Human Ecology, Vol. 34, No. 3, June 2006 (© 2006)
DOI: 10.1007/s10745-006-9021-5

Farmer Choice of Sorghum Varieties in Southern Mali

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Published online: 9 June 2006

In southern Mali and throughout the semiarid tropics, small-scale family farmers are faced with the challenge of producing adequate harvests in difficult biophysical and socioeconomic environments. Professional plant breeders have had much difficulty developing modern varieties that outperform farmers' traditional varieties in these environments, in part because of an incomplete understanding of why farmers choose the varieties they grow. Improved understanding of farmers' varietal choices can contribute to collaboration between farmers and formal plant breeders. Based on a 15-month field study in Dissan, Mali, we examine farmer's choices among their traditional sorghum varieties in terms of one or more than one variety, and short-cycle or long-cycle varieties, and the interaction between these two choices. Results support our general hypothesis that farmers choose varieties to optimize outputs in the face of variation in the growing environment and in human managed inputs such as labor and tools.

KEY WORDS: Africa; agriculture; Mali; plant breeding; indigenous knowledge; sorghum; crop varietal choice.

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INTRODUCTION

In southern Mali and throughout the semiarid tropics, small-scale family farmers are faced with the challenge of producing adequate harvests in difficult biophysical and socioeconomic environments. These marginal growing environments are characterized by low levels and high variability of rainfall and soil fertility, and low levels of external inputs. Farmers manage their environments to produce annual harvests, relying mostly on farmer varieties (FVs) of crops, in contrast to modern varieties (MVs) developed by professional plant breeders. FVs are crop varieties traditionally maintained by farmers, and can include landraces, traditional varieties selected by farmers, MVs adapted to farmers' environments by farmer and natural selection, and progeny from crosses between landraces and MVs (sometimes referred to as "creolized" or "degenerated" MVs) (Soleri and Cleveland, 2004). In this paper we use the term "variety" to refer to FVs as recognized and named by farmers, and do not have independent biological measures of the distinctness of these varieties.

Professional plant breeders have experienced considerable difficulty developing viable MVs for marginal environments, perhaps in part because of an incomplete understanding of why farmers choose the varieties they grow (Ceccarelli and Grando, 2002; Christinck, 2002; vom Brocke *et al.*, 2003; Weltzien *et al.*, 1998). One reason for this is the common assumption by breeders that MVs selected in more optimal environments will also out yield FVs in farmers' marginal environments, so that farmers' environments are not specifically targeted in breeding programs (Ceccarelli and Grando, 2002; Cleveland, 2001). As a result many farmers do not have a real choice between MVs and FVs, because there are no MVs appropriate for their growing environments, and many communities do not have direct access to MVs. Therefore, their choices are among FVs, although much of the research on farmer varietal choice focuses on the choice between MVs and FVs. In this paper we focus on choice *among* sorghum FVs in a village in southern Mali, West Africa. Understanding farmer varietal choice as a component of local food security may be able to help formal research and extension better serve the needs of resource poor farmers working in areas where MVs and professional plant breeding have yet to make significant contributions. It can also support collaboration between farmers and plant breeders in meeting these goals.

Sorghum was domesticated in Africa, and today is an important dryland cereal crop produced on six continents for human consumption, animal feed, and other uses. Sorghum is relatively heat and drought adapted and is a crucial component of regional agricultural production throughout Africa

(House *et al.*, 2000, pp. 133–134). African farmers produced nearly 23 million metric tons of sorghum in 2003 (FAOSTAT data, 2004). They use grain primarily for human food while the rest of the plant is used as fodder, building material, mulch, and fuel. There are five races of sorghum (*Sorghum bicolor* subsp. *bicolor*) in Africa: (bicolor, durra, kafir, caudatum and guinea) with different but overlapping geographic distributions (House, 1985, p. 7). Farmers grow bicolor throughout much of Africa, durra predominantly in east Africa, kafir primarily in southern Africa, caudatum in east Africa to Nigeria, and guinea in west and southern Africa (Dahlberg, 2000, pp. 108–113). Sorghum is photoperiod-sensitive, and across the N–S cline of increasing rainfall in West Africa varieties of guinea sorghum tend to increase in time to maturity. African varieties require 70–180 days to mature, with 90–150 days most common in southern Mali, and are about 3–4.5 m tall with large panicles (seed heads) (House *et al.*, 2000, p. 135; Soleri *et al.*, 2002).

Our general hypothesis is that farmers make varietal choices in an effort to optimize outputs in the face of variation in the growing environment and in human managed inputs such as labor and tools. We test this hypothesis with analysis of a case study in Dissan, Mali, of farmer choice between one or more than one variety and between short-cycle or long cycle varieties, and the interaction between these two choices. The results support our hypothesis.

FARMER CHOICE OF CROP VARIETIES

Farmers choose which crop varieties to grow, where, and in what proportions, allocating them to a range of biophysical and social environments over both space and time. Much of the theoretical framework for understanding farmer varietal choice is based on differences in performance of different varieties in different environments, what plant breeders call genotype $\times$ environment interaction (G $\times$ E) (Ceccarelli *et al.*, 1994; Simmonds and Smart, 1999). Of special interest for varietal choice is qualitative G $\times$ E interaction, commonly referred to as crossovers. For example, a crossover occurs when variety A out performs variety B in environment #1, but B out performs A in environment #2. If one of the varieties outperforms the other in both environments no crossover has occurred and there is no qualitative G $\times$ E. Environments can vary along temporal, spatial, and management axes, e.g., seasons, years, fields, locations within fields, irrigation practice, and labor or fertilizer inputs. Performance of a genotype (e.g., a variety) can include a wide range of traits including yield and yield stability, cycle length, resistance to biotic stresses (e.g., pests and disease) and abiotic stresses (e.g., drought, soil acidity), processing and food quality, and seed color and shape. If farmers do not perceive crossovers among a set of environments, then they may choose the same variety for those environments. However, farmers may prefer diversity for traits such as seed color or processing characteristics, and therefore choose more than one variety in the absence of crossovers.

When farmers do perceive crossovers between varieties for two environments, then they have to decide whether to grow one variety in both environments, or whether growing two different varieties in the two environments, accounting for the extra effort required, will produce a net benefit (Cleveland *et al.*, 2000). In this paper we use "varietal choice" to mean farmers' stated choices of varieties they will grow, though we recognize that factors such as impure varietal seed lots may lead some producers to grow and harvest varieties they did not intentionally plant (as reported in Ethiopia by McGuire, 2002).

Choice of Number of Varieties

In the neoclassical economic model a risk-neutral farmer would grow only the one variety that gives the highest profits per unit area (Smale, 2002). However, many small-scale farmers in marginal environments are risk averse (Anderson and Dillon, 1992), and environmental spatial variation increases the likelihood of crossovers between farmers' fields, or even within a field (Soleri *et al.*, 2002). Variation in time is also high—in the semi-arid tropics seasonal and annual rainfall is highly variable, and even in years with adequate total rainfall, rains may arrive late, end too early, or be too heavy during flowering or harvesting. Therefore, most farmers may often grow two or more varieties of many crops, each with distinct agronomic characteristics presumably "as a measure of insurance against vagaries of the weather, diseases, or pests" (Doggett, 1988). Farmers may also choose more than one variety because of their different quality traits. For example, interviews with 599 Nigerian farmers supported the conclusion that they grow both long-cycle and short-cycle cowpea varieties—short-cycle for food grain and long-cycle for feed during the dry season when other fodder sources are scarce (Abdullahi and CGIAR, 2003).

Number of varieties grown may also be influenced by seed source and social variables. In a study of Mexican maize farmers, choice of total number of varieties grown was related to household seed source (Louette *et al.*, 1997). Households planting mostly their own seed chose an average of twice as many varieties in comparison with those households that obtained all their seed from non-household sources. In a review of field research on farmer crop genetic resources, wealth was a common indicator for producers who cultivated more varieties compared with resource poor producers (Jarvis *et al.*, 2000). The choice of total number of sorghum varieties may be significantly related to ethnicity, as in one area of Tanzania where migrant Gogo farmers from a traditional sorghum-growing region grow more than twice the number of varieties as groups from maize growing regions (Friis-Hansen and Sthapit, 2000).

Choice of Variety Based on Cycle Length

There is much evidence that declining rainfall across the Sahel since the 1930s has led to greater adoption of shorter-cycle sorghum varieties (Adesina, 1992). In Mali, the uncertainty of rainfall has increased since the 1980s (Sasaki *et al.*, 2002, p. 2), and isohyets have moved south by approximately 100–250 km since 1961 (Dembélé *et al.*, 2001). Interviews with 80 households in four villages in the Upper Niger valley zone of Mali found that the most common reason for adoption of the three most popular sorghum varieties was early maturity (Adesina, 1992). Farmer interviews and focus groups in a village in neighboring Burkina Faso showed that farmers have shifted from 120–150 day sorghum varieties to 70–90 day varieties over the last 10–15 years (Ingram *et al.*, 2002). However, since in good rainfall years long-cycle varieties generally have higher yields (Adesina, 1992) and are rated higher for quality (Ingram *et al.*, 2002), farmers do not give them up entirely.

It is commonly assumed that low and erratic rainfall influences farmers to plant both long- and short-cycle varieties (as well as varieties which contrast in other agronomic characteristics) in the same growing season to reduce overall risk of low yield. One review found that farmers across sub-Saharan Africa planted both long-cycle and short-cycle sorghum and millet varieties (Ahmed *et al.*, 2000, pp. 56–57). Toulmin informally interviewed Malian millet farmers in their fields, and reported they grew both long- and short-cycle varieties every year. She assumed that this was because it was “very unlikely that both [types of] varieties will fail in a single year” (1992, p. 57). McGuire (2002) found that some Ethiopian farmers plant both long- and short-cycle sorghum varieties with maturity rates ranging from 3 to 6 months, but his research did not address their reasons for this, stating that “very little is known about whether farmers manage different maturity times as a livelihood strategy.”

METHODS

This study of farmer varietal choice is based on a 15-month field study in 2001–2002 in the village of Dissan in southern Mali. Fieldwork was carried out by Lacy with the aid of Dissan secretary Siaka Sangare. Farmers whose names are used gave permission in compliance with the non-anonymous and non-sensitive human subjects requirements. Households were defined by the Bamana concept of *du*, a group of people living, working, and eating together, and household members were recorded for the 2001 harvest season (i.e., may have included a small number of people who were not resident year round). Demographic data were recorded from the family identity card, which the Malian government requires be kept by every family, and during the survey representatives of each household updated and corrected this.

Two extensive household surveys were conducted: the *village survey* (November and December, 2001) included all 66 Dissan households and focused on farm management and sorghum varieties, and household production factors, including household size, ownership of agricultural equipment, total hectares planted, and sorghum seed source.

Prior to the 2002 growing season, a *group interview* on Dissan sorghum varieties with 18 people (12 men and 6 women) was conducted. Some participants responded to announcements by the town crier and some were invited because they were large-scale producers, especially helpful, articulate, and/or informative, or recommended by the village labor collective for young men. The group interview elicited information for developing the sorghum survey that followed 1 month later, and clarified information obtained during the first 6 months of the field study.

The 20 households in the *sorghum survey* (March and April and November–December, 2002) were randomly selected from each of four strata defined according to the number of people per household (small $\leq$ 11, large > 11) and total annual sorghum hectares planted per household (small $\leq$ 2, large > 2). The distribution of households was: small household(large area of sorghum ($N = 14$), small household/small area of sorghum ($N = 26$), large household/large area of sorghum ($N = 14$), and large household(small area of sorghum ($N = 12$). We also use data for these 20 households from the 2001 village survey. Varietal choice (number and names of sorghum varieties planted) was recorded for 1998–2002, and separately for 2001 and 2002.

Lacy also did an *apprenticeship study* with four sorghum farmers (one from each of the categories in the stratified sample from the sorghum survey) to learn by participant observation more about how farmers make sorghum varietal choices and manage this crop.

Soleri and Lacy conducted interviews with Dissan farmers in 2002 as part of a larger study of farmer and plant breeder knowledge and practice in five locations around the world. Data used here are on perception of rainfall patterns and risk (Soleri *et al.*, n.d.). Statistical analysis of data was carried out with SAS statistical software (SAS Institute, 2001), with significant at $P \leq 0.05$.

DISSAN: A FARMING COMMUNITY IN SOUTHWESTERN MALI

Dissan is a community of farming households in southwestern Mali that dates back to at least the seventeenth or eighteenth century. Bamanakan is the local language and the first language of almost everyone in Dissan, and some also speak Arabic, French, Fulani, or Wolof. In Mali, French is the language used for official documents and correspondence, but most Dissan farmers have only a limited knowledge of that language. Semiarid forest and household fields surround the central settlement. Dissan is located at 11°36′N, 7°31′W, 344 masl, and approximately 28 km from Bougouni, an industrial town with a combined urban and peri-urban population of 273,000 in 1998 (Republique du Mali, 1998). Bougouni and Sido, the two market towns frequented by Dissan villagers, sit on the paved road that extends south from Mali's capital city Bamako onward to Ferkessédougou in Cote d'Ivoire.

In December 2001, Dissan consisted of 881 people living in 66 households, a village mosque and school. Depending on its size, a household (*du*) either shares a single compound or a conglomeration of adjacent compounds composed of shaded sitting areas, sleeping quarters, cooking huts, and various storage constructions. The mean number of people per household was 13 (range = 2–47, SD = 8.9). Except for three teachers and a few elders who have retired from field labor, everyone over the age of eight or nine is a farmer, including the imam and village leader (*dugu tigi*). While annual rainfall in the are is high compared with most of Mali, it is extremely variable, both spatially and temporally, within and between years. For the period 1961–2003, mean annual rainfall was 1120 mm/year (SD = 174.7) as recorded at a national agricultural research station in Bougouni (Fig. 1).

According to local farmers, Dissan rainfall is slightly lower than Bougouni's. Over the 2002 growing season, two Dissan households recorded daily rainfall using simple rain gauges placed in their sorghum fields. For May–October Sumayila Sangare's household recorded 689 mm, and Mance Samake's household 718 mm. Farmers felt that 2002 was "good" though "not great" in terms of rain. Though Dissan is in a relatively wet region of Mali called the cotton zone, even in good years when many house-

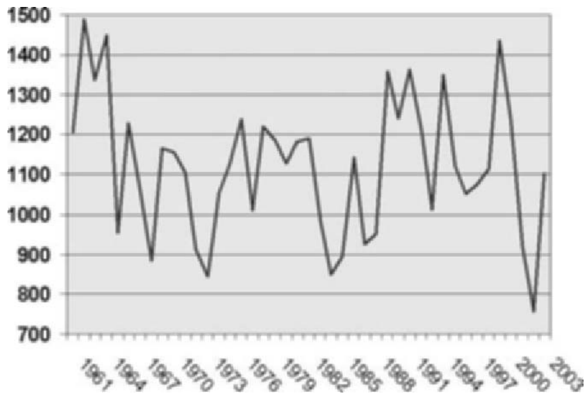

Fig. 1. Annual rainfall, Bougouni, Mali 1961–2003.

holds harvest enough grain to last the year, a large number run out of grain before the harvest.

In separate interviews carried out in 2002, the average estimate of distribution of rainfall by 13 Dissan farmers was 28% dry years, 39% normal years, and 33% wet years, with estimates of yields very similar. Also, the majority of Dissan farmers perceived qualitative GxE interaction between Dissan and another village (92%), between fields within Dissan (85%), and within fields (85%) (Soleri *et al.*, n.d.).

In 2001 rainfall was low and harvests small, and 90% households in the sorghum survey reported in 2002 that their 2001 sorghum yields were the worst in recent memory. Because of this, village leaders established a cereal bank in 2002 to assist hungry families in the community; they insisted on stocking it exclusively with maize because they said the hardest hit households typically rely on maize during food crises because it is cheaper than sorghum and other cereals.

Sorghum Varieties

In 2001 and 2002, sorghum was the most widely grown cereal in the village though many farmers also planted maize, millet, fonio, rice, and cotton. The mean area per household planted to sorghum in 2001 was 2.4 ha, followed by maize (1.7 ha), cotton (1.59 ha), millet (1.2 ha), and rice (1.2 ha). Farmers typically produce sorghum for household consumption and grow cotton as a cash crop and(or as a means for procuring agricultural inputs and short-term credit. The Compagnie Malienne de Développment des Textiles

(CMDT)—the national cotton industry and agricultural extension service for the cotton zone—is a primary source for farmer credit and inputs.

Dissan farmers said they did not have access to MVs until 2002 when, in conjunction with this field study, four households participated in testing sorghum varieties acquired from the ICRISAT (International Crops Research Institute for the Semiarid Tropics) program in Mali. In a 2002 interview, the government extension agent assigned to Dissan stated that CMDT in Bougouni offers one sorghum MV (CSM 388) for purchase. However, Dissan farmers said they were not aware of it, although some farmers were aware that CMDT offers maize "project seed" (i.e., MVs). No farmer reported having ever purchased any MVs of sorghum or maize from CMDT or elsewhere. Most family farmers in Mali do not plant sorghum MVs, especially those who have not worked with formal extension and(or breeding programs. Sorghum FVs in Mali are all guineas race, but there has been almost no work by professional breeders on improving guinea race sorghum for Mali (Yapi *et al.*, 2000).

Dissan farmers choose among a changing portfolio of sorghum FVs, each with distinct, commonly-known characteristics. Dissan households grew seven sorghum FVs in 2001 and 2002, all of the guinea race, and value each variety for its unique characteristics (Table I, Fig. 2). Based on the rainfall, household resources and preferences for the year, and seed availability, farmers choose which of seven sorghum varieties to plant. While some varieties are more popular than others, Dissan households choose only one or two (rarely three) varieties, but all farmers do not plant the same varieties. Farmer classification of varieties includes cycle length (months from planting to maturity), yield and taste. *Boboka* has the highest yield in both good and bad rain years, and is the best tasting. *Segatono* is notable for its resistance to striga, and despite the fact that less than 10% of households will grow this variety in any given year, collectively Dissan farmers have kept this variety as an option for over 30 years. *Kalo Saba* matures faster than the rest (three months) and thus helps farmers escape either early or late season drought. Although it has lower yields in good years than all long-cycle varieties except *Segatono*, it has higher yields in poor rain years than these varieties except *Boboka* (i.e., there is a crossover among *Kalo Saba* and all of the long-cycle varities except *Segatono* and *Boboka*).

Varieties also change over time. *Nzara* and *Nzaraba* appear to have largely been replaced by *Boboka*, the long-cycle variety that farmers ranked highest in terms of taste and yield. *Bakari Kuruni* is relatively new to the village, coming from a farmer in the Kayes region in northwest Mali. Though not as popular as *Kalo Saba* and *Boboka*, every year more farmers acquire and test *Bakari Kuruni* in their fields. In 2002, Sidike Sangare experi-

Table I. Farmer Sorghum Varieties in Dissan (Group Interview and Sorghum Survey)

Variety name	Characteristics agreed on by farmers in group interview						% HHs growing each variety (sorghum survey, $N = 20$)		
	Growth cycle (months)	Year intro in Dissan	Yield with good rain	Yield with bad rain (kg/ha)	Food taste ranking[a]	Distinct varietal traits	2001	2002	1998–2002
Kalo Saba	3	1994	1200	1100	1	Fastest variety	30	35	60
Bakari Kuruni	4	1990	1300	1000	4	Only 4-month variety	20	15	30
Boboka	5	1973	1500	1400	6	Highest yields w/adequate rain	50	75	75
Nzara	5	1940	1300	800	5	One of oldest local varieties	5	15	20
Nzaraba	5	1940	1300	800	5	One of oldest local varieties	5	5	5
Sanko	5	2000	1300	1000	3	Newest local variety	0	5	0
Segetono	5	1970	1200	800	2	Striga resistant	5	10	10

[a]Food taste ranking was worst (1) to best (6).

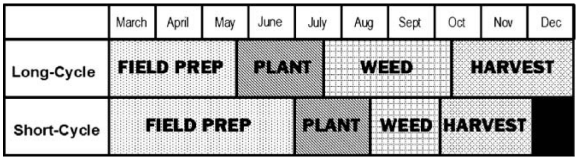

Fig. 2. Timing of activities for long- and short-cycle sorghum varieties.

mented with a pool of three short-cycle varieties acquired from northern Mali (Lacy, 2004), but because these varieties were new, unknown, and grown by only one household, we do not include them in this analysis.

Variety Choice

As their sorghum crop reaches maturity, most households identify potential seed parents in populations which performed well that year or have other desirable qualities. At harvest, farmers typically store seed panicles (and sometimes threshed seed grain) separately from food grain. While some households may save seed for more than one season, this was not observed during the field study. Under some circumstances, such as depleted seed stores or out of curiosity, farmers may identify and request non-household seed. For example, Yaya Sangare, a Dissan elder, observed and became so fond of the *Sanko* variety in his neighbor's field that he requested a couple kilograms for sowing the following year when the 2002 harvest was still over 1 month away.

When the first rains announce the onset of the planting season, farmers must choose the varieties to plant in their fields. When rains are poor and replanting is necessary, varietal choice also occurs during the planting season. All four of the apprenticeship households reported having to replant fields two to three times in 2001 because of inconsistent rains, which depleted stored seed.

FARMER VARIETAL CHOICE: ONE OR MORE THAN ONE VARIETY

A few households (8) grew no sorghum, but the majority grew one variety: in the village survey 66% (38/58), and in the sorghum survey 70% (12/17) in 2001 and 55% (11/20) in 2002 (Table II). The remainder of

Table II. Household Variety Choice: Number of Varieties and Cycle Length (Sorghum Survey, 2001–2002, $N = 20$)

	Number of households			
		Sorghum survey ($N = 20$)		
	Village survey, 2001 ($N = 66$)	2001	2002	1998–2002[a]
0 varieties	8	3	0	0
1 variety	34	12	11	5
2 varieties	23	4	6	8
3 varieties	1	1	3	5
4 varieties	0	0	0	2
Total	66	20	20	20
Long-cycle only	25	12	13	8
Short-cycle only	11	3	1	0
Long & short cycle	22	2	6	12
Total	58	17	20	20

[a]For number of varieties this is the total number of different varieties grown over the 5 years; for cycle length, this is the cumulative choice over the 5 years.

sorghum growing households grew >1 (2–3) variety. In this section we compare households that did not grow sorghum with those that did, and those that chose one with those that chose more than one variety.

Village Survey

Values of most (17/21) of the household variables in the village survey (except dependency ratio, sex ratio, sorghum hectares per person, and sold sorghum), changed in the direction of greater resources with increasing number (0, 1, >1) of varieties (Table III). In other words, it appears that households will plant more varieties when they can afford to do so. The dependency ratio increased, suggesting that in the larger households with more adult workers and other resources, growing more sorghum varieties, each worker supported more non-workers. Differences in sorghum hectares, total hectares, and pieces of major farm equipment were all smaller per person than per household. The 0-variety smaller households with fewer resources sold more sorghum than the 1-variety households, probably because they needed income, whereas the >1-variety households which sold most could probably afford to do so because of high production. For example, during the 2002 “hungry season” just before harvest, one particularly hard-hit family sold small quantities of sorghum to raise funds to purchase higher volumes of maize, the cheapest of all local cereals.

Table III. Number of Varieties Grown per Household (HH) and Key Production Variables (Village Survey, 2001, $N = 66$)

	No. of varieties per HH			
	0	1	>1 (2–3)	All HHs
Number of HHs	8	34	24	66
HH characteristics: mean (standard deviation)				
People/HH, b*	11.00 (5.95)	11.15 (6.66)	17.0 (11.20)	13.26 (8.88)
Working adults (non-students 15–65 years), b*	5.00 (2.39)	5.18 (2.88)	8.04 (5.94)	6.20 (4.39)
Dependency ratio (total HH members/non-students 15–65 years)	2.11 (0.78)	2.24 (0.77)	2.29 (0.50)	2.24 (0.08)
Sex ratio (males/females) of workers	0.72 (.45)	1.02 (0.56)	0.94 (0.34)	0.95 (0.47)
Sorghum hectares/HH, b**	0.00	2.03 (1.30)	3.02 (1.42)	2.14 (1.56)
Sorghum hectares/person	0.00	0.23 (0.17)	0.22 (0.13)	0.20 (0.16)
Total crop hectares/HH, b*	3.60 (2.71)	4.6 (3.09)	6.82 (4.56)	5.27 (1.56)
Total crop hectares/person, a*	0.32 (0.11)	0.45 (2.6)	0.42 (0.17)	0.42 (0.21)
Pieces of major farm equip/HH, b*	1.75 (2.19)	2.5 (2.5)	4.29 (2.58)	3.08 (2.64)
Pieces of major farm equip/person	0.12 (1.6)	0.20 (0.21)	0.31 (0.27)	0.23 (0.23)
HHs (%) that owned				
Cultivator plow, c*	25	38	71	48
Seeder plow, c*	25	21	46	30
Mouldboard plow	63	62	79	68
Spray pump	13	26	42	30
Donkey cart, c**, f*	13	29	67	41
Donkey, c*, f*	0	24	50	30
Cattle	38	53	75	59
HHs (%) that				
Purchased sorghum, f*	88	74	58	70
Sold sorghum	38	29	42	30
Traded sorghum	63	76	88	79
Acquired credit from CMDT, 2001	50	56	75	62

Note. a: *t*-test for for 0 varieties v. > 0 varieties; b: *t*-test for 1 variety v. > 1 variety; c: χ^2 test, 1 *df*, for 1 variety v. > 1 variety; f: Fisher's Exact test for 0 varieties v. > 0 varieties.
$^{*}p < 0.05$.
$^{**}p < 0.01$.

The significant differences were mostly between 1-variety and > 1-variety households—the latter had more people, more working adults, more sorghum hectares, more total crop hectares, and more cultivator and seeder plows, donkey carts and donkeys. There was a small number of significant differences between 0-variety and >0-variety households—the latter had more total hectares per person, and more households that owned donkeys and donkey carts, and fewer households that purchased sorghum.

Seeder and cultivator plows are important for enabling households especially those short of labor, to grow more than one sorghum variety because they reduce the time needed for the critical tasks of planting and weeding during the first 2 months after planting. However, Bakari Jakite explained that hand planting is preferred because, while seeders may be fast, they are wasteful with seed. Bakari and other farmers also report that manually planted sorghum fields yield more grain than fields sown with an ox-drawn seeder. This may explain why, despite owning two functional seeders, Burama and Abu Sangare assembled all the working males of their household, the largest in Dissan, and spent two full days manually planting 3.5 hectares of *Boboka*.

In contrast, there were no differences in ownership of moldboard plows. This is the least specialized plow, used to prepare fields for sowing by creating ridges for hand planting, for early weeding between rows which also mounds up soil around plants, and is usually accompanied by hand weeding. Farmers explained that these mounds conserve soil moisture after rains, and they help make "healthy" root systems. Not everyone does this moldboard ridging—many rely exclusively on manual weeding and/or a cultivator, which tills the soil without mounding. Donkey carts are used for transporting and broadcasting manure and ash onto fields prior to planting, and for expediting harvests. Sprayers are not typically used for sorghum.

Sorghum and Group Surveys

The number of varieties a household plants also varies with changing growing conditions, especially rainfall, as suggested by comparing choices in 2001 and 2002 in the sorghum survey. For example, 12 farmers in 2001 and 11 in 2002 planted only one variety, but over the five-year period 1998–2002, only five of these households planted one variety every year (Table II). In contrast to 2001, the rains in 2002 arrived earlier and were consistent, so most farmers did not need to replant their fields, thus creating opportunities to expand planting area and plant additional varieties. Net changes in the sorghum survey were eight households increased the number of varieties they planted, and one decreased, and 11 did not change (Table IV, Fig. 3),

Table IV. Change in Sorghum Varieties Grown (Sorghum Survey, 2001–2002, $N = 20$)

	Sorghum varieties			
HH ID#	2001	Change/HH, f*	2002	Net change in no. of vars, 2001–02
49	0	+ 1L	1 L	+1
47	0	+1 L	1 L	+1
8	0	+3 L	3 L	+3
42	1 S	NC	1 S	0
48	1 S	– 1 S, +1 L	1 L	0
21	1 S	+1 L	1 S, 1 L	+1
52	1 M	– 1 M, +1 L	1 L	0
23	1 L	NC	1 L	0
33	1 L	+1 S	1 S, 1 L	+1
38	1 L	NC	1 L	0
7	1 L	NC	1 L	0
12	1 L	NC	1 L	0
5	1 L	+1 L	2 L	+1
27	1 L	NC	1 L	0
6	1 L	+1 M	1 M, 1 L	+1
26	1 S, 1 M	NC	1 S, 1 M	0
18	1 S, 1 L	NC	1 S, 1 L	0
53	1 M, 1 L	+1 S	1 S, 1 M, 1 L	+1
57	1 M, 1 L	– 1 M	1 L	– 1
3	1 S, 1 M, 1 L	NC	1 S, 1 M, 1 L	0
Short	6 S	+2, – 1 S	7 S	
Medium	4 M	+1, – 2 M	3 M	
Long	13 L	+9 L	22 L	
Mean no., t*	1.15	0.45	1.60	
Total no	23	+12 , -3	32	

Note. S: short cycle variety (*Kalo Saba*), M: medium cycle variety (*Bakari Karuni*), L: long cycle variety (*Boboka*, *Nzara*, *Nzaraba*, *Sanko*, or *Segotono*).
t: paired comparison *t*-test of difference in means; f: Fisher's Exact Test of S + M vs. L, added and dropped.
*$p < 0.05$.

for a total of nine more varieties planted by households in the sample. The mean number of varieties per household increased from 1.15 to 1.60, and the mean change of 0.45 per household was significant.

In 2002, 10 Dissan households informally reported they had finished planting earlier than expected. Three of them searched the village for short-cycle *Kalo Saba* seed because they had time to plant an additional variety, and they believed there was enough time left in the rainy season for a short-cycle variety to mature. Samba Sangare's household visited Dugu Tigi Solomane Sangare toward the end of the 2002 planting season to trade two kilos of long-cycle sorghum food grain for an equivalent amount of Dugu Tigi's short-cycle sorghum grain for use as seed. Samba explained that one of his peanut fields failed to emerge after planting so he decided to replant it with

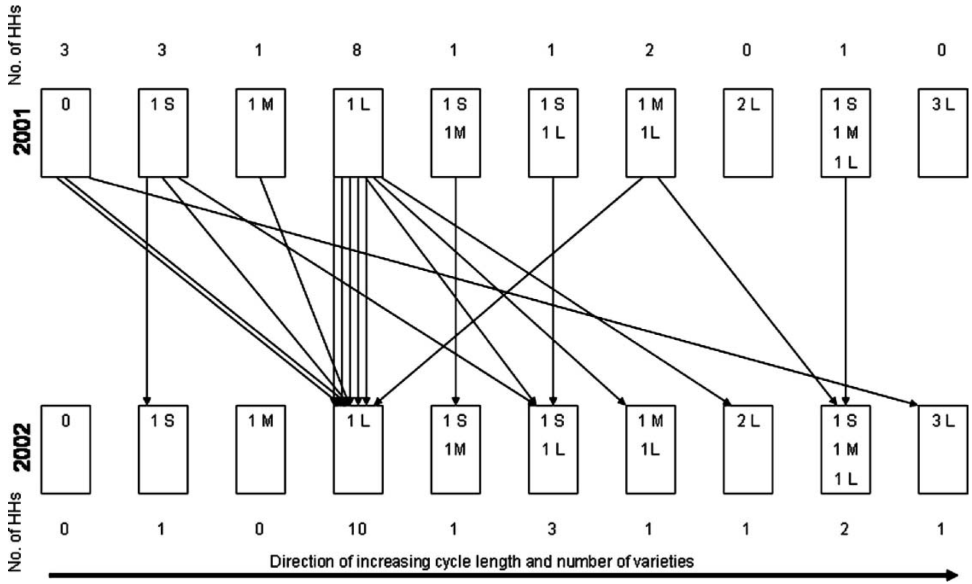

Fig. 3. Change in sorghum varieties grown by Dissan households, sorghum survey, 2001–02 ($N = 20$). S = short cycle variety (*Kalo Saba*), M = medium cycle variety (*Bakari Karuni*), L = long cycle variety (*Boboka, Nzara, Nzaraba, Sanko, or Segotono*).

a short-cycle sorghum variety, but, his own short-cycle sorghum seed was depleted.

FARMER VARIETAL CHOICE: LONG- AND SHORT-CYCLE VARIETIES

In addition to the number of varieties to plant, Dissan farmers must also choose among long-cycle and short-cycle sorghum varieties.

Village Survey

The results from the village survey for cycle length choice are less clear than for number of varieties (Table V). Seven indicators of household resources increased from short-only to long-only to long-and-short (number of people, sorghum varieties, working adults, owning spray pumps and donkey carts, trading sorghum, and acquiring CMDT credit). However, for seven others, long-only households had least resources (sorghum and total crop hectares, households owning cultivator and seeder plows, donkeys and cattle, and selling sorghum).

Only a few differences were significant. Long-and-short households grew an average of two varieties, while short-only and long-only grew one variety—when households choose to grew more than one sorghum variety, they overwhelmingly choose to mix cycle lengths, i.e., they plant *Kalo Saba* and one of the long-cycle varieties. Only one household grew two long-cycle varieties.

Weeding is a crucial element of sorghum production in Dissan, and farmers typically weed long-cycle varieties three to four times in a growing season. With one team of oxen a farmer can weed (or plant) two hectares in one day. To manually weed the same area in one day, a household would have to hire the Dissan *ton ci*—a village-wide labor collective that organizes work teams of 25–50 young men. Without a cultivator to expedite weeding, it may not be practical for some households to grow two separate cycles of sorghum. For example, some households may not have the time and labor to plant enough area in long-cycle sorghum early in the growing season. The later planting date of short-cycle varieties gives households an opportunity to increase sorghum area after the period for planting long-cycle varieties has passed (Fig. 2), particularly for households with a cultivator. Many of these households may depend on seeders to plant short-cycle varieties because the time for planting these varieties usually coincides with the labor intensive first weeding of long-cycle varieties. In 2001, 79% of households

Table V. Household (HH) Choice of Varieties by Growth Cycle, and and Key Production Variables (Village Survey, 2001, $N = 66$)

	Cycle lengths of varieties sown			
	Short only	Long only	Short + long	All HH
No. of HHs	11	25	22	58
HH Characteristics: mean (standard deviation)				
People/HH NS	12.00 (7.81)	12.12 (7.95)	16.00 (10.90)	13.57 (9.21)
No. of sorghum varieties/HH, t**	1.00 *B* (0.00)	1.08 *B* (0.28)	2.00 *A* (0.00)	1. 41 (0.50)
Working adults (non-students 15-65 years) NS	5.00 (2.61)	5.96 (4.06)	7.50 (5.71)	6.36 (4.59)
Dependency ratio (total HH members/non-students 15-65 years) NS	2.58 (1.04)	2.08 (0.52)	2.32 (0.51)	2.26 (0.66)
Sex ratio (males/females) of workers NS	1.01 (0.36)	1.00 (0.61)	0.94 (0.35)	0.98 (0.48)
Sorghum hectares/HH NS	2.36 (1.66)	2.04 (1.34)	2.93 (1.31)	2.44 (1.43)
Sorghum hectares/person NS	0.22 (0.17)	0.22 (0.16)	0.23 (0.13)	0.22 (0.15)
Total crop hectares/HH NS	5.12 (3.80)	4.77 (3.11)	6.53 (4.62)	5.51 (3.89)
Total crop hectares/person NS	0.42 (0.20)	0.45 (0.27)	0.43 (0.17)	0.44 (0.22)
Pieces of major farm equipment/HH NS	2.64 (2.42)	2.64 (2.55)	4.27 (2.69)	3.26 (2.66)
Pieces of major farm equipment/person NS	0.20 (0.20)	0.20 (0.21)	0.31 (0.28)	0.25 (0.24)
Households owning (%)				
Cultivator plow, c*	45	36	73	52
Seeder plow (e, $p = 0.06$; c, NS)	27	20	45	31
Mouldboard plow	64	64	77	69
Spray pump (d, $p = 0.06$; c, NS)	9	36	41	33
Donkey cart, d*	27	36	64	45
Donkey (e, $p = 0.06$; c, NS)	27	24	50	34
Cattle (c, NS)	64	48	77	62
Households that (%)				
Purchase sorghum	55	80	59	67
Sell sorghum f*	55	20	41	34
Trade sorghum	64	84	86	81
Acquired credit from CMDT, 2001	55	60	73	64

Note. t: Tukey's Studentized Range test for comparison of means for the three cycle length categories; categories that do not share same letter (A or B) are significantly different; c: χ^2 test, 2 df, for for frequencies of three cycle length categories; d: χ^2 test, 1 df, for for short only v. short + long; f: χ^2 test, 1 df, for for short only v. long only.
$^*p < 0.05$. $^{**}p < 0.01$.

lacking a cultivator planted only a single sorghum variety, either long-cycle or short-cycle.

As discussed in the previous section, 1-variety households tend to choose long-cycle sorghum varieties unless poor rainfall, family illness, or some other major production constraint temporarily forces them to grow only a short-cycle variety. However, despite the fact that farmers believe short-cycle *Kalo Saba* has some disagreeable qualities, including lower yields in good years and the least favorable taste, 57% of sorghum growing households in 2001 planted it (Table V). Environmental constraints may be the main reason for choosing *Kalo Saba* for all households.

Sorghum and Group Surveys

Like the number of varieties planted, the cycle length of varieties changes from year to year depending on circumstances. Farmers in the sorghum survey significantly increased the overall cycle length of varieties grown in 2002 (Table IV, Fig. 3): three short and medium length varieties were added and three dropped, but nine long-cycle varieties were added while none were dropped.

Some households may choose only short-cycle sorghum in a single year as the result of a production emergency or stress, but unlike households that choose only long-cycle sorghum, growing only short-cycle sorghum appears to be a temporary arrangement. Only one Dissan household in the sorghum survey chose exclusively the short-cycle *Kalo Saba* in both 2001 and 2002. Over the five-year period 1998–2002, a slight majority of households in the sorghum survey (12/20, 60%) chose at least one long-cycle and one short-cycle variety, and no household chose only short-cycle varieties (Table III). In 2002, a year with adequate rain, only (1/20) of surveyed households chose only short-cycle sorghum. Many farmers reported that poor rainfall distribution early in the 2001 growing season forced them to replant household sorghum fields two or three times before the plants successfully established. If a household replants early in the season due to poor rain or seed quality, enough time remains in the growing season to replant a long-cycle variety. However, if a household must replant a second or third time, long-cycle varieties become progressively less viable and their yield more uncertain, and the only choice may be short-cycle *Kalo Saba* (Fig. 2).

For example, Sedu Tarawele said he only had the resources to grow one sorghum variety in 2001 because he was the sole field worker in his six-person household, and they lacked a plow. He explained that the one variety he chose was short-cycle because inconsistent rains in the first months of the 2001 rainy season led him to doubt the viability of planting a long-cycle variety. In 2002, Tarawele remained the only field worker in his household, and he planted just one variety again, but because of consistent rains during the early part of that rainy season, he chose to plant *Boboka*, the most widely grown long-cycle variety in Dissan.

CONCLUSIONS

Our results support our general hypothesis that farmers plant a combination of long- and short-cycle sorghum varieties to optimize yield, yield stability, and post-harvest traits like taste. However, achievement of this goal is subject to a wide array of variable conditions, including rainfall, level of striga infestation, and availability of labor and other production resources, especially cultivator and seeder plows. Farmers' choices are dynamic, responding to changing conditions within and beyond their households—the better rains in 2002 compared with 2001 appear to be a major factor in the general shift toward a greater number and longer cycle length of varieties, and 60% of farmers added varieties between 2001 and 2002 (Table IV, Fig. 3).

In response to the movement of isohyets south, policymakers in Mali argue that improved short-cycle varieties are a critical part of stabilizing the country's volatile cereal production (Dembélé and Staatz, 2000, p. 60), and sorghum breeders and farmers in Dissan and elsewhere look north for shorter cycle varieties. However, our study confirms others that show farmers prefer long-cycle varieties for their superior taste and yield, and grow them when rain and resources permit. It seems important, therefore to improve both long- and short-cycle FVs, and to help farmers to improve their ability to make choices that optimize production, such as increasing availability of plows and weather forecasts. In other words, crop improvement programs need to specificaly target farmer's growing environments, and to use local germplasm as the basis for this (Ceccarelli and Grando, 2002).

Thus, our study supports the importance of varietal portfolios (Ceccarelli *et al.*, 2003; vom Brocke *et al.*, 2003; Weltzien *et al.*, 2003) available through farmer-to-farmer exchange as an alternative to the development of a small number of varieties for large scale adoption. This also conserves crop genetic diversity in situ.

ACKNOWLEDGMENTS

We thank the village of Dissan, especially the four apprenticeship households (Sumayila Sangare Ka So, Sedu Mama Ka So, Samba Sangare Ka So, and Bakari Jakite Ka So), and Siaka Sangare who collaborated in the 2001 and 2002 surverys; Eva Weltzein and Fred Rattunde of ICRISAT-Mali for generously sharing their knowledge, time, and resources; Eva Weltzein for comments on this paper and suggesting resources; the IIE Fulbright program and the Fletcher Jones Foundation of Los Angeles (SML), and the National Science Foundation (SES-9977996) (DAC, DS) for funding. Farmers whose names are used gave permission in compliance with the non-anonymous and non-sensitive UC Santa Barbara Human Subects Exemption.

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