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Farmers' common bean variety and seed management in the face of drought and climate instability in southern Ethiopia

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This study reports the various elements and contexts that characterize the farmers' use and management of common bean seed and varieties in southern Ethiopia. The study used focus group discussions, contact-farmer interviews and surveys. The results demonstrate that farmers' cropping systems and preferences vary strongly. Moreover, the high level of environmental variation and the associated risks of crop failure have increased even more with climate instability. While farmers are aware of climate instability, only about half of them have adapted some cropping practices to better cope with it. Simultaneously, markets offer different opportunities and common bean production expands in areas at slightly higher elevation. In these conditions, common bean production is increasingly important for farmers. They currently manage only modest levels of bean crop diversity. Farmers' variety and seed management practices do not show a high level of specialization and at the same time the use of off-farm seed sources is relatively high. This situation provides opportunities for strategic development and introduction of common bean genetic diversity. Earlier maturing, more drought-tolerant common bean varieties for a range of conditions, markets and preferences should be developed with an integrated understanding of farmers' production conditions and existing seed system practices.

Key words: Cropping pattern, drought tolerance, farmer-selector, farmer preference, *Phaseolus vulgaris.*

INTRODUCTION

Farmers' variety and seed management practices are based on farmers' experiences built over a lifetime and on traditions inherited from their predecessors. Farmers have been the core elements of agricultural development since the domestication of crop plants and continue to be important for the future of agricultural crops (Harlan, 1992). Their variety and seed management is the result of a complex interaction between social-economical and agro-ecological factors in which new and old technologies are continuously assessed and appropriated (Almekinders et al., 1994; Dyer and Taylor, 2008). Farmers' variety and seed management practices in traditional farming are often effective in achieving goals of adaptation and genetic gain in terms of yield but also in terms of maintaining ritual, culinary and market traits (Cleveland and Soleri, 2007). Farmers are often found

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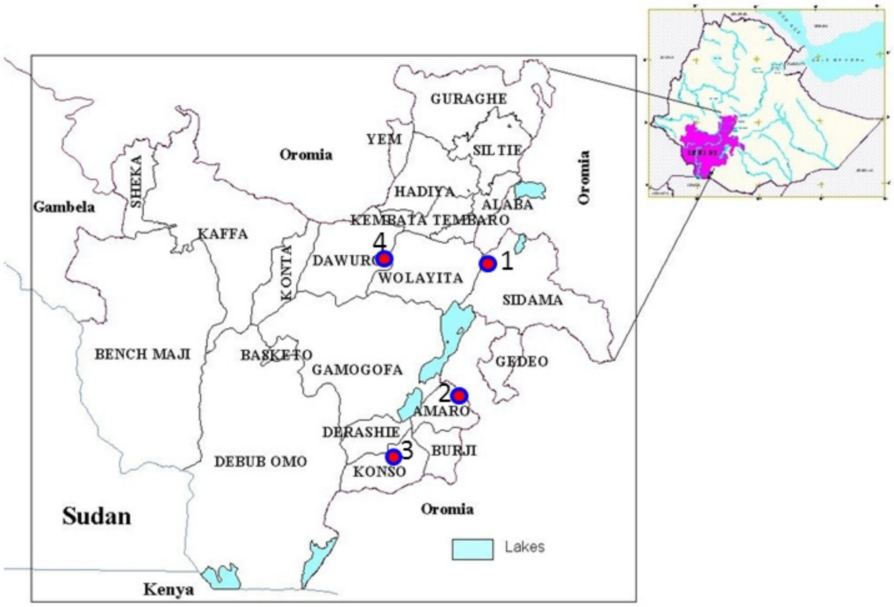

Figure 1. The study sites in the South Nation, Nationalities and Peoples Regional State, Ethiopia. 1 Boricha, 2 Amaro, 3 Konso and 4 Loma.

effective in maintaining varietal ideotypes and changing or creating more preferred genotypes or variants in the informal seed system (Berthaud et al., 2001; Soleri and Cleveland, 2001; vom Brocke et al., 2002; Nuijten et al., 2009). In the informal seed system, there are specialized farmer-selectors (Almekinders and Elings, 2001; Cleveland and Soleri, 2007; Abay et al., 2008). However, it is not only the specialized farmers who make up an informal seed system: most farmers engage in one way or another in seed production, seed diffusion and in designing new farming systems simultaneously (Offei et al., 2010). Hence, to design effective breeding strategies and understand opportunities to support farmers in mitigating the effect of climate instability, the sum of all farmers' actions matters in the farmers' seed system (Dyer and Taylor, 2008).

East Africa in particular and Ethiopia especially are regions projected to be at risk from effects of climate instability (Jones and Thornton, 2003; Funk et al., 2005). Common bean (*Phaseolus vulgaris* L.) is the principal food-security legume in this part of Africa, providing dietary protein and source of cash income for resource poor farmers (Wortmann et al*.,* 1998; Broughton et al., 2003). The crop is believed to have been introduced together with maize via the east coast of Africa by Portuguese and Spanish traders in the 16th and 17th century (Greenway, 1945; Gentry, 1969). Since then common bean farming has been primarily shaped by farmers' physical, climatic and social factors. These have resulted in a range of morphologically and genetically diverse landraces (Wortmann et al*.,* 1998; Asfaw et al., 2009; Blair et al*.,* 2010).

The formal common bean breeding program in Ethiopia has drought tolerance as a main and most important goal. The program faces the challenge to incorporate this trait in varieties that are grown by common bean farmers in multiple environments. Understanding the diversity of farmers and their socio-economic and agro-economic environments is therefore an essential component in the development of a breeding strategy, focused primarily on small-holder farmers.

This paper reports on farmers' variety and seed management practices such as plant type selection, seed saving, and exchange practices, and their associated knowledge in southern Ethiopia. It places these practices in the context of farming systems that are diverse and prone to drought, and in which common bean is the major food staple along with maize (*Zea mays* L.) and enset (*Ensete ventricosum* (Welw.) Cheesman). It looks in particular into aspects related to climate instability: farmers' perception on drought, rainfall trends and practices to cope with instability. Finally, it discusses what strategic insights a seed system study could offer to a national breeding program.

MATERIALS AND METHODS

Study area

This study focused on the southern state called South Nation, Nationalities and Peoples' Regional State, which is one of the major common bean production areas in Ethiopia. It is located in the southern and southwestern part of Ethiopia between 4°43´ and 8°58´ N latitude and between 34°88´ and 39°14´ E longitude (Figure 1). The region forms a multi-ethnic society consisting of 56 ethnic

Table 1. Physical and socio-economic characteristics of the study sites and survey farmers.

Characteristics	Study sites			
	Boricha	Amaro	Konso	Loma
Area				
Altitude (m a.s.l.)	1650-1932	1305-1450	1200-2000	800-1900
Latitude (º north)	6.76-7.01	5.60-5.99	5.17-5.56	6.58-7.07
Longitude (º east)	38.07-38.39	37.54-38.01	37.01-37.69	36.93-37.43
Annual rainfall (mm)#	963	927	617	1121
Total rainfall '*Belg*' (mm)	299	412	317	347
Total rainfall '*Meher*'(mm)	492	323	221	574
Major agro-ecology	Tepid to cool sub-humid	Hot to warm humid	Hot to warm humid, semiarid	Hot to warm sub-humid
Major soil type	Chromic luvisols, Eutric fluvisols	Eutric nitosols	Eutric regosols, Eutric nitosols	Eutric nitosols
Bean production system	Relay/sole	Intercrop/sole	Intercrop/sole	Relay/sole
Average bean area (ha) HH^{-1} †	0.30	0.28	0.41	0.73
Average bean yield (kg ha^{-1})	1550	750	690	1185
Importance of common bean	Cash, food	Food	Food	Cash, food
Ethnic group	Sidama, Wolayta	Koyra	Konso, Ale	Dawro
Survey farmers				
Number of respondents	104	110	90	71
Illiterate (%)	54	26	40	23
Female (%)	23	15	21	10
Average age (years)	44	40	41	44
Average family size (number)	8	7	9	8
Average land holding (ha)	0.81	1.06	1.94	1.58
Average land area share out (ha)	0.06	0.13	0.10	0.41
Average land area share in (ha)	0.18	0.16	0.04	0.43
Average land area rent out (ha)	0	0.02	0.03	0
Average land area rent in (ha)	0.04	0	0.06	0.01
% of HH land holding steep slope	9	7	21	13
% of HH land holding gentle slope	16	25	39	47
% of HH land holding flat slope	75	68	40	40

Rainfall data from nearby meteorology station averaged over more than 15 years, † HH household.

groups with their own distinct geographical locations, languages, cultures, and social identities. The ethnic groups are categorized according to a language taxonomy as the Omotic, Cushetic, Nilo-Sahara and Semitic super-language families. Among them, the Omotic and Cushetic groups are the most populous and diversified and cover the largest area (BoFED, 2008). Based on ethnic and linguistic identities, the region is divided into 13 zones and 8 special districts (Figure 1). The 13 zones, together with the 8 special districts, consist of 126 districts which, in turn, are subdivided into 3594 rural and 355 urban kebeles (the smallest administrative unit of the country).

Subsistence-oriented, rain-fed agriculture is the mainstay for about 90% of the region's population. The individual farm-land holding is very small and highly fragmented with 9% of the households having less than 0.10 ha, 46% having 0.10 to 0.50 ha, 26% having 0.51 to 1.00 ha, 15% having 1.1 to 2.0 ha and only 4% having more than 2.0 ha (BoFED, 2008). Crop farming typically depends on hand or oxen tillage and use of very few external inputs. The landscape is characterized by plain, mountainous and undulating terrain with an altitude ranging from 376 to 4207 m above sea level. These conditions endowed the region with a diversity of agro-climate and a large variety of crops. The diversity of people is therefore associated with a large diversity in the agro-ecological and social settings. People endure problems of recurring drought, low soil fertility, biotic stress, and continued shrinkage of landholding due to population pressure.

Common bean is grown in all 13 zones and 8 special districts in the region, in an altitude range of 1000 to 2200 m above sea level. Its production is concentrated in the Rift Valley where it grows from hot to warm sub-moist up to cool mid-elevation areas. This study focused on four sites in four districts of the region (Figure 1). The selection of the sites is based on the importance of common bean production and the intensity of marginality due to drought throughout the area (Table 1). Boricha in the Sidama zone is the most important bean production area in the Central Rift Valley part of the region. Boricha is a densely-populated, mid-elevation plain with frequent intermittent droughts during the bean growing seasons (Amede et al., 2004). The Amaro and Konso districts are located in the southern part of the Rift Valley, close to northern Kenya. These districts represent dry and semi-arid common bean growing ecologies constrained by terminal drought. Konso is characterized by degraded land with low soil fertility and terrace-based common bean farming. Cross-border common bean trade and germplasm exchange with northern Kenya have existed for a long time (Asfaw et al., 2009). The Loma district in the Dawro zone is a dry to humid mid-altitude area in the central-west part of the region where common bean is produced in a mountainous area, subject to occasional hot conditions and intermittent droughts.

Data collection

The study was carried out between May and December 2008. It used focus group discussions, interviews of and observations by contact-farmers throughout a season and surveys. The sampling unit in each interview session was the household.

Focus group discussions (FGD)

Twelve FGD were conducted which composed of a mixture of people of different gender, ages, resources and know-how on common bean. FGDs were conducted in May and June 2008. At each site, three separate discussions were held to cover the site's geographical area. Each FGD started with purposively selected 10 or more participants who were identified and invited in consultation with extension agents and kebele leaders. During the discussion the number would increase, up to 30 in some cases, with curious volunteers from surrounding farms. The discussions covered common bean cropping system, cropping calendar, inventory of common bean varieties grown or known in the locality, the preferred and non-preferred traits of the identified common bean varieties, perceived production constraints, perceptions on good and bad season for common bean farming, and perceived changes of the characteristics of weather and common bean farming in the locality. Farmers were asked to rank common bean production constraints in order of importance using the proportional piling methodology (Mukherjee, 1993). Each group received 100 common bean seeds to proportionally allocate to the constraints listed, based on their importance in causing yield loss. After calculating the rank for each group, severity of the constraints for the studies communities was determined using an index method (Smith et al., 2000). The constraints identified varied within and across study sites and resulted in ranking data of ordinal and different dimensionality. One group would identify four constraints and rank those four while another group could identify seven and rank those seven and so on. Accordingly the severity index value, s_j, for a constraint of rank r among a group of n constraints identified by group j is thus $s_j = 1+(r-1)/(n-1)$. This sets the most serious constraints across study sites ($r = 1$) to $s_j = 1.0$, the least serious constraint ($r = n>1$) to $s_j = 2.0$, and the remaining constraints assigned intermediate values between the two extremes.

Contact-farmer interviews

The group discussion was backed-up with information from contact-farmers (two each at Amaro, Boricha and Konso; none at Loma, because this site was too far to allow regular follow-up by field researcher). Contact-farmers were farmers who stood out in the focus group discussions as most knowledgeable about the crop and the environment and who volunteered to share their knowledge. The contact-farmers were visited on a regular basis during the study period for follow-up interviews. The focus group discussion and contact-farmer interviews provided input for the farmer household surveys.

Household surveys

The surveys were held in at least three kebeles at each site and captured the opinion of 375 household heads, the majority being men however, 10 to 30% women participation in surveys assured that the views of both genders were heard (Table 1). The sampled households were selected randomly from bean growers in the community with the help of kebele leaders and development agents. Data were collected using a semi-structured interview on household composition, age and sex of household head, level of literacy, and a range of questions relating to the bean varieties grown and seed management practices in general and in relation to a specific season. The survey also covered farmers' perceptions on climate, their practices to cope with climate instability and genotype $\times$ environment interaction (G$\times$E). A hypothetical scenarios for spatial G$\times$E and temporal variation for the expression of grain yield were used based on Soleri and Cleveland concept (Cleveland et al., 2000; Soleri and Cleveland, 2001). Farmers were asked for hypothetical yield variation when the same variety and seed source planted at different field in the same farm, different farm, and different community and in both a variable, stressful, typical field of the region and in a hypothetical optimal field with no constraint. During the survey, the questions were posed in the local language at the respective sites and these were back translated to Amharic in different sites to ensure the local translation to be accurate. At all sites, the semi-structured interviews were pre-tested on 10 households to ensure that the designed questionnaires were relevant to the local context.

Data analysis

The data collected were subjected to descriptive analysis using PASW statistics version 17, software. Sigmaplot version 10.0 (Systat Software, Inc, CA, USA) was used to develop graphs.

RESULTS

Seasonality and cropping system in bean farming

All study sites have a bimodal rainfall pattern that allows at least two cropping seasons in a calendar year, these being known as '*Belg*' (February – May) and '*Meher*' (June – October). The rainfall pattern is associated with a seasonal cycle of land preparation at the onset of rains, weeding and harvesting (Figure 2). The seasonal pattern in the region shows unpredictable and erratic rainfall variation (Funk et al., 2005). In many places, the first short rains in the '*Belg*' season are often less dependable than those of the second, longer '*Meher*' season. On the other hand, in areas like Amaro and Konso with semi-arid ecology in the southern Rift Valley part of the country, total rainfall is higher during the '*Belg*' season than in the '*Meher*' (Table 1). Both cropping seasons are important for common bean: more than 85% of the surveyed farmers had planted common bean in both seasons of 2008. '*Belg'* is the major growing season at Amaro and Konso whereas in Boricha and Loma, '*Meher*' season is the more important common bean season.

Cropping practices in common bean production vary across study sites. In Amaro and Konso many farmers plant larger areas with common bean during '*Belg*' season when the rainfall is relatively more dependable than in the '*Meher*' season. In Boricha and Loma, many farmers plant larger common bean areas in the '*Meher*'

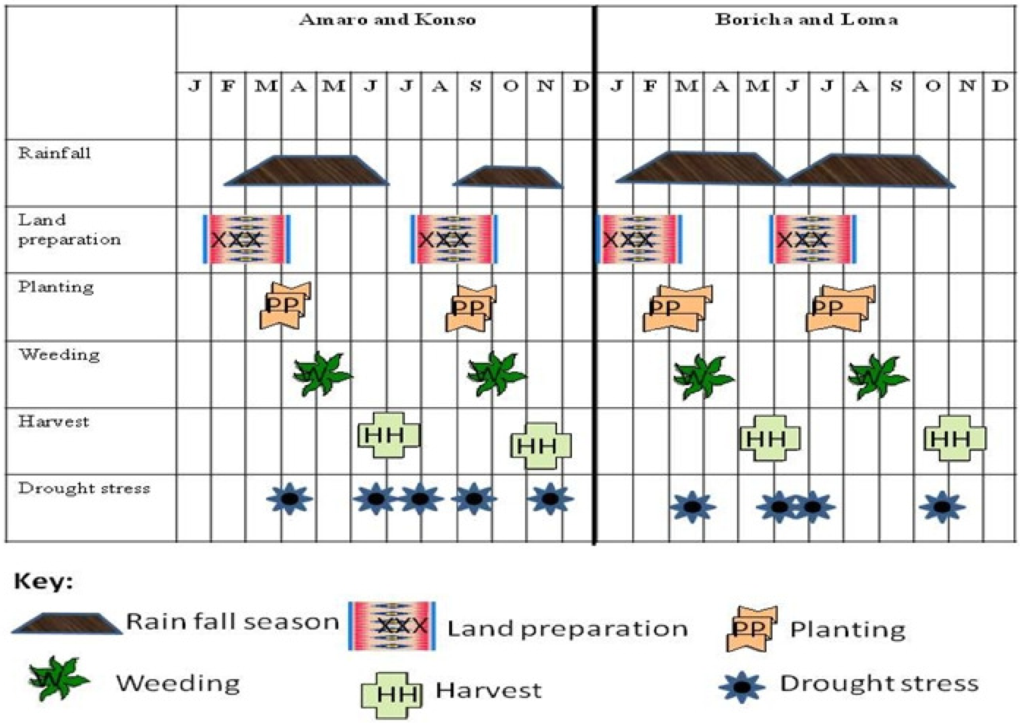

Figure 2. Common bean cropping calendar in the southern region of Ethiopia according to farmer participants of focus group discussions.

rainy season because that is the more reliable rainy season there. During the '*Belg*' season, a few farmers in Boricha and Loma plant small areas of common bean to combat hunger during May-June period when there is no other crop in the field to harvest, or to use this crop as seed source for the next planting.

In the group discussions, farmers indicated that they normally grow cereal and pulse crops in sole, inter- or relay-cropping systems, and combine these with livestock rearing. Fifty-two percent of the survey farmers planted common bean in more than one cropping system in the year 2008. Of the surveyed farmers (one individual referring different plot in their answer) 64, 50 and 38% practiced sole-, inter- and relay-cropping of common bean in 2008 cropping season, respectively. In the '*Belg*' season, farmers usually practiced sole cropping of common bean or intercropping of common bean with maize or sorghum while in the '*Meher*' cropping season, common bean was often planted as a sole crop or as a relay crop with maize or sorghum. Common bean area under sole, intercrop and relay-cropping was 43, 26 and 31%, respectively, averaged over seasons ('*Belg*' and '*Meher*') and sites.

In the practice of a system with different crops, the sequence of sowing dates for each crop and variety is decided on the basis of the crops' growing period and labor availability. Maize (*Z. mays* L.) and sorghum (*Sorghum bicolor* L.) are the major cereal crops, which require longer growing seasons than common bean; consequently farmers prioritize planting maize and sorghum at onset of rains followed later by the sowing of common bean. This practice usually exposes common bean to water deficit during critical flowering and grain filling stage when the rains terminate prior to pod development. The water deficit problem is intensified when the May dry-spell is longer during '*Belg*' season in Boricha and Loma and rainfall is limited in the short '*Meher*' season in Amaro and Konso. As a result, common bean can suffer moderate to severe water deficits, even in so-called normal seasons. This suggests that management of sowing time and thus labor in response to normal rains may matter less for common beans than it does for maize and sorghum. However, in drought seasons with delayed onset of the rains, common bean gets much attention by some farmers in the study sites in terms of time as well as labor.

Varieties planted, their differentiation and distribution

Farmers usually distinguish the common bean varieties by grain types. Although the study sites varied in ethnicity, ecological marginality, distance to market and to research center, there were no distinct differences in farmers' naming practice regarding their bean varieties. In all places farmers most often used seed color and seed size in naming common bean varieties although the words differed by language.

The survey indicated that 88% of the area planted with beans in 2008 was covered by farmer varieties whereas only 12% was planted to improved varieties. Of all farmers, 96% was growing one variety (including variety mixtures), 3% was growing two varieties and only 1% had planted three varieties in 2008, which means an average of 1 variety per farmer and maximum three varieties per farmer. Approximately 90% of survey farmers grew a pure bean variety while 10% had grown bean variety mixtures in the last five years (2003 to 2007). The practice of growing variety mixtures did not vary between the '*Belg*' and '*Meher*' seasons but farmers mostly practiced growing a pure variety under sole cropping and variety mixtures under inter- and relay-cropping systems. Varietal mixtures were grown by a considerable number of farmers at Amaro while a few farmers were growing varietal mixtures in Konso and Loma. In variety mixtures, farmers mix 2 or 3 different grain types, like for example small-red and black or small-red and white. In Boricha farmers did not grow variety mixtures at all. Boricha farmers rather practiced planting more than one variety in separate plots as a sole or relay crop. Of the improved varieties adopted by farmers in the region, 78% grew small-white, 20% small-red and 2% the large-seeded, red-mottled, Andean bean.

During the survey season, seven grain types were grown with varying distribution across study sites (Table 2). Among these, farmers categorized varieties of small-red, small-white and black into sub-types based on seed shape and growth habit while the remaining ones were not. The varieties varied in their yielding potential, growth cycle and specific traits. Farmers described small-red as the most preferred variety for local-dish making and for selling at the market. Small-white varieties were preferred for 'kiki' (local stew) and uniform harvest maturity. Black-seeded varieties were not liked in many places, except Konso, because of its non-attractiveness for eating and the associated low marketability. Carioca-types were preferred for their earliness and thereby the possibility to escape drought stress. However, women did not appreciate carioca beans because of their long cooking time. The red-mottled, large cream and cream-mottled Andean common bean varieties were liked for their culinary quality: swelling in pot while cooking, good looking dish and flavorful. Farmers perceived large-seeded Andean and small-white varieties as performing well in sole cropping and on fertile land. Black and small-red type bean varieties were considered adapted to a wide range of production systems. Farmers stated that small-red seeded varieties prefer moist mid-altitudes whereas black and carioca beans perform better in the dry land.

The relative importance of bean varieties at different study sites varied (Figure 3). Small-red was the primary class of beans cultivated by farmers in two of four study sites followed by small-white beans. Black beans were popular at Konso and Amaro where the growing area is very marginal due to drought. Only some farmers in Boricha and Amaro had planted the large seeded Andean type beans. Farmers identified three grain types in the Andean type, namely the red-mottled, cream-mottled and large cream beans of which red-mottled was dominant (data not shown). The cream-mottled bean varieties because they are susceptible to drought, are not widely grown and mostly as part of a variety mixture. Other Andean grain types such as large cream and red-mottled are grown by a few farmers around Amaro and Boricha, respectively. Large cream grain type in Amaro was preferred due to its determinate growth habit and good fit into intercropping systems. According to farmers, limited seed availability, planting date specificity and susceptibility to pests and moisture stress limit its further diffusion. Andean beans have a narrower planting date window than other bean types. These bean types are also very susceptible to bruchids during seed storage, making seed saving for next season planting problematic to farmers. Medium-seeded carioca beans were exclusively grown by farmers in Amaro. Carioca beans are said to have been introduced in the last decade or so from northern Kenya. Their local name '*Alga Hamare*' refers to the Alga or Burji ethnic group that is believed to have crossed the border into Kenya to visit relatives and in search for new seeds that would be adapted to the increasingly shorter growing period. The relative importance of bean varieties expressed as area planted showed large similarity to the importance expressed as percentage of farmers.

Farmers in Amaro and Konso prefer varieties with determinate growth habit for intercropping whereas in Boricha and Loma farmers like indeterminate varieties for relay-cropping. In the extremely dry and marginal environment of Konso, farmers planted black beans because of their moderate drought tolerance compared with other bean types. In areas receiving relatively better rainfall within Konso, farmers prefer growing small-red bean varieties for which there is a specialized seasonal grain market at the town of Karate in Konso. This market gets most of its supply from Gawada and relatively well-watered surrounding bean growing areas in Konso and is destined to northern Kenya via the border town Moyale. Near Karate town in Konso, farmers wished to grow small-red bean varieties for cash income but the marginal environment did not allow them to grow anything else but the black beans. In the Central Rift Valley near the export market of Addis Ababa, farmers planted the small-white Ethiopian export class. In places like Boricha and Loma, where small-red beans were highly marketable, farmers' preference was mostly for this type while they preferred the large seeded Andean bean varieties for home consumption.

Apart from the seven major grain types there are also minor grain types of varying different seed color and size

Table 2. Farmers' description of major common bean varieties in relation to preferred and non-preferred traits elicited during focus group discussion.

Type	Small-red	Small-white	Black	Carioca	Red-mottled	Large cream	Cream-mottled
Subtype	Light and dark red color	Round and flat seed shape	With and without tendrils	No	No	No	No
Description	Small-seeded with tendrils	Small-white	Small seed size and dull	Round shaped, medium sized, with stripes, growth habit with tendrils	Erect plant structure, thick stem, large seed size, calima type	Large seeded, long and slender seed shape, without tendrils	Large seed size, cream-mottled sugary type, with tendrils
Vernacular name	Dume (B), Engliz (L), Sora (A), Atima (K)	Wajo (B), Fillo (L), Boste (A), Atta (K)	Kolisho (B), Asimada (L), Manna (A), Abura (K)	Alga (A)	Logoma (B), Torgonia (L), Zorbo (A)	Sallo (A)	Logoma (B), Torgonia (L), Siroendo/ Zorbo (A)
Preferred trait	High market preference, preferred for local dishes, yields well, good for relay and sole cropping, well adapted to local conditions	Matures fast and uniformly, good for 'kiki' (local stew), good for sole cropping	Yields well, tolerates drought, disease and weevil, tastes good, adapted to all cropping systems	Matures fast, escapes drought, tastes good, gives less flatulence	Medium maturing, tastes like meat, fast to sell and good market price, good for fresh-grain consumption	Matures fast, tastes good, preferred for intercropping and fresh-grain consumption	Tastes good, cooks fast
Non-preferred traits	Does not tolerate drought, matures late, susceptible to disease and weevil, not suitable for intercropping, lacks uniform maturity, flatulence problem	Does not tolerate drought, susceptible to disease (rust) and weevil, low yield, requires fertilizer, shattering is a problem, not preferred in local dishes like '*nifro*'	Not attractive to eat, no market demand, late maturing, high flatulence	Low yield, not good for inter-cropping develops tendrils, lacks uniform maturity, does not cook fast	Low yield, does not tolerate drought and weed infestation, very susceptible to disease and weevil attack (seed storage is a big problem), prefers fertile soil	Does not tolerate drought, low yielding, susceptible to disease and weevil (seed saving is a big problem)	Very susceptible to drought, disease and weevil, matures late, yields are low
Growth cycle (days)	85-95	80-85	90-100	70	75-80	60-70	>90
Yield with good rain (kg/ha)¥	1267 (655-1452)	896 (530-1196)	929 (789-2400)	844 (608-2200)	865 (822-2400)	600 (400-1500)	683 (647-1100)
Yield with bad rains (kg/ha) ¥	468 (230-782)	381 (200-659)	372 (310-1200)	434 (100-1200)	383 (288-680)	300 (50-500)	255 (247-350)

¥, Farmer estimated yield mean and range; A- Amaro, B- Boricha, K- Konso, L- Loma.

that are probably the result of crossings within varietal mixtures. Few farmers grow this minor grain types in a variety mixtures and the off-types are not recognized or named as a variety.

Farmers' variety and seed selection practices

Farmer varieties like the small red, black and cream mottled are probably a mixture of lines. Some farmers recognize differences in seed color, seed size and growth habit within a seed lot, but they recognize it as a single variety because its components belong to a single grain type. Most

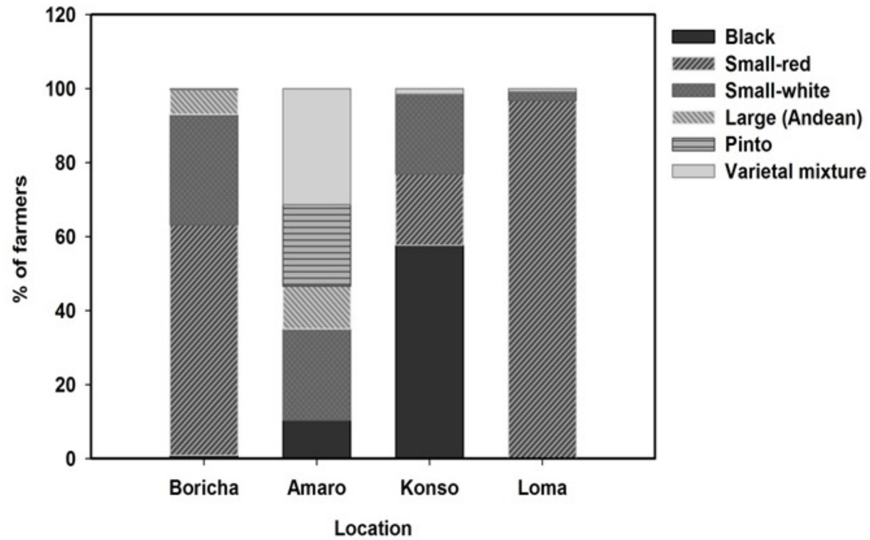

Figure 3. The relative importance of common bean grain types by percentage of farmers growing the varieties in year 2008 in the region. Data of Andean varieties were pooled and areas planted in *Belg* and *Meher* are accumulated.

surveyed farmers (71%) practiced some form of mass selection to save seed for next season. The selection intentionally or unintentionally may affect the variation of seed size, seed color and growth type of the seed lot. For example, when eliminating shriveled, under-developed or cracked seeds through winnowing, the farmers un-intentionally selected genotypes in the seed lot with larger seed size. Among those practicing selection, 53% selected plants before harvest in the field, 15% at harvest just before threshing, and 7% separated seed from grain just after threshing while 18% practiced cleaning seed just before sowing. Nearly 7% of farmers combined practices of before harvest in-field plant selection and after-harvest seed sorting. Among those who practiced before-harvest, in-field plant selection, 29% selected from anywhere in the field, 38% selected from the best parts of the field including the border rows, 7% said they selected from any part of the field excluding border rows and 26% mentioned selecting from best part of the field excluding the border. In-field selection was mostly done by men while post-harvest seed sorting especially before planting was carried out by women and children. Seed storage was the responsibility of men in all study sites except in Konso where women managed seed storage.

When selecting seeds or plants to renew seed lots, farmers most often selected for well-filled grains, heavy pod load (large number of pods per plant), full seed color development, early maturity, absence of weevil damage (seeds not attacked by weevil), drought tolerance (plants survive drought stress and produce some seed), disease tolerance, seed size (mostly larger size preferred), clean pods (field resistance against insect pests), growth habit, immature and seed coats without cracks or other damage (Figure 4). Primary criteria used for in-field selection were pod load and pod length, maturity, disease and insect pest resistance whereas screening seed for pest damage during storage, seed color development, grain fill (plumpness), seed size, seed cracking and immature seeds were practiced at post-harvest seed selection. The use of the selection criteria was not the same across study sites. For instance, farmers practicing relay-cropping in Loma selected for indeterminate growth habit while those practicing intercropping in Amaro looked for determinate growth habit. No farmer used separate fields for producing seeds. However, some farmers at Boricha and Loma used '*Belg*' season plantings almost exclusively as a seed source for '*Meher'* plantings and seed lot renewal.

Although some farmers distinguished differences within a seed lot, farmers' knowledge on source of genetic variation was generally limited. More than half of the survey farmers (57%) reported observing off-type beans in their field sometimes. Those observing off-types considered different sources of the off-type seed: seed mechanical mixture (35%), natural occurrence (53%), or of unknown cause (12%). When observing off-types, 29% took no action and left off-types in the field, 65% would harvest them separately for sowing the following season and 6% rogued them out from the field. Those who harvested off-type seeds separately did not claim they were developing a new variety. They said to plant off-types separate in the next season and, depending on the performance, either eat it, mix the seeds with the mother seed stock again, or keep it as new variety if they see some future advantage for the line.

Some farmers at Amaro and Konso planted variety

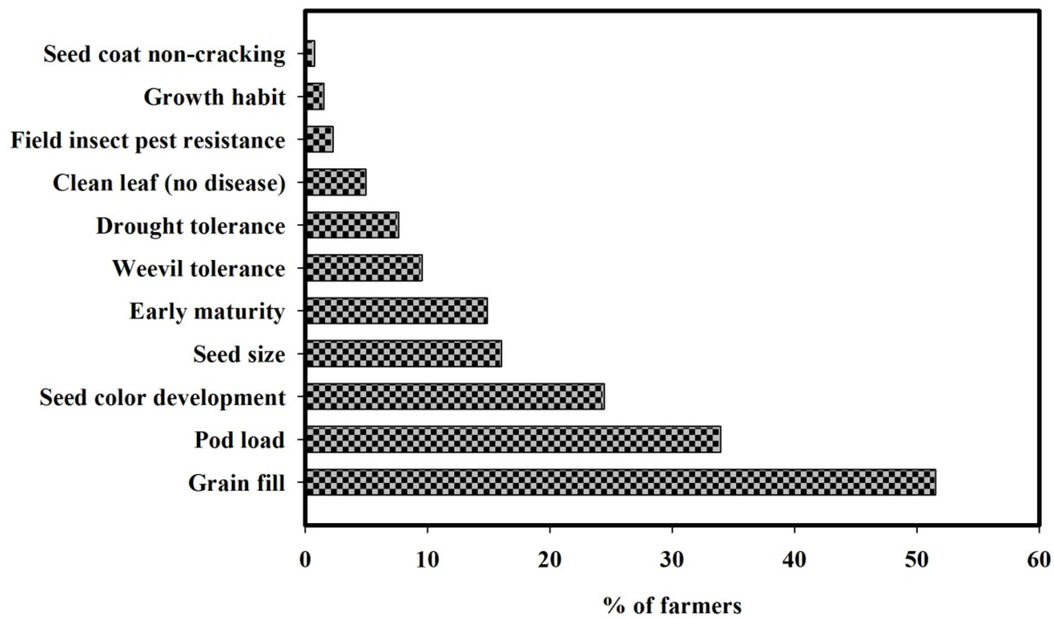

Figure 4. Farmers' selection criteria for renewal the seed lot of their bean varieties. Traits and % of selector farmers using the traits for selection in farmer survey.

mixes to mitigate the effect of drought stress. Some farmers purchased seeds of different varieties, mixed them, and would re-select in seasons with drought stress those that survived for their variety mix next season. Other farmers bought seed lots that are mixtures. Most farmers considered early maturity as a drought escape, not as a real tolerance mechanism, but still preferred this trait under drought conditions in all the study sites. Farmers observed that early-maturing varieties were often more susceptible than late-maturing genotypes when drought came early.

Very few farmer-selectors considered strong root system and early vigor in their selection as a trait for drought tolerance. Farmers who used root pulling force resistance perceived deep rooting as allowing plants to extract moisture from deeper in the soil and to enhance plant survival during stress. Vigorous plants were considered as a sign of strength to survive harsh environments.

Varietal change and seed replacement

Since about 40% of common bean seed used by survey farmers in 2008 originated from off-farm seed sources (Figure 5), seed lot replacement rate is relatively high, given that common bean is self-pollinating and genetic degradation of varieties is therefore not very strong. Farmers replaced their seed lot when seed quality of particular variety had deteriorated; for example, when all the seed was shriveled, reduced in size, diseased or discolored, or when yields decreased. This could be the case after an extremely dry season, or when – as farmers considered – the seed was tired. Farmers also changed their seed lot when their seed was damaged by storage pest (weevil), after total crop failure and when all produce was eaten. Farmers pointed out during the group discussions that refreshing seed stock every 3 to 4 years was good practice and that a younger seed stock was better than an older tired seed stock.

Farmers grew the same variety without change for very long periods, on average for 10 to 11 years with low variety turnover (Table 3). However, the average age of a variety and seed lot turnover varied between varieties and across locations. Black and small-red varieties were grown for a longer time than carioca and cream-mottled varieties. Farmers in Boricha grew the same variety for shorter periods of time as compared to other sites. This site is relatively close to the research and extension site of Southern Agricultural Research Institute (SARI) and farmers pointed out that they changed their variety when new germplasm arrived the farming system via the extension program and the visits of researchers or relatives or when they acquired new seed lots in trade exchanges with neighboring ethnic groups.

The seed-lot turnover highlighted in Table 3 refers to total seed lot replacement (usual after total loss). About 14% of survey farmers had fully refreshed their seed lot during the last five years with new, younger stock completely replacing the old lot; 11% had in the seed lot change also changed to a variety with a new grain type. More than 70% of survey farmers partially replaced their seed lot or mixed in new fractions of seed at least twice in the last five years (data not shown).

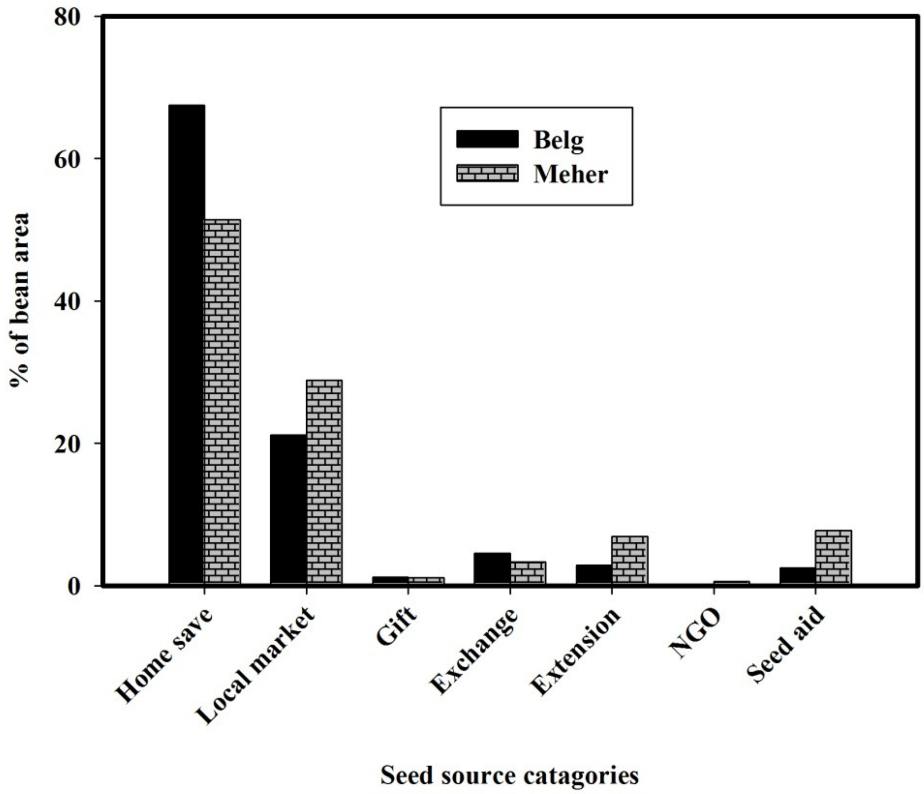

Figure 5. Common bean seed source variation between seasons indicating off-farm seed procurement for renewal of varieties.

Table 3. Average 'age' (years) and the frequency of seed lot replacement for varieties in southern region, Ethiopia.

Variety type	Boricha		Amaro		Konso		Loma	
	'Age' of variety (years)	Seed lot replacement frequency†	'Age' of variety (years)	Seed lot replacement frequency	'Age' of variety (years)	Seed lot replacement frequency	'Age' of variety (years)	Seed lot replacement frequency
Small-red	11	3	19	0	11	1	8	1
Small-white	6	2	9	1	3	1	1	0
Black			10	2	21	2	23	5
Red-mottled	6	2	12	1				
Carioca			6	1				
Cream-mottled			7	1				
Average	8	2	11	1	12	1	11	2

† Seed lot replacement frequency here refers to the number of times farmers fully refresh seed lot of a variety.

After total loss, 91% of the farmers replaced their seed stock from the local market, 5% from friends, 3% got a new seed stock as a gift from family, and 1% combining local market and friends. Of all survey farmers 48% had provided seed to other farmers in the last five years as a gift, of whom 55% were friends or families within the village; 14% were friends or families from outside the village and 32% were acquaintances from both inside and outside the village.

Farmers' perception on drought, rainfall and genotype × environment interaction in common bean farming

In the focus group discussions farmers came up with a

Table 4. Farmers' ranking of common bean productivity constraints using proportional piling methodology and severity index to rank the constraints across different groups. Data were collected in three separate focus group discussions (G1, G2 and G3) at four study sites.

Constraints	Boricha			Amaro			Konso			Loma			Severity index
	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3	
Drought	1	1	1	1	1	1	1	1	1	1	1	2	1.02
Low soil fertility		2	3				2	2	2		2	3	1.31
Weevil	4		2	2	2	5	3	5	4	2	3	1	1.47
Vertebrate pest				4	3	2				3	5		1.49
Disease	2	4	5	6	5	5		4					1.67
Weed infestation	5		5	3	6	4							1.69
Field insect pest	3	5	4	7	6	3	4	3	3	4	4	4	1.71
Excess rain		3		5	4	7	5				6	5	1.81

list of factors that according to their experiences cause the greatest yield losses (Table 4). The constraints varied within and across study sites. However, farmers in all study sites except in one group at Loma considered drought as the most significant constraint, followed by low soil fertility and weevils (*Zabrotes subfasciatus* and *Acanthoscelides obtectus*). Other limiting factors included vertebrate pest, diseases [especially angular leaf spot (*Phaeoisariopsis griseola*), common bacterial blight (*Xanthomonas axonopodis* pv. *phaseoli*) and the rust (*Uromyces appendiculatus*)], weed infestation and field insect pests [especially bean stem maggot (*Ophiomyia* spp.)], worsening drought stress, pod borer (*Helicoverpa* spp.) and aphids (*Aphis fabae* and other species). Excess rainfall was not considered a very important constraint, but it was mentioned to occasionally reduce yields. Only drought and field insects were mentioned in all focus groups, the other factors were left out in at least one focus group. In Konso and Loma, weed infestation was not considered a production challenge but rather a problem of laziness of the producer. At the mid-high altitude site in Loma farmers have slightly better rainfall and did not rank drought as the first constraint to common bean yield.

From the group discussions, contact-farmer interviews and survey, it was clear that smallholder farmers observe changes in the climate that affect their bean production. In the survey, 58% of the farmers considered that common bean yields decrease while 35% perceived an increasing trend in the last 10 years. The majority of the farmers (93%) perceived that over the last ten years rainfall is increasingly inadequate and its distribution changing. It is increasingly common that rains start late and terminate early, while also dry-spells during growing period getting longer and more frequent. Moreover, the number of rainfall showers reduces, their length becomes shorter and their drops smaller. They also observe that rainy clouds and fogginess decrease or even when it is cloudy or foggy there is no rain. Hail becomes less frequent or not seen at all and summers are considered hotter than 30 or 40 years ago. Farmers shared the feeling that changing weather patterns shorten the growing season, resulting in a tendency to shift to early-maturing crops and varieties. This tendency seems stronger in the dry and lowland ecologies as compared to cooler mid- and highlands. Since common bean is faster maturing than cereals, farmers saw it as a crop that allows them to adapt to these changes. This explains why many farmers grew common bean in larger area as compared to 15 years. Due to the changing weather pattern, common bean farming is expanding and shifting to mid- and higher-altitude production ecologies where the crop was not grown by farmers before. But farmers are increasingly concerned about the impact of climate instability on common bean production. Farmers felt that frequent moisture stress events during recent cropping seasons had already resulted in a drop in common bean production per unit area but total production in their individual farms as well as their village increased in recent years due to a larger common bean area.

This trend is confirmed by the long-term common bean production statistics of the region. The regional statistics show an upward trend with strong variation from season-to-season while total rainfall of the main cropping season ('*Meher*') averaged over 15 meteorological stations in the same region shows counter-variation (own collected data, not shown). This inverse relation is explained by the decision of farmers to go for longer cycle crops whenever rainfall is adequate and using common bean in the seasons with delayed or scantier rains. Common bean has a shorter growing cycle, which fits into the seasons where rains are short.

Farmers in group discussions and contact-farmer interviews talked about a 'good' or 'bad' season when evaluating common bean production. Rainfall deficit at any stage of common bean crop growth that reduced production or resulted in crop failure was considered a bad season for common beans. Farmers described how different rainfall phenomena presented themselves in good and bad season (Table 5). Farmers characterized the onset and end of the rain as increasingly unpredictable. Delayed start of the rains is the most

Table 5. Farmers' description of good and bad seasons in bean farming.

Underlying factor	Description for good season	Description for bad season
Onset of rain	Starts normally at the usual time of the rains for the location. Starts in February for '*Belg*' season and June 20th onwards for '*Meher*' season for Boricha and Loma; Starts in March/April for '*Belg*' and August/early September for '*Meher*' in Amaro and Konso.	Starts later than the usual time causing delay in planting time, shortened growth period, pushing the crop into heat stress at the end of the season. Delay up to mid-April in '*Belg*' and delay up to July for Boricha and Loma and up to end of September for Amaro and Konso in '*Meher*' season.
End of rain	Ends normally in the season as in mid-May in '*Belg*' and October 15 for '*Meher*' season at Boricha and Loma whereas rain ends at end of May in '*Belg*' and end of November in '*Meher*' season for Amaro and Konso.	Ends earlier than usual. The rains stop when the crop is at flowering and grain filling, early termination of rain in the season for instance ends in beginning of May in '*Belg*' at all location and September for Boricha and Loma and October for Amaro and Konso in '*Meher*' season. Sometimes extended rain at end of the season causes harvest loss.
Mid-season drought	None, not a problem.	Very frequent mid-season drought, rain breaks for more than two weeks at flowering, main problem is exposure of plants to intermittent drought.
Rainfall distribution	Even rainfall distribution throughout the season, allows period of sun for farm operation, very normal, not windy, no hail, rain falls at reasonable intervals.	Excessive rain all the time without interruption, heavy rains all at once and no rain at other times in the season, very few showers in whole crop growth period in the season, high rainfall at flowering, low rainfall at flowering and grain filling stage of the crop, heavy and continued rain at physiological maturity.
Rainfall amount	Not too much not too little; soil moisture is good throughout the crop growth period.	Too much rain at some times causing erosion (loss of top soil and sometimes loss of crop) or in extreme cases water logging, very long rainy season not good for beans, or small amount of rains that does not allow crop development.

common feature that has caused delayed planting and shortened growth periods. Farmers also indicated that it was not the total rainfall but rather the rainfall at the critical stages of crop growth that mattered. Exposure of common beans to dry spells towards the end of the season and early termination of rainfall can be critical for good flowering and pod filling. Two weeks without rain can in any stage of common bean growth significantly affect performance and ultimately reduce yield. Generally, farmers characterized the impact of drought on the common bean crop as caused by early season, mid-season (intermittent) drought or end of the season (terminal) drought. Yield losses were perceived as high when drought occurs before or during flowering in all study sites except Boricha. In Boricha, farmers perceived that higher yield losses could also occur due to drought stress during grain filling. In Boricha, farmers grew common bean primarily for cash (market) hence they attach yield loss due to drought not only to reduction in volume but also to loss of seed quality for marketability.

Farmers in all study sites shared the opinion that common bean is not drought tolerant but does not appreciate excessive rain either. Farmers said that varieties varied in their reaction to water availability: black beans were considered most drought tolerant whereas the large-seeded Andean types were found very susceptible. On the other hand, varieties like '*Alga Hamare*' (carioca) were perceived to escape terminal drought because of their early maturity. Farmers said that sometimes a farmer might lose a variety because of drought, but usually (s)he could still get the same variety from a local market, relatives or friends who had received better rainfall in the other parts of the village or outside the village. Farmers did not want to see any variety lost from their production system and indicated that more varieties would be useful in coming years to combat drought.

The survey showed that farmers perceived yield of the same bean variety as varying over locations and seasons/year. With regard to spatial yield variation, surveyed farmers perceived yield variability within field (69%), between fields (87%) and between villages (92%), whereas 87% had an understanding of time × genotype × environment interaction. Rainfall or weather variation and

Table 6. Farmers' perceived cause of genotype × environment interaction in common bean farming in southern Ethiopia.

Causes	% of farmers mentioning the cause for G×E	
	Spatial	Temporal
Rainfall or weather variation	39.5	84.4
Soil fertility variation or decline	86.9	21.2
Disease and pest gradients	0.8	1.9
Slope and soil gradients	5.3	0.0
Seed bed preparation method variation	1.1	5.0
Sowing time variation	0.0	5.9
Weeding/hoeing/crop management difference	0.5	0.3
No idea	6.4	0.0

Source: Farmer survey in this study, N = 375.

Table 7. Farmers' proactive and reactive changes in bean production practices to reduce drought effect on common bean.

Reactive mechanisms	% of farmers	Proactive mechanisms	% of farmers
Use of supplementary irrigation	16.8	Use early-maturing varieties	33.3
Clean weeding of the field	12.5	Use drought-resistant varieties	22.7
Re-sowing	6.4	Conservation tillage / open ridges	14.9
Shift to another crop	4.5	Plant variety mixture	6.7
Reduce sowing area	3.7	Dry planting	5.3
Direct runoff into the field	0.5	Deep sowing	2.7
		Deep and repeated ploughing	0.5

Source: Farmer survey in this study, N = 375.

soil fertility differences were perceived as the main causes for spatial and temporal yield instability of their common bean crops (Table 6). Many farmers expressed an interest in varieties that show stable yields over time and space (77%), 12% wanted to have responsive varieties for a given year but some farmers (11%) reflected their quest for both. The reasons for having both stable and responsive varieties were to minimize risk or to fit the crop to the weather.

Farmers' adaptive strategies to reduce drought effect on common beans

About half of the surveyed farmers did take some adaptive measures to reduce drought effect on common bean (Table 7). Of those practice adaptive measures, one-third changed common bean production practices as a reaction to occurring drought effects, whereas the remaining two-thirds changed practices proactively to reduce the vulnerability of common bean farming to drought. The use of early-maturing and drought-tolerant varieties was one of the popular adaptation strategies practiced by the farmers. This is apparent by the recent introduction of the early-maturing carioca variety around Amaro and growing black beans in more drought marginal environments at Konso. The planting of varietal mixtures by some farmers is also meant to buffer drought risk on common bean yield in addition to diversity in varieties (see earlier description on bean farming).

Recently, in Loma and Boricha some farmers had turned to a repeated plowing of a part of their land so as to be sure the land was ready for sowing at the first rains. When farmers experienced delayed starts in the rainy season, they turned to sowing earlier-maturing or drought-tolerant varieties. Also when first sowing was affected by a 'false start' of rain (that is, early-season drought) then farmers either re-sowed common beans or shifted to earlier-maturing crops. Timely weeding was practiced to avoid competition for moisture. Dry planting and deep sowing were practiced to effectively use the earlier and often heavier rains particularly in Amaro and Konso. Conservation tillage mostly of the open furrow type was practiced to allow rainwater infiltrate into the soil at Amaro and Boricha. Adaptive practices in crop and soil management are deep rooted culture in the Konso trace-based farming system (for more details on Konso adaptive strategies refer to Tadesse, 2010; Beshah, 2003). Farmers' adaptation strategies are unevenly distributed over individuals and study sites (data not shown).

DISCUSSION

This study supports the generally observed diversity of agro-ecological and socio-cultural conditions for smallholder farmers in southern Ethiopia. Farmers in different areas have varying preferences for plant and grain types of common bean and most farmers traditionally grow a small-seeded red or black variety. The large majority of the farmers grow only one variety. Bean plantings comprised of a range of cropping patterns (sole, inter- and relay-cropping), with plantings in both the '*Belg*' and the '*Meher*' season, each with its specific features in the different regions. Farmers clearly notice that the local climate is instable and changing. They observe increasing frequencies of delayed on-set of the rains, intermittent drought periods and early end of the rainy season. Together this increases the frequency of total crop failure and severe yield reduction. The study shows that farmers have their traditional agronomic practices to cope with the variation of climate within and between seasons, but so far only about half of the farmers have adapted their cropping practices in one form or another to the increasingly variation and shortening of the rainy seasons. The remaining half of the farmers mentioned that they have taken no actions to address drought problems in beans. It may seem that many farmers do not see drought as a big problem, but many farmers perceive drought as punishment from God and man can do nothing except praying to God to reverse the situation. It may also be that for some farmers beans are less important for adaptive measures than other Ethiopian crops like enset, sorghum, or barley where they have rich local knowledge. Better weeding, deeper sowing and earlier land preparation are among the practices to better benefit the rains, but the use of drought resistant and earlier maturing varieties and crops probably represents the principal opportunities for farmers. The short life cycle makes common beans an increasingly important crop for farmers in South Ethiopia to battle drought, as often the longer maturing maize or sorghum crop cannot complete its growing cycle when rains and sowing are delayed.

Crop genetic diversity is instrumental in the buffering of environmental variation. This is not to undermine the importance of other coping strategies like agronomic practices and seeking off-farm work to overcome environmental limitations. In case of drought linked with climate instability, agronomic practices can be incomplete or impractical depending on farmer production conditions. Most traditional bean growing areas are rolling hilly lands in which for many farmer capital and resource are limiting to apply agronomic solutions. As part of an integrated solution, crop genetic diversity in the form of drought resistant and earlier maturing varieties and crops is preferable. It once obtained as the simplest and most economical to use (Beebe, 1991). For farmers growing beans genetic diversity means the use of several varieties in mixed or unmixed form, in either sole, inter- or relay cropping. However, given the relatively low level of common bean genetic diversity in individual farming systems and the study area as a whole, this buffering mechanism can be considered as highly underused. This is because farmers do not have access to a sufficient range of suitable bean diversity adapted to their local context – 'supply-limited'. If they did, they surely would all be growing many different varieties. This is the reason so few or no more than one variety, apart from those who mix grown in the study area. As a result farmers focus their local knowledge on more 'Ethiopian' crops like enset, sorghum, or barley, where there is great genetic diversity available.

The relatively fast adoption of new early-maturing carioca bean varieties that were introduced in Amaro may be indicative for the interest of farmers in learning about a new form of adapted bean diversity and points to the potential that crop genetic diversity has in supporting farmers to mitigate the effects of variable growing conditions.

Other factors also play a role in the demand for new diversity. For example, the expansion of common beans growing at the slightly higher elevations. Beans can now be grown in these slightly cooler environments because the increasingly shorter growing season now reduces the chance that late rains affect the harvest there. The market also proves to be an important driver of demand for new bean varieties. The small-white bean finds easy adoption since farmers in the Central Rift Valley experience that it fetches a good price when sold to bean exporters (Asfaw et al., 2012). Farmers are also interested in large-seeded Andean common bean types because they like it for consumption and they expect it to be easily marketable because of its superior culinary quality.

The study of farmers' seed saving practices does not show a high level of specialization. This does not however, necessarily mean that farmers are not knowledgeable or that their knowledge cannot be developed. The high level of environmental variation and the associated risks of crop failure also imply that local crop development practices are less effective. This is underlined by the relatively high frequency of seed stock replacement: keeping a seed stock of good quality apparently requires effort. The relatively high turn-over of seed stocks also provides an opportunity to introduce new varieties. If farmers seek new seed for planting, the chances of them adopting new varieties increase. To make use of such opportunities, diversity needs to be available in the form of adapted germplasm and strategic introduction of adequate volumes of seeds.

Genetic diversity could be introduced in different forms (segregating or in the form of more or less advanced lines). Work in Central America has indicated that local selection may result in more diversity and better adaptation (Humphries et al*.,* 2005; Almekinders, 2011) and also the selection work in the formal breeding program indicates that better adapted varieties can be acquired from local selection (Asfaw et al., 2012). Ideally, relatively small amounts of early generation seeds with promising backgrounds could be introduced to different environments from which varieties would be developed through local selection. However, farmers' involvement in selection of segregated materials requires not only expertise, but also investment and a high level of commitment. In highly variable environments like those of southern Ethiopia, participatory variety selection as a decentralized form of selection of advanced materials with farmers may be more feasible (Asfaw et al., 2012). Seasonal evaluation trials in which farmers select and keep the seeds of varieties they favors are less risky investments than on-farm selection processes of 2 to 4 generations. However, this means at the same time that the variety development and selection process is largely directed by the breeder. Knowledge of the local conditions, changes in agro-ecological and socio-economic conditions, and diversity caused by climate instability and market dynamics are then crucial to define a breeding strategy that meets the need of the farmers. This study in particular shows that the farmers' needs cannot only be considered as an articulated existing demand. The demand is also partly an extrapolated demand for which it is essential to understand climate instability and market trends and to know characteristics that the genepool can provide. Only on the basis of an integrated understanding of farmer production conditions and existing seed system practices a breeder can contribute to an overall package of mechanisms that harness and equip farmers to adapt to their dynamical context.

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