13 Investigating Farmers' Knowledge and Practice Regarding Crop Seeds: Beware Your Assumptions!

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Supporting small-scale traditionally based agriculture is increasingly seen as a viable and desirable alternative to the large-scale industrialized food production system (IAASTD, 2009; De Schutter, 2010). We and others believe that local farmers' knowledge (FK) and practice is an essential element for successful, mutually respectful partnerships between farmers and formally trained scientists to support and improve traditionally based agriculture in ways that are socially equitable and environmentally sustainable. Much of our research conducted with colleagues has focused on understanding FK and management of crop genetic diversity. We have emphasized observation and quantitative analysis of farmers' practices and their results to understand their biological and genetic consequences, and elicited farmers' knowledge through posing questions based in the contexts of their experiences (Soleri and Cleveland, 2009).

This work grew out of testing the general hypothesis, based on our informal experiences, that the cognitive abilities of resource-poor and often illiterate farmers are no different than those of other humans, including scientists, and that farmers' practices make sense in their local contexts. In the process of conducting this research we have also identified the untested assumptions of researchers that contrast with our general hypothesis. Testing those assumptions has helped us to formulate specific alternative hypotheses that speak directly to strategies for agricultural research and change. In the process, we have tested hypotheses about many aspects of FK and practice and have been most surprised, and learned the most, when our own assumptions have not been supported. In this chapter we describe three examples of such surprises and how they pushed us to a more profound and useful understanding of our own knowledge and assumptions, as well as FK.

Common Assumptions about Farmer Knowledge

Much of the discussion of and research on FK is based on its assumed degree of similarity with formal Western scientific knowledge (SK) in terms of its reflection of empirical reality and its capacity to effectively address farmers' needs. Here (Box 13.1) we outline three common essentializing views of farmers and associated assumptions about FK and practice that require testing and add our own fourth perspective.[1]

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Box 13.1. Views and assumptions

(a) The ignorant farmer
FK is different from and inferior to SK. The professionalization of science contributed to the divide between farmers and the formally trained researchers who were often part of organizations that defined science as a unilineal progression from informal inferior knowledge to superior ways of understanding the world. 'Development' was premised on the assumption that FK is different from and inferior to formal Western knowledge, even among scientists who empathized with farmers.

(b) The barefoot scientist farmer
FK is similar but inferior to SK. Documentation of some positive empirical outcomes of applying FK that were consonant with the outcomes of applying Western SK, and with the goals and logic of Western society, produced another view of FK. In this view FK is similar to SK, but hampered by lack of tools and methods. From this perspective farmers were seen as diminutive versions of formally trained scientists.

(c) The wise farmer
FK is different from and superior to SK. The view that FK is superior to SK was based in part on evidence that FK often seemed to have positive and sometimes superior efficacy in, and sometimes beyond, local contexts, and based on social and environmental failures of formal science in agricultural development. This frequently led to a value-based argument for the superiority of FK and belief in a mythical wise farmer who was ecologically and ethically better than scientists. It became easy to conflate challenging negative stereotypes through empirical research with an uncritical reification of FK.

(d) The complex farmer
Our overarching hypothesis is based on a holistic, dynamic view of knowledge – depending on the context, FK can be both different from and similar to SK, and both superior and inferior to SK in terms of its efficacy in advancing social and environmental sustainability. For example, both farmers and scientists are often able to describe accurately or predict empirically verifiable outcomes of crop genotype × environment interactions under conditions within their own experiences, but not able to do so under conditions beyond their experiences (see below).

By taking the complex farmer approach, we thought we could avoid the unfounded, essentializing assumptions of other common perspectives on FK. However, it was unavoidable that we also made untested assumptions about FK, including farmer goals and motivations. These were sometimes based on what we thought they *should* be, influenced by our own values and our understanding of Western science. But because we were also aware that our assumptions could misrepresent farmers' values and experiences in the absence of actual research, we tested our assumptions as hypotheses, sometimes with surprising results. This chapter describes three examples of such surprises. We also suggest how others doing similar research can minimize chances of undermining their understanding with their own untested assumptions. But first we describe our basic methodology.

Our Methodology

Our overarching methodological goal was to investigate farmers' knowledge about agriculture in farmers' own terms, that is, using elements and contexts they were familiar with, or could easily imagine. A key component of this methodology is what we refer to as an ontological comparator, which allows us to avoid, as much as possible, using SK as the standard for evaluating FK when testing hypotheses (Soleri and Cleveland, 2005, 2009). We define ontological comparators as basic models of reality that can be used as relatively neutral common referents to evaluate both the farmer's and the scientist's understanding of empirical reality, and expectations based on that understanding. As Western scientists, we defined these comparators using the most basic knowledge as described by Western science, about which there is no disagreement, although scientists often disagree about the interpretation and use of this basic knowledge at higher levels. For example, we would consider the statements that 'water moves from higher to lower levels' and that 'plants need water to produce a harvest' to be ontological comparators. Scientists and others recognize these simple statements, yet can disagree about their application due to their different experiences and assumptions and the different contexts in which they are applied; for example, the amount of water that should be applied to a field to optimize yield. The fact that scientists disagree about how the basic knowledge of the ontological comparators is applied supports their use for investigating FK and SK.

Another key component of our methodology is scenarios, which are often based on ontological comparators and which create hypothetical situations within which farmers can apply their knowledge (Soleri and Cleveland, 2005). Scenarios depict genotypes, environments and situations with which farmers are familiar, such as the variable resource-limited environments of their fields. But scenarios can also present novel situations that farmers can imagine and extrapolate to, based on their experience, such as uniform growing environments without significant resource limitations. We often use props to make it easier for farmers to participate, such as photographs of plants, seeds from their own harvests, or stones of different sizes to represent different amounts of annual rainfall. We have found that farmers from many different countries, growing different crops in different environments, all participate enthusiastically in responding to these scenarios.

For example, we documented farmers' expectations for phenotypic variation across familiar and novel growing environments, and their distinction between high and low heritability phenotypic traits (Soleri and Cleveland, 2001; Soleri *et al.*, 2002). While we found that both farmers and plant breeders are aware of the components of phenotypic variation (Box 13.2, eq. 1), and use that knowledge to achieve their goals, both FK and SK were also affected by the limited experiences of farmers and scientists. We found that most farmers may not see or have access to genetic variation for low heritability traits such as yield, even though such variation exists, because it is hidden by the high level of environmental variation in their fields (Fig. 13.1). This means they may not carry out seed selection for traits like yield, even though it is important to them.

On the other hand, plant breeders may not be aware of qualitative genotype-by-environment interactions among different crop populations because they have not experienced the range of variation in growing environments that farmers work with (Ceccarelli, 1996). This means that their assumption about phenotypic traits like yield can be biased by their relative lack of experience, for example in predicting the performance of varieties across environments (Cleveland

Box 13.2. Equations describing basic biological models used

In our research we have primarily used ontological comparators about the relationship between plant phenotypes, plant genotypes and plant environments, and about the determinants and results of plant selection, using as ontological comparators the basic biological models described in the following equations:

- **the source of phenotypic variation:**

$$V_P = V_G + V_E + V_{GXE} \quad \text{(eq. 1)}$$

which states that phenotypic variation (V_P) is the result of variation in genotype (V_G), environment (V_E) and genotype-by-environment interaction (V_{GXE});

- **the heritability of that phenotypic variation:**

$$H^2 = V_G/V_P \quad \text{(eq. 2)}$$

which states that broad-sense heritability (H^2) is the proportion of phenotypic variation accounted for by genotypic variation; and

- **the determinants of the response to selection:**

$$R = h^2 S \quad \text{(eq. 3)}$$

which states that the phenotypically expressed genetic gain due to selection (R) is the product of narrow-sense heritability (h^2), and the selection differential (S), where S is the phenotypic difference between the selected individuals and the population from which they are selected.

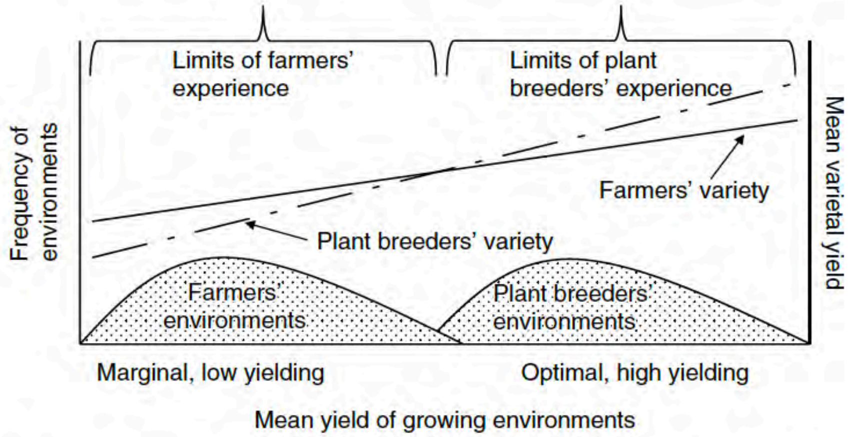

Fig. 13.1. Different experiences affect knowledge and practice. (From Soleri *et al*., 2002, used with permission, partially based on Ceccarelli (1989, 1996)).

and Soleri, 2002). This example of farmers and scientists agreeing on some aspects of empirical reality, but not on others, supports our use of ontological comparators. Different contexts, and different experiences, values and goals, can result in differences in interpretations and expectations between farmers and scientists, but also among farmers, and among scientists.

In addition to questions based on an ontological comparator, we also elicited farmers' own opinions of a technology, based on their personal experiences and values. This was one part of the first research example described below.

Example 1: Farmers' Perceptions of Risk and Transgenic Maize

Discussions about transgenic crop varieties became particularly heated in 2001 when Quist and Chapela (2001) reported transgenes present in a small sample of traditional maize plants in Oaxaca, Mexico. The polarized debate included declarations about what this meant for small-scale traditional farmers, and advocates with conflicting views claiming to represent farmers' best interests. For example, the flow of transgenes to farmers' traditional maize varieties was described as 'crime against all the indigenous peoples and farmers who have for millennia protected [maize], for humanity to be able to enjoy' (Melina Hernández Sosa, of UNOSJO, an Oaxacan non-governmental organization (NGO), cited in Vélez Ascencio, 2003), or alternatively as a welcome addition which augments Mexican farmers' varieties and agriculture and which they are lucky to get for free (AgBio View, 2002). However, there was no systematic attempt to document and understand what farmers themselves thought about transgenesis or transgenic varieties (TGVs) and the risk those might pose; that is, there was no attempt to engage farmers beyond discussing their preferences for a final product in the form of a maize variety.

Eliciting preferences among a limited number of predefined finished technologies has been a common way to use FK in agricultural development. For example, researchers in Kenya asked maize farmers if they had trouble with stem borers (a major pest in the area) and interpreted their affirmative answer as implying that they wanted transgenic stem borer-resistant maize (KARI and CIMMYT, 2007). To address the lack of direct comments by farmers, we conducted research on perceptions related to transgenic maize with 334 farmers reliant on maize for food and livelihood in six communities, two each in Mexico, Guatemala and Cuba (Soleri *et al*., 2005, 2008).

What did we hypothesize?

Our goal was to ask farmers' opinions regarding fundamental aspects of transgenic maize in order to facilitate their evaluation of the complex issues involved. We wanted to document their responses so that they could be included in discussions about policy and practice. We hypothesized that farmers would reject the new technology, based on our assumption that they were committed to their traditional farming and maize varieties and were distrustful of unfamiliar technologies introduced from the outside, and their associated risks.

How did we test our hypotheses?

To elicit FK about transgenic varieties in a manner that did not over-simplify the varieties or eliminate farmers' perceptions of risk or opinions on key aspects of them, we deconstructed transgenic maize (Fig. 13.2) into the transgenic technology itself, the variety it was present in, and its possible consequences. We first asked farmers about the technology of transgenesis per se, by describing a process in which a property from another kind of plant or animal could be inserted into maize seed in a laboratory by scientists (Fig. 13.2a). We stated that when planted the seed would grow normally, but the plant would have that inserted property, using the example of resistance to damage by caterpillars.[2] After this description we asked farmers if they thought the process was good, bad, or depended on the outcome. We then asked farmers about varieties that were different combinations of technology (transgenic or not) and with different genetic backgrounds (farmer and modern varieties) (Fig. 13.2b). This is because transgenesis could in theory be used in farmers' varieties, not only in the proprietary hybrids where it has been applied, and evaluations of transgenesis and genetic backgrounds are often confounded. We did this by asking farmers to rank their preferences among four maize varieties: their own local farmers' variety (FV); a familiar modern variety (MV) in the form of a hybrid sold in local seed stores; their FV with 'properties' (e.g. transgenic, TGFV); and the MV with 'properties' (e.g. transgenic, TGMV). Finally, we asked farmers about some of the potential consequences of using a transgenic maize variety in their fields (Fig. 13.2c), including the need to acquire seed of a new variety from the formal seed system after 6–7 years when yields of currently used varieties declined (as might occur due to the evolution of resistance in the caterpillar that had been controlled by that variety), and the cost of that seed (Table 13.1).

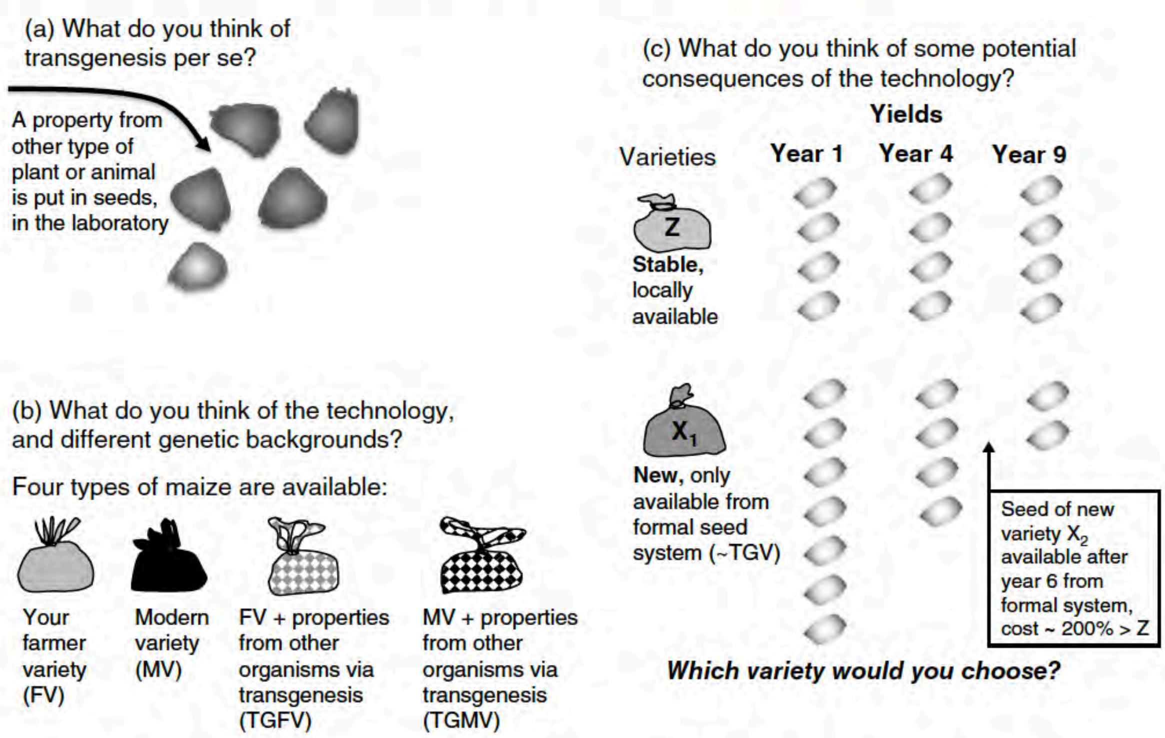

Fig. 13.2. Deconstructing transgenic maize for farmer assessment.

Table 13.1. Farmers' opinions and risk perceptions regarding transgenic maize: questions and responses (data from Solani *et al.*, 2005).

			Country		Community	
Question	Our assumption	Actual finding (summary)	Name (*n*)	%	Name (*n*)	%
Is transgenesis per se good, bad, or depends only on the outcome?	Farmers would be unified in rejecting the technology per se, saying it is bad / unacceptable because it is unknown, may be considered a violation of culturally significant maize, and from an outside system that some mistrust	Our assumption, tested as a hypothesis, was not supported by a majority of farmers; responses varied substantially by country and by community	Responses that transgenesis is unacceptable			
			Cuba (114)	42%	La Palma, Pinar del Rio (56)	28%
					Mayorquín, Holguin (58)	55%
			Guatemala (110)	17%	El Rejón, Sacatepequez (55)	33%
					La Máquina, Suchitepequez (55)	2%
			Mexico (110)	43%	Santa Inéz Yatzeche, Oaxaca (55)	51%
					Comitancillo, Oaxaca (55)	35%
			Total (334)	34%		
Which genetic background is preferable for maize for your family to eat?	Farmers would be pro-FV,[a] they would prefer local FV-based varieties above all others because of preferred culinary and gastronomic qualities; their top two most favoured varieties would be FV and TGFV[b]	Our assumption, tested as a hypothesis, was not supported. The most common ranking pattern was anti-transgenic, ranking any non-transgenic variety as better than any transgenic ones; their top two most favoured varieties were FV and MV[c]	Anti-transgenic responses			
			Cuba (114)	64%	La Palma, Pinar del Rio (56)	50%
					Mayorquín, Hollguin (58)	78%
			Guatemala (110)	76%	El Rejón, Sacatepequez (55)	80%
					La Máquina, Suchitepequez (55)	73%
			Mexico (110)	74%	Santa Inéz Yatzeche, Oaxaca (55)	71%
					Comitancillo, Oaxaca (55)	76%
			Total (334)	71%		
Which variety would you choose? (See Fig. 13.2)	Farmers would reject variety representing TGV[d] because of consequences	Our assumption, tested as a hypothesis, was supported for the large majority of farmers	Farmers choosing stable variety, not one with potential local consequences of TGV[d]			
			Cuba (114)	NA	La Palma, Pinar del Rio (56)	NA
					Mayorquín, Holguin (58)	NA
			Guatemala (110)	83%	El Rejón, Sacatepequez (55)	93%
					La Máquina, Suchitepequez (55)	73%
			Mexico (110)	90%	Santa Inéz Yatzeche, Oaxaca (55)	86%
					Comitancillo, Oaxaca (55)	94%
			Total (232)	86%		

[a]FV, farmers' variety; [b]TGFV, transgenic farmers' variety; [c]MV, modern variety; [d]TGV, transgenic variety

These questions were designed to elicit farmers' opinions based on their values and experiences, based in part on the ontological comparator that variation in a plant's phenotype is determined in part by what it consists of, i.e. by V_G as well as V_E (Box 13.2, eq. 2). In other words, farmers would understand that changing the makeup of plants, by inserting a property of another plant or animal, would change the plants' phenotypes.

What did we find?

We were surprised by the results, with more than 60% of farmers responding that if the technology has potential to increase their maize yields, they were open to considering it. Still, when asked to rank the four varieties for sowing, most farmers gave ranking patterns that placed any variety without transgenes (FV, MV) higher than transgenic varieties (TGFV, TGMV); that is, the technology itself may not be inherently negative, but that did not mean they would automatically accept it. However, farmers in one Guatemalan community, with high levels of agricultural commercialization and industrialization and already using MVs, ranked all varieties very closely, but with transgenic varieties favoured over non-transgenic ones. For eating, everyone preferred FVs, but overall ranking patterns showed 53% and 70% of farmers strongly disfavoured transgenic maize for both sowing and eating, respectively (Soleri *et al.*, 2008). Finally, a large majority of farmers did not accept the likely consequences of the technology, including dependence on the formal seed system for seed acquisition, higher seed costs and the need to replace varieties periodically due to declining yields. For the farmers we interviewed, increased dependence on formal seed systems, and the associated costs and risk, were substantial disincentives.

How did this change our understanding?

Based on our analysis of farmers' responses, and informal comments they made while discussing the questions, it became clear that our assumption regarding farmers' opinion of transgenesis per se was simplistic and ignored their lived reality. Instead of a simple rejection of technology and resistance to change, many of these farmers are looking for ways to improve farming and their lives in general. Their answers showed that they were open to change that could help them to do this, including consideration of novel technologies. However, farmers did not accept novel technology without question; they were not naïve and did not automatically trust new technology and its effects on their health and farming. Their responses indicated caution regarding both growing and eating the produce of a novel, unknown technology like the one we described. And that technology is unacceptable if it means increased reliance on systems beyond their control, like markets or the government for seed acquisition, or forms of exploitation which they have experienced in the past and which continue today. Our questions focused on some of the most basic issues surrounding maize TGVs; of course there are other aspects of TGVs to be investigated that we did not address in our research. But even with these limited questions we learned that to portray farmers as simply rejecting transgenic maize oversimplifies them as anti-technologists whose rigid culture excludes them from assessment of new technologies for potential adaptation to their circumstances and needs. It is equally true that a majority of these farmers would not willingly accept this technology based on the concerns expressed in response to questions (b) and (c) in Fig. 13.2. Farmers may not want TGVs, but many are interested in technologies and methods that can support and improve their farming and community in ways consistent with their values, their resources, and their social and biophysical environments.

Example 2: What Maize Farmers Expect and Accomplish with Seed Selection

On-farm seed selection and conservation is a characteristic of traditionally based farming systems, is critical for *in situ* conservation of crop genetic diversity and is increasingly considered part of a strategy for adaptive, resilient agriculture under changing conditions (e.g. Murphy *et al.*, 2005; Vernooy *et al.*, 2015). Research on seed networks in traditional farming systems has shown that they are often a combination of self-provisioned seed as well as frequent local exchanges, and less frequent experimentation with novel material, including MVs (e.g. Louette *et al.*, 1997; Soleri *et al.*, 2005). These practices are usually characterized by less stringent genetic criteria in selection and choice compared with those of scientists, allowing gene flow that generates and maintains crop genetic diversity, as has been documented in a number of studies, for example wild-crop gene flow in sorghum (Mutegi *et al.*, 2012) and clonal–sexual propagule gene flow in cassava (Elias *et al.*, 2001; Duputie *et al.*, 2009; McKey *et al.*, 2010).

On the other hand, precision by some farmers in selecting seed and choosing seed lots for diverse criteria can be greater than that of scientists, which can also function to maintain diversity. Indeed, at least some farmers are capable of extremely fine-grained classification and discrimination when they believe that this will be agronomically helpful (e.g. Worthington *et al.*, 2012) (see below).

What did we hypothesize?

We undertook this research to quantify and document farmers' seed selection and its outcomes. Using the response to selection as our ontological comparator (Box 13.2, eq. 3), our hypothesis was that when selection differentials are substantial – that is, when the difference between the mean of the selected plants is significantly different than the mean of the entire population they are a part of – then farmers, like plant breeders, are using seed selection to genetically change and improve their varieties. This was based on our assumption that, like formally trained scientific plant breeders, farmers believe this cumulative change will create crop populations that better serve their needs; that is, they are selecting for heritable change (Table 13.2). This widespread assumption is part of the legacy of the way in which selection has been conceptualized since Darwin (Cleveland and Soleri, 2007b). It was also based in part on our previous research with these farmers showing that they understood the difference between high and low heritability traits in their crops (Box 13.2, eq. 2) (Soleri and Cleveland, 2001). In retrospect, we fell into the trap of assuming that farmers were in a sense barefoot scientists, applying astute insights to overcome the methodological limitations they were working with, but having the same goals as plant breeders: a heritable, cumulative response to selection.

How did we test our hypothesis?

We designed a number of experiments to understand what a small sample of farmers ($n = 13$) expected to accomplish, and did accomplish, when they selected their own maize seeds on farm. These experiments quantified components of selection practice (Fig. 13.3), allowing us to investigate the contribution of each component to the response to selection. To do this, these experiments were based on the ontological comparators $H^2 = V_G/V_P$ and $R = h^2 S$ (Box 13.2, eq. 2 and eq. 3). In addition, we asked farmers why they selected seeds, instead of simply using a random sample from the same population, and in further research presented a much larger sample of farmers ($n = 380$) with a scenario (Fig. 13.4) based on the response to selection formula, comparing the outcomes when using selected versus randomly sampled seeds from the same original population.

What did we find?

When farmers' actual selection practices were quantified, we found that despite selection differentials (S) comparable to those achieved by plant breeders and an understanding of heritability (h^2), response (R) to farmers' key selection criteria (seed and ear size) was zero (Soleri *et al.*, 2000). That is, they were not producing a cumulative genetically based change in their maize populations as a result of their seed selection. Yet seed selection for those criteria was virtually universal among farmers, despite being costly in terms of their time and in a number of other ways (Table 13.3).

When asked directly why they selected seeds, instead of using a random sample, most farmers replied that this was their custom. In comparing the outcomes when using selected versus randomly sampled seeds in the scenario

Table 13.2. What maize farmers accomplish and expect to accomplish with seed selection (data from Soleri *et al*., 2000, 2002 and authors' surveys).[a]

Question	Our assumption	Actual finding (summary)	Selection differential (S) (response to selection (R) ≅ 0)				
			Location (n)	Ear diameter	Ear weight	Ear length	100-grain weight
What response to selection do farmers *accomplish* with their maize seed selection?	Significant selection differentials (S); cumulative response (R) in form of directional phenotypic change in selection criteria	Significant selection differentials, but no significant phenotypic change over generations (R = 0)	Oaxaca, Mexico (13)	0.95	1.14	0.88	0.85
			Proportion of farmers answering advantages of seed selection only last 1 year				
			Location (n)	%	Community (n)	%	
What response to selection do farmers *expect* with their maize seed selection?	Heritable, cumulative, phenotypic change, improvement, in selection criteria	No change, improvement that persists past 1 year	Oaxaca, Mexico (380)	82%	Four Central Valley communities (199)	81%	
					Four Sierra Juárez communities (181)	82%	

[a]*T-tests* for all S values significantly different from original 100 ear samples, $p \leq 0.05$.

(see Fig. 13.4), 82% of the 380 Oaxacan maize farmers responded that seed selection provides an advantage in the field for the first year after selection, but no cumulative phenotypic change over 10 years of selection (Table 13.2) (Soleri *et al*., in preparation, p. 1). That is, their expectation for what selection for these quantitative traits would accomplish is very different from plant breeders' expectations, and different from what we had also assumed.

Initially our findings were discouraging and perplexing to us; they did not fit our expectations, based on our assumptions, and did not seem to make sense given the costs associated with using selected seed. However, the results were not so surprising, given the fact that seed and ear size are quantitative traits strongly influenced by the environment. Still, as is always the case, there was variation among farmers' responses. While most farmers stated they selected large seeds for planting because it was their custom, three farmers among the original 13 commented that the selected larger seeds would grow better than unselected ones, though individual plants from these seeds would not yield more than randomly selected seeds. This comment led us to consider other ways in which selected seeds could provide an advantage over randomly selected ones, focusing on seed size.

Compared with many other crops, seed size in maize is relatively plastic (Sadras, 2007); that is, it can change a lot depending on the maternal plant's growing environment. Studies of maize have documented that larger seed size can provide significant advantages in the early stages of plant growth, including more rapid development (Pommel, 1990; Bockstaller and Girardin, 1994; Revilla *et al*., 1999). However, existing studies used materials, seed sizing parameters and environmental treatments relevant to

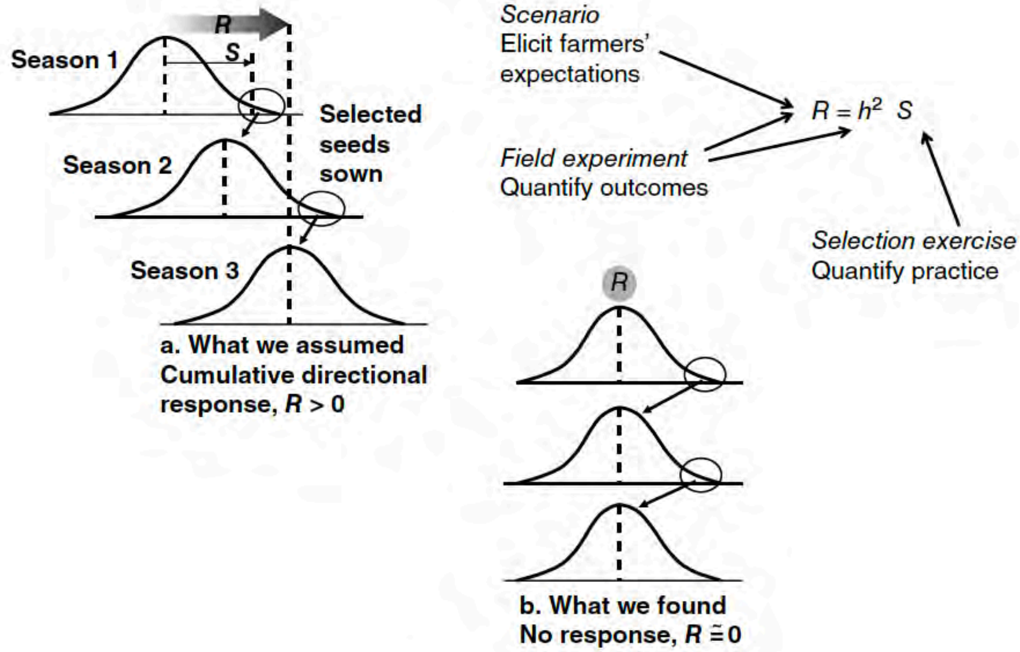

Fig. 13.3. Components of selection practice and how we quantified them.

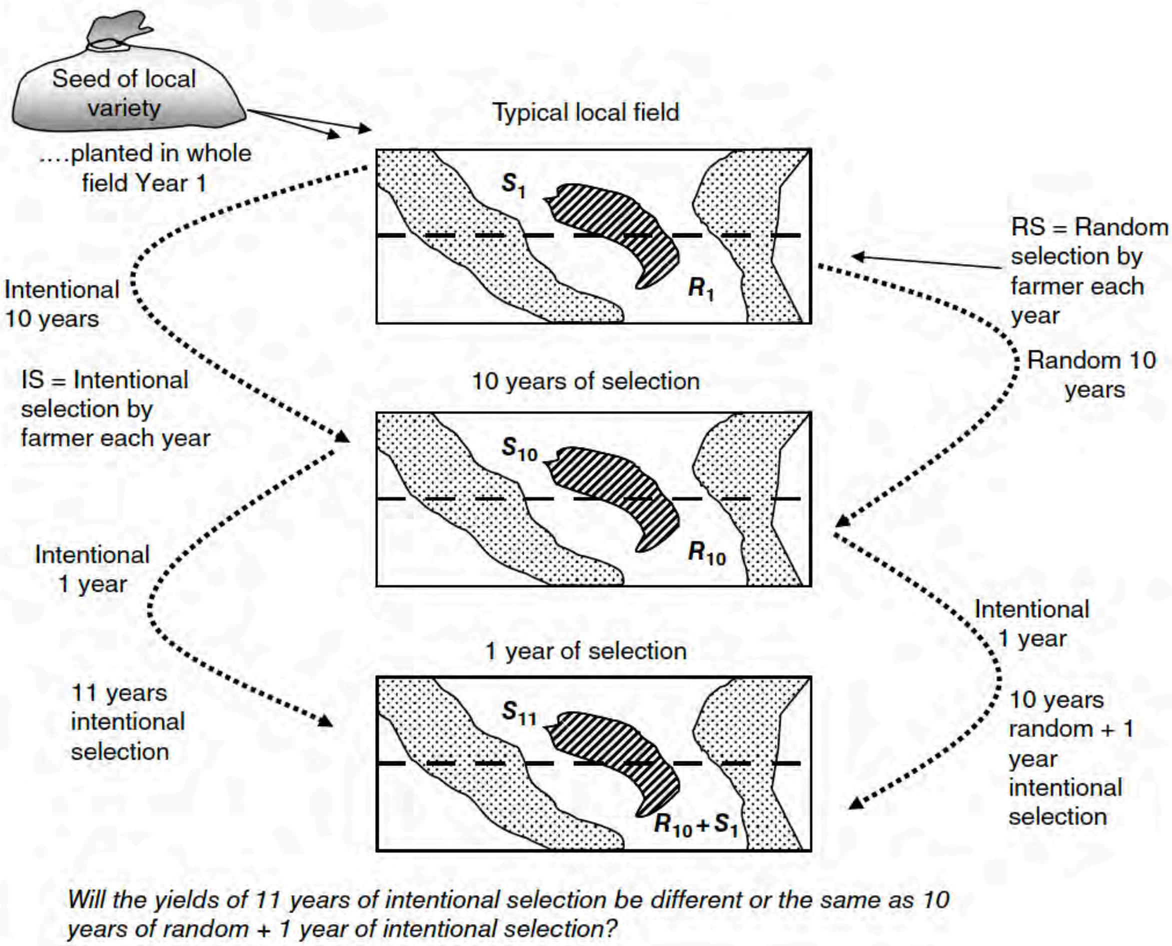

Fig. 13.4. Seed selection scenario presented to farmers.

industrial agriculture in temperate regions. We did not know if benefits would still be present in farmers' varieties or if there would be differences between farmer-selected and random samples of the same maize population. To test this, DS collected seed of a white and yellow maize variety from one farming household in each of two communities in the Central Valley of Oaxaca in December 2009. For each variety the households provided us with seeds they selected for planting and a random sample from the same maize population, all identified at the same time.

In autumn 2010, DS conducted a small greenhouse experiment[3] to see if farmer-selected seed had any advantage over seed that had not been selected (Soleri *et al.*, in preparation, p. 2). We looked at characteristics that are advantageous early in life, including vigour of early growth measured by seedling size and number of leaves. In the majority of comparisons, the selected seed was superior to the unselected seed (Table 13.4), indicating an ecological advantage, even with no genetic response to selection. This finding was consistent with the majority of farmer responses to our selection scenario, indicating that farmer seed selection provides a benefit in the first year, but no heritable, cumulative advantage.

How did this change our understanding?

This research is ongoing, but even with the results to date, it is clear that preconceptions hindered our understanding of the role of seed selection. Despite ascribing to a 'complex farmer' view of FK, we unconsciously made oversimplified assumptions about seed selection influenced by the perspectives of Western plant science,

Table 13.3. Some differences between seed selected for sowing and a random sample from the same population.

	Random sample of seed	Farmer-selected seed	F value	*P*
Seed weight (g)[a]	0.3324a	0.4810b	428.41	0.0001
Seeds/kg	3008	2079	~ 50% > number seeds/kg in random sample	
Market cost (MXP)/kg (December 2009)	7.5	10		

MXP = Mexican pesos
[a]N=140 seeds of each; Tukey's means separation, means followed by different letters are significantly different, $p \leq 0.05$.

Table 13.4. Early growth of farmer-selected and randomly sampled seeds from the same populations of four maize varieties. (In paired comparisons, variety means followed by different letters are significantly different, $P \leq 0.05$.)

		Variety			
Variable	Seed	A	B	C	D
Leaf count A	Selected	2.876a	2.721a	2.607a	2.564a
	Random	2.628b	2.565b	2.579a	2.526a
Plant height A (cm)	Selected	13.702a	13.284a	12.321a	11.736a
	Random	11.879b	11.724b	11.756a	10.524b
Leaf area A (cm²)	Selected	5.694a	6.712a	5.476a	5.726a
	Random	5.084a	5.591b	4.645b	4.478b
Leaf count B	Selected	3.540a	3.435a	3.352a	3.252a
	Random	3.343b	3.065b	3.230a	2.956b
Plant height B (cm)	Selected	25.891a	25.094a	24.139a	21.686a
	Random	22.485b	22.408b	22.251b	19.584b
Leaf area B (cm²)	Selected	13.055a	12.172a	10.947a	9.233a
	Random	9.007b	10.013b	9.559a	7.555b

implying that farmers were barefoot plant breeders. We assumed farmers' seed selection was a practice that identified individual plants with superior phenotypes that were heritable, and would therefore contribute to a cumulative process of microevolution, and that this was their intention. Instead, our research indicates that farmers are well aware of the difficulty of achieving a cumulative response for those traits and do not expect to do so. However, seen in terms of the environments they are working with, the apparent ecological advantages resulting from seed selection make the persistence of that practice easy to understand. While this will need to be investigated further, especially in farmers' growing environments, the data thus far confirm the rationale for farmer seed selection. There may be other advantages as well.

We are now exploring the possibility that, in addition to providing an ecological advantage, this selection may help to conserve the genetic diversity in farmer-managed crop populations. Even though their selection differentials were significant and similar to those sought by plant breeders, the variation in seed size in farmers' seeds is in large part a response to the heterogeneity of the environments where the parent plants grow, for example variations in soil quality or water availability that are common within a field or local area. Plant biologists have observed that in some cases this can 'mask genetic variation' (Sultan, 1987), even protecting genotypes that might otherwise be eliminated (Rice *et al.*, 1993). If this occurs, farmers' selection may serve to protect crop genetic diversity, in addition to other functions.

Thus, what formally trained scientists might see as ineffectual intentional selection by farmers may in fact produce meaningful non-genetic ecological benefits and contribute to maintaining genetic diversity that is useful both locally and globally. A few others have quantified farmer practice with similarly surprising results that have changed our understanding of how traditional agricultural systems function. For example, in cassava propagation in French Guiana (Elias *et al.*, 2001; Pujol *et al.*, 2005), greater vigour and farmer preference for heterozygous seedlings resulted in increased diversity maintenance in this staple crop that is predominantly propagated vegetatively. In contrast to the case with maize, where selection is largely based on non-heritable phenotypic differences, in cassava selection of plants based on phenotypic differences that are heritable led to similar outcomes: the protection of diversity.

Example 3: Consistency and Variation in Farmer-Identified Bean Varieties in One Community

Farmer-named varieties have long been important units of diversity management on farm and widely used basic indicators of diversity for crop genetic resources conservationists. The use of named varieties as diversity indicators has been supported by studies where farmers presented with a number of seed lots have generally agreed on how to classify those lots into varieties (Sadiki *et al.*, 2006). But improving our understanding of what farmer classification means at a community level is challenging, especially when there is variation in both the seeds and the farmers doing the classifying. For example, the extent of community-wide agreement among farmers in sorting unclassified seeds into farmer-named classes is unknown, but affects whether farmer varieties are an over- or under-estimate of the diversity present.

What did we hypothesize?

We undertook this research to investigate bean classifications that were confusing to researchers, by documenting and analysing farmer classifications. As in Example 2, our tendency was to assume that farmers were careful taxonomists and that community membership and farming in similar environments with similar materials would mean high consistency in the way farmers classify their local crop seeds. We thought of named varieties as consistently constructed units, and that within varieties different seed lots were comparable, but that seed lots of different varieties were distinct, and even mutually exclusive. That is, seed A was a member of either variety X or Y, and could not simultaneously be seen as a member of both. The assumption we were testing in our hypothesis was that there was a high level of agreement among farmers about how to classify individual seed phenotypes and the genotypes they represent.

How did we test our hypothesis?

To investigate varietal classification among farmers we quantified practice using a reference sample including seeds from each of the three *Phaseolus* species grown locally (*P. vulgaris*, 87; *P. dumosus*, 73; *P. coccineus*, 75), all collected in the same community in the Sierra Juárez region of Oaxaca, Mexico. By asking each farmer individually to organize the same complete sample into varieties, we were able to quantify farmers' knowledge applied to the same set of seeds. Controlling the seeds themselves allowed a focus on the variation among farmers' classifications, allowing us to document farmer classification and what that means for genetic diversity.

What did we find?

We found that common named varieties represented broad seed morphology types, but that there was little consistency among farmers for how individual seeds were classified, except for one variety (Soleri *et al*., 2013). The recognition of broad types supported previous findings that when presented with already constituted seed lots, farmers tended to agree on varietal names, but our finding of inconsistency at the level of individual seeds, for example within a species (Table 13.5), indicated that varietal names underestimate diversity. Is this because farmers are not capable of finer levels of discernment and can only form approximations of a shared classification? Our additional research with the same farmers and bean varieties showed this was not the case, but that they were able to discriminate differences within a species down to the sub-racial level and deploy these to different growing environments, as documented by using simple sequence repeat (SSR) DNA markers in farmer-managed *Phaseolus vulgaris* populations (Worthington *et al*., 2012).

How did this change our understanding?

Our results suggest that inconsistent classifications among farmers may reflect idiosyncratic skills and needs. Variation in farmer knowledge and practice of classification may be another point in the farming system where diversity is preserved, even if it is not what we as researchers may have anticipated, as was the case with maize seed selection in Example 2. It may also be another example of how formal scientific precision could in fact undermine the diversity maintained in community seed systems – diversity that may contribute to farmers' ability to work effectively with the spatial and temporal variability and change present in their bean fields. The type of stringent replicated precision formally trained scientists associate with skilled taxonomies may simply not be necessary, or even desirable, in all seed classification systems.

Table 13.5. Agreement in farmer classification of *Phaseolus* bean species into varieties (data from Soleri *et al*., 2013) (n = 9 farmer sortings).

Question	Our assumption	Actual finding, summary	Adjusted Random Indicator of mean agreement among farmer classifications (0 = agreement comparable to chance; 1 = complete agreement among classifications)			
			Species (*n* seeds)			
			All species (235)	*P. vulgaris* (87)	*P. dumosus* (73)	*P. coccineus* (73)
Is there agreement among individual farmers' taxonomies of the three *Phaseolus* species they grow?	Farmers are barefoot taxonomists, there will be high agreement among their bean species classifications	Levels of agreement among farmers' classifications are low	0.20	0.31	0.10	0.03

Conclusion

We all seek patterns and meanings that are familiar, or based on the familiar, and sometimes this is all we can see, no matter how empathetic and open we believe ourselves to be. In the case of research on local FK, the assumptions that our pattern-seeking can lead to may be inaccurate. This inaccuracy may risk misunderstanding or misrepresenting farmer practice, and the needs and goals of farmers themselves, or any group or individuals we partner with in research. Positive respectful attitudes towards farmers and their local knowledge are subject to distorting research assumptions, in a similar way that less respectful attitudes are.

Through the examples outlined here, we have found that using methods that seek farmers' knowledge from their perspective are very useful for testing these assumptions and can lead to a deeper and richer understanding of FK and farmer practice. Specifically, it is important to: (i) deconstruct technologies when eliciting FK and opinion to provide a more informative and nuanced understanding than simply asking preferences between finished products; (ii) ask farmers questions, based on their own experiences, that clarify their goals and expectations; and especially (iii) quantify practice so that empirically based assumptions, including our own as researchers, can be tested. These lessons can facilitate successful partnerships between farmers and formally trained scientists to support and improve small-scale agriculture in ways that are socially equitable and environmentally sustainable.

The common assumption that traditionally based farmers successfully conserve crop genetic diversity *in situ* has been supported with evidence of the diversity in terms of species, varieties of a species, varietal heterogeneity and genotypic heterozygosity maintained by farmers. But the different ways in which this diversity is maintained, and what might threaten it, will vary with variation in crop populations, local environments, farmers and other elements of the farming system. In hindsight it seems obvious that we assumed farmers have comparable cognitive abilities as scientists, but failed to consider, or imagine, how the nature of farmer practice and intent could be so different from that of scientists. Anticipating our findings was simply beyond our own capacities as researchers when we started these investigations, but being able to listen to farmers and test what we thought was occurring enabled us to move beyond those limitations.

Progress in understanding farmer knowledge and practice will come from research that compares farmer and scientist knowledge in terms that minimize bias in favour of either, and that emphasizes testing the assumptions all of us have as researchers. The results can be surprising, or even unsettling, but also push us as researchers to explore processes and outcomes we may never have anticipated.

Acknowledgements

We thank the many farmers who have worked with us and whose patience and good humour is an essential ingredient in our understanding described in this chapter; our colleagues on the research described above with assessment of transgenic maize (Flavio Aragón Cuevas, Mario Roberto Fuentes, Humberto Ríos Labrada), maize seed selection (Steven E. Smith) and bean classification (Margaret Worthington, Paul Gepts); and Paul Sillitoe for inviting our contribution to this volume.

Notes

[1] We have discussed these views more extensively elsewhere (Cleveland and Soleri, 2007a), with the four perspectives identified there as: (i) the economically irrational farmer; (ii) the economically rational farmer; (iii) the socio-culturally and/or ecologically rational farmer; and (iv) the complex farmer.

[2] Resistance to caterpillar damage is a common trait of transgenic varieties, based on version of the Bt gene, originally from a soil bacterium, *Bacillus thuringiensis*.

[3] This was a split-split-split plot design using the four farmers' varieties: yellow and white maize each from two families in different communities.

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A catalogue record for this book is available from the British Library, London, UK.

Library of Congress Cataloging-in-Publication Data

Names: Sillitoe, Paul, 1949- editor.
Title: Indigenous knowledge : enhancing its contribution to natural resources management / edited by Paul Sillitoe.
Other titles: Indigenous knowledge (C.A.B. International)
Description: Wallingford, Oxfordshire : CABI, 2017. | Includes bibliographical references and index.
Identifiers: LCCN 2017016224 (print) | LCCN 2017039849 (ebook) | ISBN 9781780648118 (ePDF) | ISBN 9781780647074 (ePub) | ISBN 9781780647050 (hbk : alk. paper)
Subjects: LCSH: Indigenous peoples--Ecology--Case studies. | Traditional ecological knowledge--Case studies. | Natural resources--Management--Developing counries--Case studies. | Conservation of natural resources--Developing countries--Case studies.
Classification: LCC GF50 (ebook) | LCC GF50 .I527 2017 (print) | DDC 304.2--dc23
LC record available at https://lccn.loc.gov/2017016224

ISBN-13: 978 1 78064 705 0

Commissioning editor: David Hemming
Editorial assistant: Emma McCann
Production editor: Marta Patiño

Typeset by SPi, Pondicherry, India
Printed and bound in the UK by CPI Group (UK) Ltd, Croydon, CR0 4YY