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96a. EVALUATING THE POTENTIAL FOR FARMER-BREEDER COLLABORATION: A CASE STUDY OF FARMER MAIZE SELECTION FROM OAXACA, MEXICO

Daniela Soleri, Steven Smith, David Cleveland

96b. ON-FARM RICE VARIABILITY AND CHANGE IN SIERRA LEONE: FARMERS' PERCEPTIONS OF SEMI-WEED TYPES

Catherine Longley

Abstract

The central argument of both of these papers is that farmers manage crop variability in distinctive ways. The first paper discusses how formal plant breeders can potentially contribute a great deal in a collaboration with farmers to improve crop varieties for local use. Yet to do so, plant breeders and other outside researchers must have some understanding of local selection practices and their impact on crop populations, in terms of the concepts central to the genetic theory underlying plant breeding. In this research we integrated methods from both social and biological sciences to better understand selection and its consequences from farmers' perspectives, but in terms of the concepts used by plant breeders. Among the households we worked with, farmers' selection practices were not always effective – yet they understood quite clearly the reason for this and had no expectations of responses to selection in some traits given the methods available to them. A role for plant breeder collaboration with farmers was indicated by farmers' statements, practices and genetic perceptions regarding selection as well as the genetic response of their maize populations to selection.

In the second paper, Catherine Longley discusses how farmers from two ethno-linguistic groups in Sierra Leone have contrasting perceptions of the semi-weed rice, salli foreh. *The ways in which these perceptions relate to local cultural beliefs, knowledge systems and agricultural practices are analysed.* Salli foreh *is thought to exist as a hybrid that acts as a bridge for gene exchange. Farmers' different perceptions of* salli foreh *may affect the potential for natural out-crossing and creation of new biological variability. The paper illustrates how different farming communities manage variability in distinctive ways and highlight the need for detailed ethnographic characterisation in understanding farmer influences on processes of micro-evolutionary change.*

Acknowledgements

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CONTENTS

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—Catherine Longley

Acronyms

CPB	collaborative plant breeding
GLM	general linear model
H	heritability
R	response to selection
S	selection differential
V_G	genetic variance
V_P	phenotypic/total variance

96a. EVALUATING THE POTENTIAL FOR FARMER-BREEDER COLLABORATION: A CASE STUDY OF FARMER MAIZE SELECTION FROM OAXACA, MEXICO

Daniela Soleri, Steven Smith, David Cleveland

1 INTRODUCTION

In response to the challenge of making agriculture more sustainable, some researchers have suggested participatory or collaborative plant breeding (CPB). CPB can potentially improve varieties adapted to the needs of low-resource farmers in marginal environments, and lead to enhanced in situ conservation of crop genetic resources. However, as with other applied research, CPB has, until recently, been dominated by deductive reasoning regarding farmer knowledge and practices and their effects on crop populations. While this is not entirely unjustified, there are enough differences among many CPB situations and between CPB contexts and those of conventional plant breeding for it to be valuable to consider local, empirical evidence and the possibility for inductive reasoning and subsequent decision-making. For example, many researchers are interested in understanding what farmers hope to accomplish with their selection and their understanding of how that selection works. However, assumptions based on how farmers respond to simple questions and/or on what outside researchers assume, may not always accurately reflect farmers' actual insights and goals, and generalisations made from specific situations may not be valid. As an example, several studies observed that farmers often test new varieties in optimal environments, such as home gardens with adequate moisture and fertile soil, and evaluate them for later planting in more stressful environments, as a way to reduce the risk of losing the variety (e.g. Ashby et al., 1995; Soleri and Cleveland, 1993). Alternatively, some farmers frequently plant new varieties on their worst land, which has also been interpreted as a risk aversion strategy (Sthapit et al., 1996; Witcombe, 1998).

Despite the wide range of interpretations regarding what CPB actually involves, there are recurrent themes in the research literature (e.g. Ceccarelli et al., 1997; Weltzien et al., 1998). First, a central point of agreement across disciplines is that the value of CPB lies in its relatively close attention to adaptation to local socio-cultural and biophysical conditions (e.g. Eyzaguirre and Iwanaga, 1996). Second, CPB entails some interaction between formal plant breeders or other researchers and farmers, with the objective of making crop varieties better meet local needs. The success of plant breeders' work is due, in part, to the application of knowledge of population and quantitative genetics and statistics to the crop improvement problems they are investigating. Other factors contributing to this success are experience, luck and intuition, the 'art' of plant breeding. Though often important (Duvick, 1996; Simmonds, 1979), this 'art' is specifically tied to individuals and/or environments, whereas fundamental genetic and statistical principles remain constant across a range of contexts. To apply these principles to help solve the specific challenges of local crop improvement, plant breeders must be able to understand farmers' selection goals and their local crop populations in terms of the fundamental concepts used in plant breeding. Basing collaboration on untested assumptions extrapolated from experience in conventional breeding contexts – the deductive approach – may not always be appropriate. In addition, such assumptions neglect the aspect of CPB about which there seems to be greatest agreement – the value of local biological and socio-cultural adaptation for achieving crop improvement for low-resource agricultural systems.

While many of the features characteristic of CPB situations make obtaining meaningful empirical data challenging, an increasing number of investigations including the one reported here, are trying to do just that. This paper provides an overview of our findings from a small study of farmers' selection of maize seed in the Central Valleys of Oaxaca, Mexico. Our overall goal for this work was to improve researchers' understanding of the local seed selection process so that they could contribute most effectively to collaborative improvement of that process. Specifically, we wanted to understand seed selection from the farmers' perspectives, but in terms of the concepts relevant to plant breeders.

2 METHODS

Site and sample selection

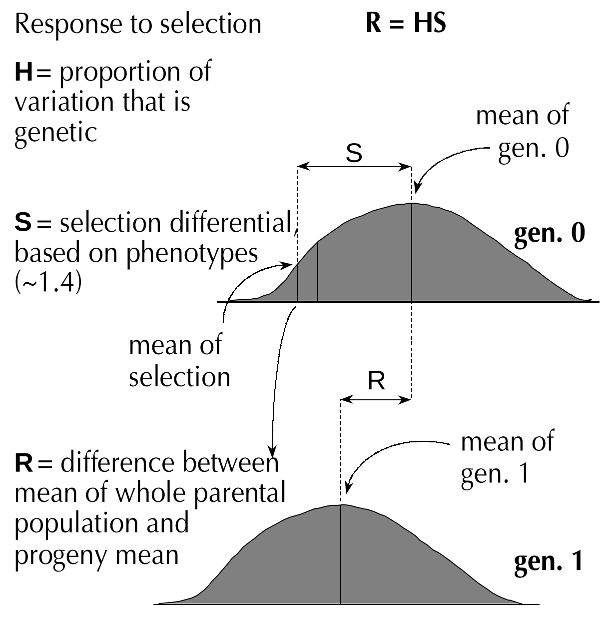
In this study we worked with eight farm families in Santa Maria, a community in one of the wettest of the three Central Valleys, the Zimatlan Valley, and with five families in San Antonio, a community in the Mitla Valley, the driest of the three. Households were initially selected for participation in another component of this research concerning quantitative description of their crop populations (see Soleri and Smith, n.d.). Some households were identified through recommendations of fellow community members and municipal authorities as households known to be managing diverse maize varieties or 'good' (e.g. hardworking, not large-scale) maize farmers. Others were chosen during walking tours of the field areas in the 1996 spring planting season. The two most important distinguishing characteristics of households in those communities: gender of household head and wealth were considered in the attempt to make the sample as representative as possible. Interviews were conducted with the individuals primarily responsible for agriculture, typically a wife and husband, or mother and son, as well as younger workers who usually deferred to the primary pair. Much of the data reported here, however, refers to only three households from each community whose maize populations were included in the field experiment described in section six of this paper. The small sample size was dictated to a great extent by the nature of this investigation, which attempted to integrate accurate social science research with robust biological data that often requires substantial replication. For example, for each of the six households, 400 individual maize plants were extensively documented in the field experiment.

Selection

In broad terms, there are two ways in which scientific plant breeding can contribute to low resource agricultural systems: i) through the development and delivery of varieties that perform better than those currently grown; and ii) by introducing methods which households, communities, or other local entities can use to improve the results of their own selection. In either case, where seed is maintained from year to year by households, crop populations will ultimately be managed and selected by the households cultivating them and, therefore, information regarding their selection practices and the implications for the crop populations will be critical for planning any plant breeding activities, collaborative or otherwise.

In plant breeding, selection is the discrimination between individuals or populations, that determines which will contribute to the next generation. Through selection, plant breeders try to create a final population that shows most desirable performance for specific selection criteria. This artificial selection – or directed evolution as one plant breeder has called it (Simmonds, 1979) – in combination with natural selection defines the genetic structure of the crop population. Our discussion concerns only intrapopulation selection and not that of choosing between populations or varieties. In this paper, selection of planting *seed* is discussed referring to maize (also referred to as kernels), however selection may also be practiced on tubers, cuttings or other propagules depending on the plant species and agronomic practice.

Figure 1 Response to selection



Many farmers practice selection, yet this process has rarely been documented and understood beyond descriptions of selection criteria (for an exception see Louette and Smale, 1998). Farmers choose between varieties or populations of a crop species. Within a population, farmers typically practice mass selection – selection of individual plant phenotypes, composing the next generation by bulking the seed of those selections. In addition, their crop populations are subject to ongoing natural selection (also essentially mass selection) for fitness during each growing and storage season.

To better understand farmers' selection we examined what farmers were doing in terms of a fundamental equation used by plant breeders. A basic version of the equation for response to selection (Simmonds, 1979) is a good starting place for identifying what information about farmer selection might be valuable in preparing plant breeders for collaboration. This equation states that the response to selection (R) is the product of two factors, H and S (Figure 1).

$$R = H\,S$$

In this equation, H is heritability – the proportion of the total variation in a trait that is genetic. Specifically, $H = V_G/V_P$, where V_G is genetic variance and V_P is the phenotypic or total variance in a given trait. The other major source of variation is the environment (V_E), for example, the soil and water conditions where a plant is growing.

The selection differential (S), is a measure of how the individuals selected differ from the rest of the population. Specifically, it is the difference between the mean of the whole population and the mean of the selected group, expressed in standard deviation units (Falconer, 1989:192). Response can be quantified as the difference between the mean of the whole population (from which the parents were selected) and the mean of the next generation that is produced by planting the selected seeds under the same conditions. Response will increase as S increases and/or as H increases. The results of selecting for a given trait improve as the proportion of phenotypic variability contributed by genetic variance increases. That is, selection among genotypes is based on phenotype, but response to selection is a function of genetic variability and H (DeLacy et al., 1996).

The research reported here is a beginning step in understanding farmer selection and its impact on crop populations, attempting to describe some of the elements in the response equation. Farmers were asked the following four sets of questions, each of which is discussed in the next four sections of the paper. Each section includes the relevant materials and methods and summary of findings.

Concerning S (the difference between the phenotypic mean of the whole population and that of the selected individuals) we asked:

1) What are farmers' explicit criteria for maize seed selection?
2) What are farmers' selection criteria as reflected in the maize ear phenotypes that they actually choose? What are the S for these criteria? What do these patterns suggest about the type of selection farmers are attempting?

Concerning H we asked:

3) What are farmers' genetic perceptions regarding H? How do these perceptions define their expectations for R?

Concerning R (the difference between the phenotypic mean of the progeny of the selected individuals and the phenotypic mean of the whole parental population) we asked:

4) What is the actual genetic R to farmers' selection in crop populations?

3 FARMERS' EXPLICIT SELECTION CRITERIA

What are farmers' explicit criteria for maize seed selection?

Materials and methods

Formal and informal interviews and participant observation were conducted with 13 collaborating households. Farmers were asked what they were looking for when selecting ears for seed, and why those traits were desired.

Findings

Farmers in this region of Oaxaca, as in most other areas of Mexico, select maize seed for planting entirely post harvest, typically as whole ears (Smale et al., 1998). Farmers' selection criteria as reported can be divided into three categories. The first concerns criteria relating to viability of planting seeds – all ears with evidence of pest or disease damage to the seed or cob are discarded without further consideration of other characteristics. The next category includes traits that contribute to large ears and large kernels; especially ear length and weight. The final category encompasses a number of traits that define a varietal type or subtype, and in our sample included traits like grain type (e.g., flinty vs. starchy), grain form (round vs. flat), cob and husk color. Although criteria in the third category varied between households and communities, the first two categories were universal and primary.

4 SELECTED PHENOTYPES AND KIND OF SELECTION ATTEMPTED

What are the criteria of farmer selection as reflected in the ear phenotypes they select? What are S for these criteria? What do these patterns suggest about the type of selection farmers are attempting?

Materials and methods

Because stated selection criteria may not always accurately reflect actual or implicit criteria, or may be misunderstood in verbal descriptions, this part of the research attempted to identify selection criteria based directly on the ears farmers chose – compared to those they did not choose. A simple selection exercise was conducted with farmers using a random sample of 100 ears of white maize from farmers' fields, for which plant morphological, reproductive phenology and ear traits were documented (see Soleri and Smith, n.d.). Two maize populations were used, one from each of the study communities. Households were asked to make selections from the population from their community only and then to select their choice of the best ten ears for use as planting seed. Differences between trait means of the total 100 ear samples and 10 per cent selections from the sample were evaluated using *t*-tests with statistical significance at the 0.05 level.

Findings

Traits: In our small sample of households, farmers from both communities consistently selected for increased ear size from among pest and disease-free ears (Table 1). Compared to the 100 ear sample, the ears selected by farmers had larger diameters and lengths and were heavier overall. Ear row number showed no significant difference between the 100 ears and 10 selections across households and communities. Thus their explicit selection criteria accurately reflect the traits that farmers actually seek when selecting seed for planting.

Selection differentials: For those *t*-tests that were significant, farmers' selections resulted in selection differentials ranging between 0.65–1.09 and 0.73–1.40 for ear length and ear weight, respectively. This

Table 1 Trends in phenotypes of farmers' 10% selections and 100 ear samples: Comparison of means

community/ household	ear diameter	ear length	ear weight	100 grain weight	kernel row number
San Antonio					
Maria	↑*	↑*	↑*	↑	↑
Jose y Xotchil	↑*	↑*	↑*	↑	↑
Juan y Paula	↑*	↑*	↑*	↑*	↓
Sta. Maria					
Mario y Cleotilda	↓	↑*	↑	↑	↓
Sara	↑	↑*	↑*	↑*	↓
Fam. Espinosa	↑	↑	↑*	↑	↓

* t-test significant at $p \leq 0.05$

compares with a selection differential for a 10 per cent selection typically sought by breeders of 1.4–1.8 (Fountain and Hallauer, 1996; Hallauer and Miranda, 1988:166).

Kind of selection: For those ear size traits of greatest apparent interest to farmers and showing significant *t*-tests, farmers appear to be attempting directional selection, choosing individual phenotypes that represent a tail of the population distribution. Figure 2 illustrates this for a trait farmers are selecting for (ear length) and can be contrasted with Figure 3 for a trait that is not a selection criterion for farmers in this area (kernel row number).

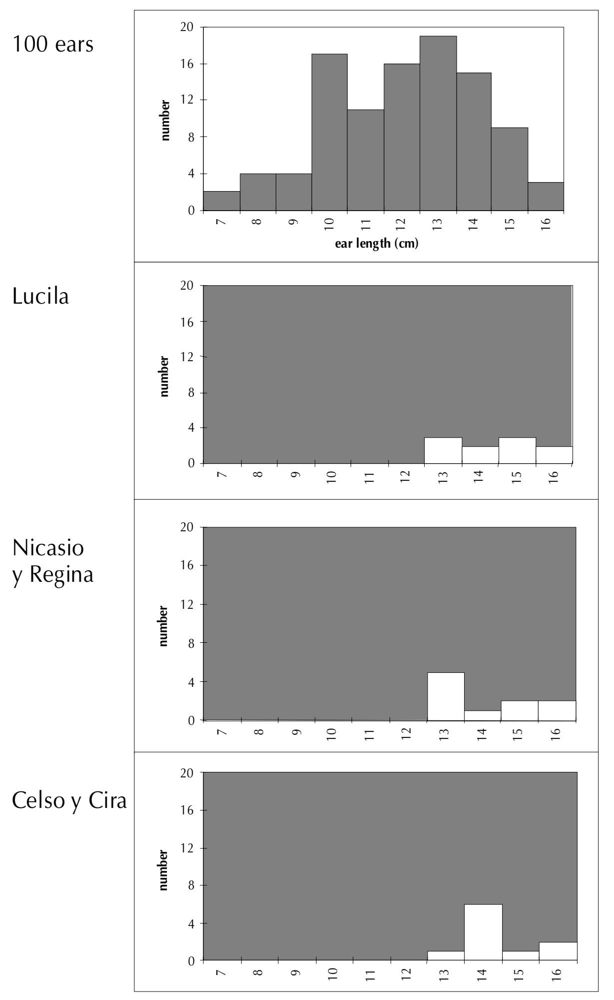
5 FARMERS' GENETIC PERCEPTIONS AND EXPECTATIONS FOR RESPONSE TO SELECTION

What are farmers' genetic perceptions regarding H? How do these define their expectations for R?

Methods

To understand their selection practices and expectations, farmers were asked a series of questions regarding their genetic perceptions, e.g., perceptions of the role of genetic variation (V_G) and H in selection.

Figure 2 San Antonio 10% selections: Ear length

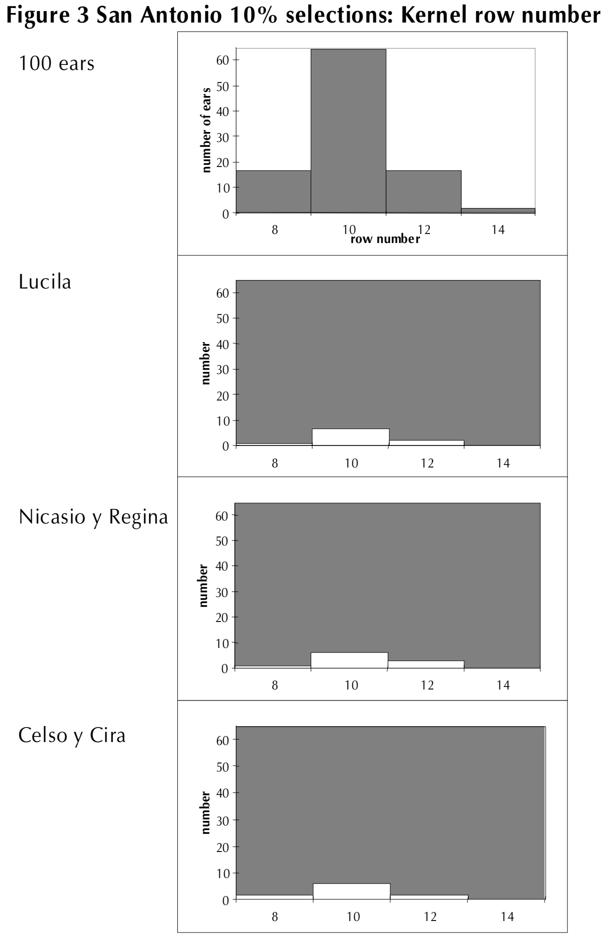


We approached these issues using fictitious scenarios regarding the expression of qualitative and quantitative traits in a variable, stressful environment typical of the region (normal field) and a hypothetical uniform, 'good' field that did not limit growth potential. These scenarios built on farmers' experience, but also presented some situations that were unfamiliar to them – for example, a uniform field, without resources limiting plant growth. Questions about the expression of traits in normal and optimal environments were designed to provide outside researchers with a framework for understanding how farmers perceive concepts such as heritability in their maize varieties.

Findings

We asked farming households what the outcome of the following scenarios would be. First, from a local population of maize that included plants with both red and yellow tassels (actually glume and anther colour), if seed were taken only from plants with red tassels what would the predominant tassel colour of the plants grown from this seed be if i) those seed were planted in a typical, variable field? and, ii) those seed were planted in a completely uniform, good field (Figure 4)? Tassel colour is a relatively simple, qualitative trait minimally influenced by environmental factors with high heritability, and it is also a trait that farmers notice and occasionally select for. Response to these scenarios was that tassel color will be

Figure 3 San Antonio 10% selections: Kernel row number



predominantly red in either field, as it will not be affected by the growing environment.

We asked households about similar scenarios regarding ear length – one of the central selection criterion. We asked if, from a typical harvest of variable sized ears, only seed from the large ears was sown, what the size of the ears produced in a typical variable field would be, as compared to those produced in a uniform, good field (Figure 5)? Ear length is a quantitative trait having substantial genetic variation and is greatly influenced by the environment in which the plant is grown. Again responses were consistent, but this time stating that the variable field would produce a harvest of variable ear lengths while the harvest from the uniform field would consist of uniformly large-sized ears.

Like formally-trained researchers, most farmers base their understanding of genetic variation and H on their own experiences. In the Central Valleys of Oaxaca, V_E even within fields is substantial (Soleri and Smith, n.d.). Farmers' responses are overwhelmingly that 'the environment is everything' for some traits of interest to them such as ear length. They distinguish quite clearly between traits of low (e.g. ear length) and high (e.g. tassel color) heritability and their expectations for response to selection reflect this understanding. In addition, when challenged with these hypothetical situations, the components of which they are familiar with, some farmers make sophisticated analyses of the determinants of V_P that suggest an understanding similar to that of plant breeders. For example, two households pointed out that even after five cycles of isolation and selection for a highly heritable trait such as tassel color, some non selected phenotypes will still occur – a few yellow tassels among the population selected for red tassels – a result that outside researchers would attribute to recombination in a heterozygous population.

Expectations of response to selection: It appears that for traits with low heritability, farmers did not generally hope to change varieties through selection. Both the lack of expectations of change and the concern with maintenance of current traits appear to be a pragmatic recognition of the substantial V_E and large amounts of gene flow via cross-pollination that must occur under local conditions: areas of vast – in some cases year-round – maize cultivation, often in very narrow (11 m) fields. Nevertheless, their answers indicated an awareness of selection and the ability to use it when they felt it desirable and possible. Still, they typically have very low expectations regarding traits that comprise their seed selection criteria. In this study farmers attributed their low expectations to cross-pollination and their understanding of the influence of V_E on plant phenotypes in their fields (H of those traits). Interpreted as such, their expectations appear to reflect two basic observations by formal researchers. First, the lack of control over pollen sources (extensive cross-pollination) effectively reduces H of phenotypes by as much as one half in comparison to its level under biparental control. Second, due to a medium to low H, progeny of selected individuals will tend to reflect more the mean of the entire population from which the parents were selected, than the mean of the selected parents alone (Simmonds, 1979).

Figure 4 Genetic perceptions: Tassel colour

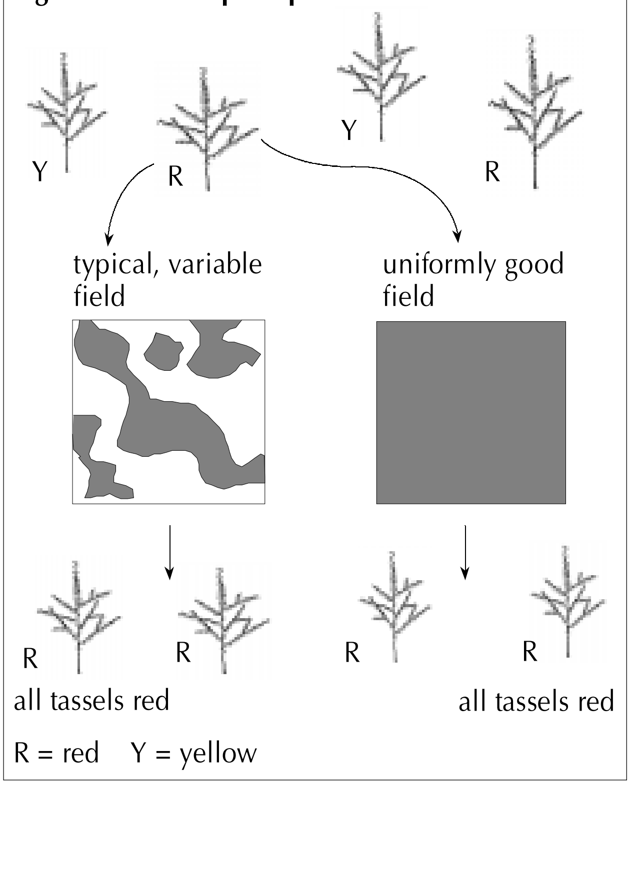
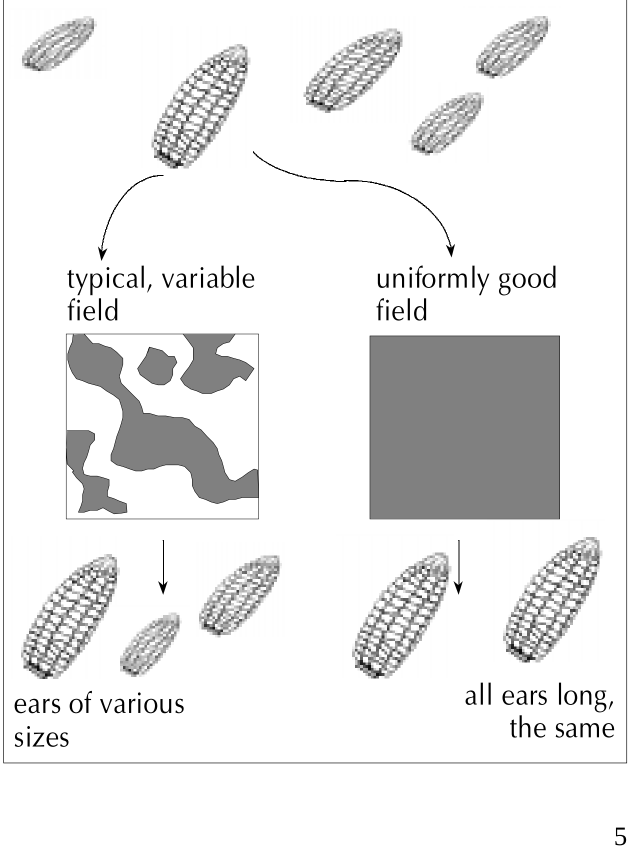


Figure 5 Genetic perceptions: Ear size



6 GENETIC RESPONSE TO FARMER SELECTION

What is the difference in the phenotypic mean of the progeny of the selected individuals and the phenotypic mean of the whole parental population (R) for farmers' selection in their crop populations?

Materials and methods

White maize populations from three collaborating households in each of the two study communities were used. Three generations of farmer-selected samples and two generations of corresponding random (non selected) samples from the same populations were obtained from each household (Figure 6). These were sown in a completely randomised block design using split plots with main plots representing households and the generation/type of maize population occurring as sub plots[1]. Eight replications were sown in a farmers' field in Santa Maria in Spring 1998. All field preparation and management was typical of local practices. Data was collected on plant morphological (plant and ear heights, stalk diameter, ear leaf dimensions, number of primary tassel branches), reproductive phenology (days to anthesis, anthesis-silking interval), and post harvest ear traits (ear length, diameter and weight, kernel row number, grain yield and 100 grain weight). Analyses were accomplished using general linear model (GLM) procedures (SAS version 6.12) with plants per hill and plant spacing as covariates. Generation and type (random or selected) means within household populations were compared using orthogonal contrasts.

Findings

For the great majority of traits documented, and across all of the populations, there were no significant differences evident between the means of the whole random population and selected samples derived from these as represented by their progeny generations. Similarly, significant differences were not observed between random samples of the same population over generations.

These findings suggest that with their current selection strategy and over the generations included in this study, the genetic variance, especially that which can be passed from parents to their progeny, for farmers' selection criteria is very low relative to V_E, resulting in no statistically significant response. That is, despite adequate selection differentials for traits of interest, under this selection method, H appears to be so low that there is no response to selection. In this sense the ultimate impact of farmer selection appears comparable to random selection, leaving population means relatively unchanged from year to year. This finding requires qualification for two reasons. First, it is based on a very small number of cycles and is therefore incapable of detecting longer-term, less dramatic trends that may be significant when measured over a greater time period. Even under experimental conditions, formal breeders often obtain low responses to mass selection that may not be easily detected in a few cycles (Hallauer and Miranda, 1988). Secondly, these findings refer to the effects of farmer selection only and do not pertain to the potentially great consequences of natural selection and stochastic factors in environments and seed systems such as this one, where for example, the majority of farmers experience crop 'failure' due to drought in one out of every four years (Dilley, 1993). Given such conditions, the potential for genetic drift – random changes in population genetic structure – may be substantial.

Given farmers' low expectations for response to selection, substantiated by the results of this field trial, why do they persist in selection for large ears and seeds and pay a premium for large-sized grain for seed in the market, when they could purchase more small-sized seed for the same amount of money? When asked this question, one household suggested that larger seeds may provide an advantage in terms of germination and seedling growth, especially under stress such as drought. This would shift selection for size into the first category for seed selection (see section three above) – traits concerning seed viability and

Figure 6 Response to selection field trial: Year and type of seed used for each population

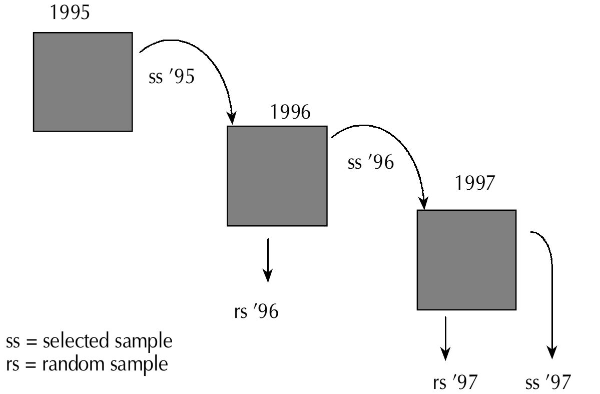


Table 2 San Antonio selection differentials: Ear traits

household	ear diameter	ear length	ear weight	100 grain weight	kernel row number
Maria	0.69*	1.06*	1.15*	0.35	0.09
Jose y Xotchil	1.29*	0.99*	1.25*	0.64	0.25
Juan y Paula	1.02*	1.09*	1.40*	0.97*	0.06

* t-test significant at p ≤0.05

not inheritance of traits *per se* – making the low expectations for response irrelevant in determining how selection is conducted (see also Louette and Smale, 1998, for similar findings regarding seed viability). This hypothesis will be tested in future experiments with seed size. Another household, while acknowledging no expectations for positive, directional change, expressed concern that without this selection for large seeds, there might be a change for the worse in the maize populations over time. However, the overwhelming response of all households, including the two just described above, was that this is a habit that persists despite widespread recognition that it has no consequences in terms of changing population traits. Whether this is a preference based largely on unarticulated recognition of the physiological superiority of large seeds, or is based on custom or aesthetics, cannot be ascertained until the effect of seed size on plant performance is investigated. Even then determining the original motivation for a contemporary 'custom' would be difficult but should not preclude the possibility that it was a concern for seed viability and seedling vigor.

7 CONCLUSION

Returning to the response to selection equation introduced earlier, the findings of this small case study suggest the following answers to our initial questions:

1. Farmers' explicit selection criteria focus on ear qualities that concern seed viability, ear and kernel size and traits concerning varietal type.
2. In the selection exercise, farmers sought ear phenotypes that were significantly longer and heavier as well as usually having wider diameters and greater 100 grain weight the 100 grain weights of those selected were greater than those not selected as compared to the entire 100 ear sample from which they selected. For ear length and weight, farmers achieve substantial S values with their selection, often close or equal to values typically sought by formal plant breeders.
3. The pattern of selection for these criteria is directional, frequently selecting only phenotypes above a particular 'threshold' value.
4. Despite 2 and 3 above, all households expressed a theoretical perspective regarding the potential for response to selection in which S and directional selection are largely irrelevant. Among the same traits for which they achieve substantial S values and exercise directional selection, they have no expectations for response to their selection.
5. Using their current selection methods, H of farmers' primary selection criteria is low, as they are very quick to point out. For many but not all households, this may be accompanied by the belief that there is simply no V_G for a trait, or perhaps more accurately, that there might as well not be given the way they experience it. This perception could easily occur due to the swamping of V_G by V_E in the environments in which they are working. In fact, many breeders may have the same problem perceiving the effects of extreme V_E on V_P due to the limited range of V_E they have experienced relative to that experienced by many low-resource farmers (e.g. Ceccarelli, 1989).
6. Actual response to farmer selection was approximately zero in this study, consistent with farmers' own expectations and their comments regarding H of traits.

What do these preliminary findings imply in terms of plant breeders and farmer-breeders working together to develop improved varieties that better meet local needs? Given extant environments and selection strategies, development of 'improved' varieties must include either fixation for critical traits and provisions to maintain those despite cross-pollination and low H for those traits in local environments; or plant breeders must be prepared to continually replace those varieties as they degenerate under local conditions. Collaboration to make farmer selection more effective seems much more probable, and in many ways more desirable, than continual replacement.

These findings indicate that the farmers we worked with have a good understanding of how and why their selection does what it does. They obviously have no problem identifying desirable ear phenotypes and achieving adequate selection differentials for these. Farmers' genetic perceptions and observations describe attributes of the populations or environments they work with, and give breeders valuable insights that might otherwise require extensive experimental work, or simply be left to deductive assumptions. The insights into farmers' genetic perspectives help researchers move beyond overly simplistic deductive reasoning regarding both farmers' understanding and the nature of the environments in which those farmers are working. These insights place their actions in a very different light than has been the case in the past when such farmer-practices may have been interpreted as naïve at best. The results suggest that i) farmers clearly understand that, given the methods available to them, they cannot hope for greater response to selection, and the field trial confirms this; and ii) these are extremely variable within-field environments resulting in negligible H estimates for simple mass selection.

These findings also suggest a meaningful and needed contribution for plant breeders to CPB efforts in this area: collaboration with farmers to make simple, viable changes in their selection strategies that will increase H of their selection criteria. To make a lasting contribution, this increase and the associated increase in response must be sufficient to reward and reinforce the amended selection approach from the perspective of the farmers using it.

ENDNOTES

1 Blocks are placed randomly, within them households are each allocated the same number of adjacent subplots (five in this case). Subplots are randomly allocated to each of the five different populations.

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96b. ON-FARM RICE VARIABILITY AND CHANGE IN SIERRA LEONE: FARMERS' PERCEPTIONS OF SEMI-WEED TYPES

Catherine Longley

1 INTRODUCTION

For over a decade, anthropologists and other professionals involved in agricultural research and development have contributed to various on-going debates broadly relating to what is known as farmer participatory research. Farmer participatory research allows farmers – particularly those in complex, diverse and risk-prone environments – to play more of a determining role in the research and development process. The involvement of farmers in developing improved crop varieties for increased agricultural sustainability is generally referred to as participatory or collaborative plant breeding (CPB). The thinking behind presently-developing strategies for CPB is convincing and straightforward: if breeders are able to work in partnership with farmers, formal crop breeding efforts would be made more appropriate to the needs of farmers, particularly those in less favourable environments. The need to bridge the gap between local knowledge and scientific knowledge is often reiterated, implying that a detailed understanding of both types of knowledge is a necessary prerequisite to the development of effective CPB strategies.

The focus of much of the literature relating to local knowledge and agricultural development was initially on the more technical aspects of farmers' knowledge. More recent contributions have emphasised the importance of social and cultural aspects of farmers' knowledge, and this has been accompanied by the use of theoretical perspectives from the social sciences. Rather than examining simply *what* is known by local farmers, the question of *how* it is known has increasingly been explored. In applied literature relating to agricultural development and natural resource management, local knowledge is generally understood to be gained through the activities of farmer experimentation and innovation. In contrast, the question of 'how' knowledge is gained has tended to be addressed in the more theoretical literature by research into cognition, perception and classification.

The ways in which genetic variation and crop varieties are perceived and classified by local communities form an important aspect of farmers' knowledge that is highly relevant to the development of collaborative plant breeding strategies. Contrary to Boster (1985), who appears to regard perception as a *visual* process which takes place prior to, and independently of, any assessment regarding the *utility* of a particular crop variety, the approach taken in this paper follows that of Ingold (1992) who links perception with action: farmers' perceptions of their crops and crop varieties are essentially practical and can be seen to be reflected in local agricultural activities. Ingold's model places primary emphasis on the use-values or 'affordances' of particular objects, in this case rice types.

Based on fieldwork among semi-subsistence rice cultivators in north-western Sierra Leone, this paper describes farmers' perceptions of a semi-weed rice commonly found as an off-type in farmers' fields and known locally as *salli foreh*. The perceptions and agricultural practices of farmers from the two neighbouring ethnic groups in the research area are seen to differ according to the cultural characteristics of the communities studied. Scientific knowledge concerning rice genetics and evolutionary change is presented and the potential for the on-farm creation of 'new' rice varieties by local farmers is explored.

Whilst further analysis of the samples collected is required to determine whether or not the on-farm presence of *salli foreh* actually promotes gene exchange, the farmers do not see themselves as agents of varietal change. In other words, any changes that might occur are the unconscious result of farmer practices. This particular example is used to highlight some of the differences between farmer and breeder knowledge and practice. However, this is not to deny that there are also similarities between these two knowledge systems. The final section of the paper considers the implications of these findings for collaborative plant breeding efforts.

2 RICE VARIABILITY AND CHANGE IN WEST AFRICA

The genus *Oryza* includes some 25 species, of which only two (*O. glaberrima*, *O. sativa*) are cultivated. *O. glaberrima* is confined to Africa, and is thought to have been domesticated from the wild species *O. barthii* (formerly known as *O. breviligulata*) over 1,500 years ago. Other wild rice species that occur in West Africa and have been included within the *O. glaberrima* species complex are *O. stapfii*, *O. punctata*, and the perennial *O. longistaminata*. The Asian rice species, *O. sativa*, is thought to have been introduced to West Africa in about the 15th century by Portuguese traders (Ogbe and Williams, 1978) and even earlier by overland caravan traders who arrived from North Africa.

The *O. sativa* and *O. glaberrima* species complexes have been described as 'evolutionary species that are still undergoing incessant and dynamic changes through the hybridisation-differentiation cycles' (Katayama, 1990: 194–5). Although rice is predominantly self-pollinating, percentages of spontaneous out-crossing range from 0–6.8 per cent in cultivated types, and between 30–40 per cent in wild types (Oka and Chang, 1961), suggesting that the percentage of out-crossing among weedy domesticates might be somewhere between the two. A very weak isolating barrier exists between *O. barthii* and *O. glaberrima*, and gene flow by introgression still occurs in nature, mostly from the former to the latter (Ogbe and Williams, 1978). The extent of outcrossing in *O. longistaminata* is even greater than in *O. barthii*. Despite a strong isolating mechanism acting on the F1, *O. glaberrima* appears to be absorbing genes from *O. longistaminata*. In short, there is evidence of 'continual complex hybridisation pathways' within the *O. glaberrima* species complex (Ogbe and Williams, 1978: 63)

Hybrids are frequently produced when the parental species grow sympatrically, resulting in a particular form that can coexist as a weed with the cultivated plants. Experimental work has shown that these weedy off-types produce complex hybrids that are double recessive for the gene combination that creates the crossing barrier, allowing them to be easily crossed with other *barthii, sativa* and *glaberrima* types to produce further hybrids. As such, these weedy off-types may act as a bridge for gene exchange, both within a species complex and between different species (Chu and Oka, 1970).

Data collected from farmers in the case study area reveal that the semi-weed rice type known as *salli foreh* is thought to exist as such a hybrid capable of acting as a bridge for gene exchange. Panicle analysis of rice samples collected from upland farms in the case study area reveal that farms belonging to Susu cultivators contain higher proportions of off-types than those of the neighbouring ethno-linguistic group, the Limba. The different ways in which Susu and Limba farmers perceive off-types, and *salli foreh* in particular, are thought to affect the potential for gene exchange and the biological creation of new variability through processes of hybridisation and recombination.

3 THE SIERRA LEONE CASE STUDY

A total of 23 months' anthropological fieldwork between 1993 and 1997 was undertaken in north-western Sierra Leone among farmers from two neighbouring ethno-linguistic groups, Susu and Limba. The Susu of the case study area are trade-oriented Muslims. Though orthodox Islam represents the Susu cultural ideal, this co-exists with a strong belief in spirits and witchcraft. The Susu draw strong distinctions between categories of nature and culture (Thayer, 1983): the natural world, or that associated with the bush, is generally seen as a fearful and threatening environment. The Susu prefer the urbane, socially ordered domain of the town or village; to spend extended periods in the bush, as the Limba do, is regarded by the Susu as 'uncivilised'. In common with other Islamicised Mande groups of West Africa (see Linares, 1992; Copans, 1980), groundnuts are an important cash crop in the Susu agricultural system. An average Susu household is unable to produce enough rice to meet its subsistence food needs and relies on income from groundnut sales and other trade activities to purchase rice, often from neighbouring Limba farmers.

The Limba regard rice farming as rather more than a means of subsistence production: in the same way that trade and Islam form important aspects of Susu identity, rice cultivation has been described as the defining feature of what it means to be Limba (Finnegan, 1967; Fanthorpe, 1994). Though many Limba of the case study area consider themselves as nominally Christian or Muslim, their belief in spirits, notions of witchcraft and the power of 'swears' play more of a part in their daily lives than either Christianity or Islam. Limba cultural beliefs present a greater affinity to the natural world than the Islamic beliefs of the Susu.

Despite many broad similarities in the agriculture of the two groups, it is possible to distinguish what might be called 'Limba' and 'Susu' agricultural systems. Limba farmers tend to concentrate on rice, which is grown both for subsistence and for exchange purposes, whereas the Susu grow less rice and more groundnuts. On average, Susu upland rice farms are half the size of Limba farms, due to the higher population density and shortage of fertile uplands among the Susu. Although I have used ethnic labels as a shorthand way of distinguishing the two systems, it is important to note that ethnicity alone does not adequately account for the differences between them.

Rice is grown for subsistence in both upland (rain-fed) and lowland (swamp) ecologies. Since *salli foreh* most often appears on upland farms, this paper is concerned with upland rice farming. Upland farms are temporary fields cultivated according to shifting cultivation practices in which fallowed land is cleared and a crop rotation involving rice, groundnuts, and *fundi* (*Digitaria exilis*, also known as *fonio*) is followed for three or four years. Although upland rice may be cultivated on small, private plots controlled by individual farmers, most upland rice farms are worked by households under the leadership of the head of the household.

Early on in the course of the fieldwork, rice samples were collected from farmers' fields throughout the case study area and analysed by crop scientists at the Rice Research Station at Rokupr. The scientists' results clearly showed that the rice collected from Limba farms displayed a higher degree of varietal purity than that collected from Susu farms. Over 180 samples were collected by the researcher and ActionAid field staff from upland farms in 25 Susu and Limba settlements by using a quadrat to measure a one-metre square area of mature rice. The scientists who subsequently analysed the collected samples reported that rice taken from the Susu farms tended to contain more than a single variety and that, in one case, as many as 18 different varieties were found within the one-metre square sample. The level of varietal mixing was found to be considerably less in the Limba rice samples. In other words, the varietal purity of the Limba rice tended to be greater than that of the Susu rice (Malcolm Sellu Jusu, *pers. comm.*).

These contrasts in on-farm varietal purity are thought to be related to subtle differences in the agricultural practices of the two groups. The mixed rice found on Susu farms is partly explained by the deliberate practice of interspecific rice cropping adopted by some Susu farmers (see Longley and Richards, 1993). This technique is not practised among the Limba, who regard the on-farm mixing of rice varieties as most undesirable. A shortage of household labour may prevent Susu farmers from handling seed in ways that prevent the accidental mixing of varieties, resulting in the unintentional presence of off-types. *Salli foreh* is a commonly observed off-type on upland rice farms in the case study area. Since seed for planting is generally saved from the previous season's harvest, such off-types will persist from year to year if they are not removed by roguing.

4 FARMER PERCEPTIONS OF *SALLI FOREH*

Salli foreh is a particularly distinctive rice type, featuring an erect panicle and displaying grains with a black seed coat. *Foreh* translates as 'black' and among the Limba the same rice is also known as *salli oboleh* ('black *salli*'). Among both Susu and Limba *salli foreh* is considered by farmers to be among the oldest rice types in the case study area. Farmers say that this rice type almost always appears on upland farms and that no matter how hard one may try to eradicate it, it will persist. It is sometimes referred to as *dakbé*, a word that can be literally translated as 'created here'. A widely known Susu story suggests that *salli foreh* existed in the area before the first settlers arrived. According to the story, the first time the original settlers made farms in the area, *salli foreh* rice germinated and began to grow before the farmers had even scattered any seed. The rice appeared at a place where a cobra had been burnt accidentally during the clearing of the farm. There is the suggestion that the rice appeared by metamorphosis of the snake, and for this reason it is sometimes referred to as 'cobra rice'. Said to attract cobras when grown in large quantities, many Susu farmers believe it is dangerous to enter a store containing *salli foreh*, particularly during the night when it is difficult to see snakes – the rice has a black seed coat, like a cobra.

Farmers' observations clearly suggest that *salli foreh* exists as a semi-weed. It is said to do well in poor soil and is not attacked by insects. It is regarded as a strong or powerful rice which has the ability to overcome other varieties. For this reason, Susu farmers never intentionally mix it with other varieties. The panicle neck breaks easily when the rice is ripe and if not harvested in time, the panicles are liable to fall to the ground. It is sometimes described by Susu farmers as witch rice. Another common off-type, similarly regarded as witch rice by the Susu, is known as either *koya* or *salli fikhé* (lit. white *salli*). A number of farmers reported that wherever the 'improved' Rokupr-released variety, ROK 3, is planted, *koya* will almost always appear as an off-type, suggesting that these two rice varieties may exist in some kind of symbiotic relationship. Of eleven one-metre square samples of *samban konko* collected from farmer's fields, six samples were found to contain panicles of *koya* in varying proportions ranging from one to 24 per cent (analysis provided by Alieu Sartie). It may well be that *koya* exists as a companion weed to ROK 3.

One Susu farmer further revealed to me that both *salli foreh* and *salli fikhé* act as protectors against witches. Their strength is associated with their ability to fight against witches and repel witchcraft. These perceived qualities serve to discourage Susu farmers from removing these weedy off-types from their farms. (Alternatively, the fact that such off-types can never be fully removed from upland farms might be conveniently qualified by such beliefs.) Both varieties are said to attract snakes and devils, and it is for this reason that they are rarely planted in pure stands by Susu farmers.

Salli foreh is clearly recognised by Susu farmers as a self-seeding rice, yet it cannot be classified among the quick-shattering wild rice types that yield empty grains. The observation that the rice just appears on the farms, without having been planted by man (whether on purpose or accidentally), may render it particularly problematic for the Susu, who typically make strict distinctions between the natural and social worlds (Thayer, 1983). Fully-domesticated rice is completely dependent on man for its successful reproduction through cultivation – in this sense it might be seen to be part of the social world – whereas wild rice is neither planted nor harvested and is clearly regarded as part of nature. *Salli foreh* is both feared and revered by the Susu because it appears to exist in both worlds: it is not dependent on man for its reproduction, yet it can be harvested, cooked and consumed along with cultivated rice types.

Limba farmers also recognise these biological features of *salli foreh*, yet it does not carry for them the same symbolic associations with snakes and witches. The Limba regard *salli foreh* like any other rice type and it is associated with neither ill luck nor good luck. Limba farmers are more likely to plant these varieties in pure stands: over nine per cent of Limba farmers planted *salli foreh*, whereas less than three per cent of Susu farmers planted this variety in 1996. One reason why the Limba do not fear *salli foreh* might be that they have a closer association with the bush and do not fear the natural world in the way that the Susu do.

5 ROGUING AND SEED SELECTION PRACTICES

Methods of roguing and seed selection are regarded by farmers as particularly time-consuming activities and are not commonly practised by farmers in the case study area. Those farmers who have been observed to undertake roguing or seed selection tend not to do so on a regular basis but only when it is deemed necessary, either to acquire especially interesting off-type material for further testing or to obtain a pure seed type from a particularly mixed stand. From the small number of cases of roguing and selection that were observed among the case study farmers, differences between Susu and Limba practices appear to exist. It should be noted that in the case study area, rice is normally harvested in bunches using a sickle.

If an upland farm contains mixed varieties, Limba farmers have been observed to obtain pure seed for the following season by harvesting a portion of the farm panicle by panicle, selecting only those panicles of the desired variety. This activity is generally carried out by an individual farmer over the course of several days, just prior to the main rice harvest. In this way, a significant quantity of pure seed is obtained and stored for planting. Susu farmers claim that they do not have the patience to undertake panicle selection in the way that the Limba do; moreover, they do not regard the presence of mixed rice varieties on their farms as problematic. In contrast, Susu farmers have occasionally been observed roguing off-types from harvested bundles of rice. This practice allows small quantities of a novel seed variety to be gathered for future testing.

6 MICRO-EVOLUTIONARY PROCESSES OF VARIETAL CHANGE

Although rice is predominantly self-fertilising, the process of hybridisation is particularly important in the evolution of cultivated rice (Oka and Chang, 1961) and cycles of differentiation and hybridisation can be promoted by the presence of companion weeds in a farmer's field (Harlan, 1970; de Wet and Harlan, 1975). Hybridisation can either occur between two cultivated varieties or between a cultivated variety and its associated weed relatives and/or weedy domesticates. For hybridisation to occur, a mixture of cultivated varieties and/or weedy types must be present in the farm environment. The likelihood of hybridisation taking place can either be reduced or increased by particular agricultural practices.

The observations on seed selection and roguing practices presented in the preceding section are consistent with findings concerning the greater degree of varietal purity found in upland farms cultivated by Limba farmers. The greater degree of varietal mixing that occurs on Susu farms theoretically encourages hybridisation and recombination, whereas higher degrees of varietal purity promote the genetic stability of the cultivated types. In this way, cycles of hybridisation and differentiation may exist in the on-farm environments of Susu and Limba farms respectively, promoting the local generation of novel variability by recombination and selection within the case study area.

Susu farmers allow *salli foreh* to exist as a weedy off-type on their farms because it is believed to protect against witchcraft. However, its close association with snakes prevents many Susu farmers from cultivating it in pure stands. If *salli foreh* is capable of acting as a bridge for gene exchange, the persistence of this weedy off-type on Susu farms would increase the likelihood of hybridisation with fully domesticated, cultivated rice varieties. In this way, Susu farmers may unconsciously promote the conditions under which hybridisation – and hence the creation of novel planting material – might occur. In contrast, the Limba remove off-types such as *salli foreh* from their farms by roguing. Unlike Susu farmers, Limba farmers do not fear to plant *salli foreh* in pure stands. By cultivating *salli foreh* in pure stands, it is possible they provide the spatial isolation necessary for genetic differentiation to occur. This example illustrates how the contrasting cultural beliefs and agronomic practices displayed by Limba and Susu farmers living side by side may together influence the overall evolutionary processes of varietal change within the case study area.

7 CONCLUSIONS

The interactions between small-scale farmers and their crops are much more complex than the deliberate activities relating to seed and varietal selection. The case study presented here suggests that the on-farm emergence of new varieties can be understood through the interactions of farmer knowledge/ perceptions/practice with the specific reproductive ecology of a particular crop. This paper has focused on rice variability and the biological and social processes that act to promote it on-farm. Micro-evolutionary processes of varietal change – the processes that produce the genetic variation upon which selection acts – may well be influenced by human actions (Lester, 1989). Such human actions refer here to the agricultural practices of farming communities rather than the task-oriented activities relating to seed or varietal choices that are made by individual farmers.

The emphasis of this paper has been to highlight the ways in which farmer knowledge differs among different farming communities. Just as there are major differences among plant breeders in their schools of thought and the ways in which they approach their work, so there are differences among farmers in the ways in which they perceive and manage genetic resources. This paper has highlighted the *cultural* factors that influence these differences; similarly, features of social organisation, access to land and labour, population density, livelihood strategies or economic factors may also account for differences between farming communities in their management of genetic resources. In working with farmers to develop collaborative plant breeding strategies it is the task of social scientists to understand factors such as these and the ways in which they relate to genetic resource management.

Current methods for CPB research that work essentially with groups of farmers run the risk of over-simplifying and decontextualising local knowledge because such groups are merely groups of *individuals*. Ethnographic or sociological research is additionally required to incorporate the technical knowledge of individual farmers within an analysis of the wider social and cultural aspects of the *community*. Whilst it has been shown that development practitioners have sometimes made the mistake of concocting communities where they do not exist (Blench, 1998), I would also say that the current trend for CPB to focus on individuals or farmer groups risks overlooking communities where they do exist. The different perceptions of *salli foreh* in Susu and Limba communities illustrate how two communities with different cultural backgrounds treat seeds in distinctive ways. In addition to the varietal characterisation that plant breeders undertake as part of CPB, attention must also be paid to the ethnographic characterisation of the farming communities that CPB practitioners aim to work with.

It is particularly important that this ethnographic characterisation should aim to go beyond the methodological focus on selection that has pervaded much of the literature to date on CPB. This paper has highlighted a case in which farmers may unconsciously be promoting the processes of hybridisation and recombination that produce the genetic variation upon which selection acts. By overemphasising the role of selection in farmers' management of crop genetic resources, there is the danger of overlooking the ways in which farmers may promote the on-farm generation of genetic novelty.

Since the case study farmers do not see themselves as agents of varietal change, the example that I have detailed in this paper is perhaps best described as an example of the ways in which farmers play a role in the evolutionary processes that occur under domestication, rather than as an example of farmer breeding.The evolutionary changes that take place under domestication are based upon complex and dynamic interactions between farmer knowledge, agricultural practice, crop ecology and environment. Indeed, the complexity of these interactions makes it difficult, if not impossible, to determine whether the changes that occur are the result of natural or human processes. It is for this reason that both ethnographic and varietal characterisation are required in understanding farmers' management of crop genetic diversity and local crop development. Collaborative plant breeding should then be regarded as a strategy through which on-going processes of evolutionary change under domestication can be harnessed in ways that will benefit the farmers concerned.

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