, rapidly-changing and difficult-to-trial technologies in new genetic backgrounds would lead to increased herding (Stone 2007; Stone 2011). The intensification of herding as evidenced by the rising peakedness of fads does not offer conclusive proof of exacerbated deskilling; it is difficult to definitively attribute such trends in agriculture to single factors. However it certainly is consistent with the prediction of increased deskilling. The intensified herding helps to confirm the underlying theory of types of learning, in that an extreme lack of reliable payoff information leads to copycat decision-making to overwhelm better mousetrap assessments.

Exacerbated deskilling resulting from quickening technological change in Bt seeds is clearly relevant to the contentious debates on the use of adoption as an index of positive farmer assessment of the new technologies. This analysis points to the conclusion that blanket characterizations – as “smart” evaluators of new technologies or as incapable of learning – are folly. Skilling is situational: rigorous assessment of successive “mousetraps” is virtually impossible in the worsening information environment described here.

Second is the surprising finding of a strong regular periodicity in fads. While the periodicity in adoptions bears a striking resemblance to the Norton-Bass predictions for successive substitutive adoptions, we believe it is being driven by a different dynamic. Norton and Bass assume the periodicity of successive products to be driven by external invention and business decisions, but this periodic cycling appears to be entirely internal to the social process of emulation and herding. Repeated four times, the cycle is highly unlikely to be accidental; we can even predict that Jackpot seed will account for at least 50% of district-wide cotton choices by 2014, to be followed by a crash in sales.

Fig. 9. Shape of major fads. The top 39 village fads were aligned so that their peaks coincided, and percentages were averaged.
The final set of insights concerns disadoption. This is interesting given that investigation of seed choices was initially conceived as an inquiry into adoption – using seed adoption as a window into agricultural decision-making in challenging environments, in a country where we (and many others) were keenly interested in adoption of GM seeds in general. In the end it does provide a unique view of decision-making, but with particularly notable dynamics pertaining to disadoption. The cycles of disadoption that give the curves their distinctive shape differ from the drop-offs in simple adoption models, which come from the rapid shrinking of the pool of those who have yet to adopt. They also differ from the drop-offs in models of successive adoptions, which occur as buyers move towards a mousetrap shown to be better by payoff information. The valleys in the fad curves represent the dissolution of widespread and enthusiastic herds; they are periods of disparate casting about, indicating that hopes of striking gold have again been thwarted.

Funding

Stone’s research in India has been supported by the National Science Foundation under Grants No. 0314404 and 0078396; by the Wenner-Gren Foundation for Anthropological Research; by Washington University; and by the John Templeton Foundation. Fieldwork by Flachs was funded by the Lynne Cooper Harvey and Jacob K. Javits Fellowships; by Washington University; and by the John Templeton Foundation. Fieldwork by Diepenbrock was funded by Washington University.

Acknowledgments

Some of the data collection was overseen by A. Sudarshan Reddy, and some data were collected by Fiona Sloan as a participant in Washington University’s Village India Program. For logistical support we are grateful to the Rural Development Foundation.

References

[51] GEAC (Genetic engineering Approvals Committee. Genetic engineering Approvals Committee, Yearwise list of commercially released varieties of Bt cotton hybrids by GEAC (Year 2002-Upto may, 2012); 2012.

Glenn Davis Stone is Professor of Anthropology and Environmental Studies at Washington University in St. Louis. He is an anthropologist whose research focuses mainly on ecological, political, and cultural aspects of agriculture; in recent years he has been particularly interested in issues relating to genetically modified crops and to alternative farming. He has been conducting fieldwork in India since 2000, as well extensive fieldwork in Nigeria, the Philippines, and rural North America. He is president of the Anthropology and Environment Society and author of the blog FieldQuestions.com. Andrew Flachs is an Oberlin graduate, currently a PhD Candidate at Washington University. His research interests include indigenous knowledge and agricultural change in both North America and South Asia. He conducted ethnographic fieldwork in Warangal District in 2012 and 2013, Christine Diepenbrock majored in Biochemistry at Washington University and also studied food security. She conducted several research projects under Stone’s supervision, including fieldwork in Warangal in Summer 2012. Now in the PhD program in Plant Breeding and Genetics at Cornell University, her focus is on field-based phenotyping and improved nutritional quality of food staple crops.