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The Contribution of Farmers' Breeders in Meeting Food Security: The Case of Sorghum (*Sorghum bicolor* (L.) Moench) in Ethiopia

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Summary

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important cereal crop worldwide and it is the third most important crop in Ethiopia. The national average yield amounts 1302 kg/ha. In order to assess the achievement in farmer breeding various types of research were undertaken. These include survey research to quantify the trend in productivity, the level of and reasons for adoption of improved varieties, yield performance and preference evaluation of farmers' varieties (FVs) and improved varieties (IVs). As per the trend analysis over the last four decades, total production and yield per hectare has increased by 11.63% and 14.2% respectively. However, area allocated to sorghum has decreased over years by -2.93%. The lack of consistent productivity is attributed to the fluctuation of environmental factors. Sorghum production in Ethiopia is predominantly based on varieties developed by farmers. The share of IVs is very low. FVs and IVs are adopted by 87.3% and 12.7% of the farmers respectively. Besides, the adoption of IVs is limited to the lowland crop ecology. The comparative yield of FVs is higher than IVs by 132%. On top of yield, farmers do prefer their varieties for other multipurpose values namely feed, fuel wood and construction material. FVs under production are identified in each *wereda*. Farmer breeding has been successful compared to four decades of formal breeding. On the other hand, both farmer and formal breeding are not without weaknesses; a comparative balance sheet is outlined for both. Ideotypes for the three major crop ecologies are suggested and integrated plant breeding is anticipated to develop the proposed ideotypes thereby increase sorghum productivity in the region.

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important cereal crop worldwide. In the year 2005, sorghum was grown worldwide on 43,727,353ha with an output of 58,884,425 metric tons (FAO, 2005). The productivity of sorghum varies across the different parts of the world. The world average yield being 1314 kg/ha, and yield of developed countries is 3056 kg/ha and that of developing countries is 1127 kg/ha. Despite the low productivity in the developing countries, they accounted 90% of the area and 77% of the total output produced (FAO, 2005). Ethiopian national average yield amounts to 1302 kg/ha (CSA, 2005). The low productivity of sorghum in the developing countries can be attributed to biophysical, socio-economic and policy related factors affecting directly and indirectly sorghum production. One reason could be the low level of sorghum research investment in human, financial and material resources development and low input production system.

The Ethiopian Sorghum Research was incepted in 1957 by Alemaya University, the then College of Agriculture with the subsequent initiation of Ethiopian Sorghum Improvement Program (ESIP) with the fund from International Development Research Centre (IDRC), Canada. As of then, sorghum breeding activities were done in the different ecological parts of the country by different national and international organizations. The collection, evaluation, characterisation and conservation were one of the primary activities. Closer to 8000 indigenous collections were made (PGRC/E, 1986). Various types of crossing programs were undertaken to solve sorghum production problems.

The formal breeding (FOB) have released over sixteen varieties since 1957. Of these, seven were from introduction and nine were from selections of landraces. Of the total released varieties five, four and seven were recommended for the highland, intermediate and lowland areas respectively (EARO, 2000). From the indigenous collection, nine varieties have been released. These include *Alemaya 70, ETS 2752, Dedessa 1057, Asefaw white* and *Gambella 1107*, *Chirro, Alemaya 1* and *2*. The level of adoption of improved varieties is not quantified. Even if there is no quantified data on impact of Improved Varieties (IVs), the majority of the farmers are growing Farmers'

Varieties (FVs) in the three sorghum ecologies (Mekbib and Farley, 2000). Notwithstanding this fact, formal breeding (FOB) is still continuing with the same objectives and strategy (EARO, 2000). Similaraly, farmers have been doing continuous selection and improvement of their varieties for years to meet their changing needs, climate and farming systems. As opposed to FOB, the varieties developed in the Farmer Breeding (FAB) have been well adopted by farmers and are being grown still.

In view of the gap mentioned above, it is indispensable to compare FAB and FOB, assess the achievements made in FAB and its impact on sorghum production in the region in particular and in Ethiopia in general and orientate FOB to meet diverse needs of the farmers and thus develop sustainable sorghum production systems.

Hence, the objectives of this study were to:

1. Assess the trend in sorghum productivity in Ethiopia
2. Compare farmers and improved varieties for yield and yield related traits
3. Assess the level of adoption of improved and farmer varieties
4. Identify the most important farmers varieties in each weredas for enhancement
5. Develop a strategy to integrate FAB and FOB

Materials and methods

Study area selection.

Eastern Ethiopia (Fig 1) is selected for the following reasons: firstly, sorghum is the first food crop in the region, in area, production and importance; secondly, the sorghum production in the region is mainly dependent on the FVs and hence ideal sites for studying the impact of FAB; thirdly, the growing of sorghum in the diverse biophysical (Table 1) and socio-economic environments helps to tap the diverse indigenous technical knowledge (ITK) associated with the sorghum breeding. In the study area sorghum is planted on a total area of 188, 413 ha with a total production of 239,190 metric tons. The number of sorghum growing households were 635,342 (CSA, 2005).

Figure 1

Table 1

Crop acreage, yield and total production data.

Data on acreage, yield and total production of sorghum from 1961 up to 2002 was taken from the Central Statistical Authority of Ethiopia and FAOSTAT data base.

Field experiment for performance evaluation of IVs and FVs

FVs and IVs, total amount of 14, were evaluated in 5m x 3m plots in Randomised Complete Block Design (RCBD) with three replications in the year 2000 and 2001 on 11 sites. Inter-row and intra-row distance of 0.75m and 0.20m were used respectively. Recommended rate of fertilizer DAP and UREA at a rate of 100 kg/ha were applied. All other recommended crop protection and agronomic measures were applied whenever it was necessary. Harvesting was done after it reached physiological maturity. Grain yield was adjusted to 12.5% moisture content. Yield data was presented only for Alemaya for two years and two sites. Descriptions of sites are indicated in Table 2.

Table 2

Survey research

In order to assess achievements in FAB and FOB and to assess the reason and level of adoption for IVs various interviews were undertaken. These were focused group (based on gender and wealth) interviews with 360 farmers; key informant interviews with 60 elderly farmers and development agents; on farm monitoring and participation with 120 farmers. These were followed by semi-structured interviews with 250 farmers. All the aforementioned activities were organised and implemented in collaboration with respective farmers, Farmers' Association and Bureaus of Agriculture in each sites.

Farmers' preference evaluation

Farmers in each test sites were invited for evaluation around physiological maturity of the seven IVs and FVs. Both individual and group evaluations were made with a total of 168 farmers, of which 139 are men and 29 are women. Pairwise and direct matrix preference ranking were made for the genotypes in each sites. The average number of farmers for both preference ranking was 12. The participating farmers have been growing sorghum individually and they represent the farmers in each test sites.

Data analysis

Collected data was subjected for descriptive statistics, ANOVA, multiple regression, and log-linear regression analysis using STATISTICA, SPSS version 10 statistical and MINITAB Ver. 14 softwares.

Results and discussion

Revisiting four decades of FAB achievement: the contribution of FVs for national food security

Globally the assumption is that most traditional varieties or FVs are replaced by modern varieties in green revolution. These have happened for rice and wheat in Pakistan and India and for maize in Mexico as the performance of IVs were better than FVs. On the contrary, here in the study it is shown that FVs have resisted the defeat and are still under production as most of them are better than IVs. Why FVs are still under production? What are the weakness of IVs? How to enhance FVs for increased productivity?

The importance of sorghum FVs for meeting national food security has been very significant for over four decades. This is shown (Fig 2) by the trend in area and production of sorghum for the last 42 years, 1961-2002. In spite of some of the changes in area and production over the years, there has been a steady increase in the yield and production of sorghum.

As per the trend analysis over the last four decades, total production and yield per hectare has doubled. There was 11.63% increase in total production. The yield increased amounted to 14.2%. The highest yield which amounted 1600 kg/ha was recorded in the years 1979-1983 because of favourable climate. Besides, this was the time where there was villagisation (collective settlement and organization of farmers) program and a practise of using increased plant population and fertilizers. Since then there was no significant change in the trend of input utilization. However, the lowest yield was recorded in 1984-85, and this was the time where Ethiopia was hit by severe drought.

On the other hand, area allocated to sorghum has decreased over years. The percent decrease amounted to -2.93%. In the year 1993, the acerage and production of sorghum was the lowest sorghum owing to the cessation of Eritrea from Ethiopia.

Briefly, the last four decades assessment of productivity trend in sorghum has shown stable improvement. Most of the area allocated to sorghum is planted with sorghum varieties developed by farmers over years. The performances of these varieties are considerably good (See Table 2). This is enhanced by continuous farmer selection of varieties and adjustment of varietal portfolios per the prevalent and predicted environmental circumstances. The change in crop productivity is attributed to the fluctuations of crop and environmental management. The dominant environmental factors are annual precipitation, seasonal rainfall and soil water content at planting, and growing season evapo-transpiration. The crop management factors are crop stand, protection and fertilization. This was substantiated by the fact that crop acreage being similar the yield and total production increases in good years and decreases in bad years.

Comparative performance of FVs and IVs

In view of the failure for the year 2000 in most sites, mean performance data of two years of two sites at Alemaya is used for performance comparison. There was a significant difference among varieties for plant height, biomass, seed weight and grain yield on two sites in Alemaya (Table 3). The trend for yield performance of the genotypes is similar across sites for the year 2001(not shown). Similarly, group comparison of FVs and IVs showed significant difference for yield and yield related traits (Table 4). There was a general superiority of FVs over the IVs in plant height, biomass, seed weight and grain yield.

Table 3

Table 4

Comparative preference ranking of FVs and IVs in sorghum production ecologies

Sorghum is produced in Ethiopia in the three crop ecologies (Table 1). The type of varieties needed and the selection criteria is different by agro-ecology. Across the crop ecologies farmers have multiple selection criteria as opposed to formal breeders. This is very clearly shown in the continuous on farm selection and maintenance of their own varieties adapted to specific crop ecology. One thing that is obvious in the FOB is the objective gears mainly to grain yield. Other grain equivalents such as feed, fuel wood value and construction values are rarely considered. Hence, IVs have very limited production niches. To corroborate these farmers' assertions, varietal preference assessments using pair wise and direct matrix ranking were made over 11 sites. However, data for pair wise ranking is presented for three sites, one from the three ecologies, only as the ranking is similar for other sites within each ecology.

In line with direct matrix ranking, across the 11 sites by 168 farmers (Table 5), the first selected FVs were: *Fendisha White and Muyra White Long (1),Muyra Red Long (2) Wegere Red (3).* This showed that there is a wide gap in the mean rank values among the FVs and IVs groups.

In the pairwise ranking at Babile, Hirna, and Chelenko (Table 6), the first three varieties selected are FVs. In Babile, *Fendisha White, Muyra Short and Muyra Red Long*; Hirna, *Muyra White*, *Muyra Red* and *Fendisha White* and in Chelenko, *Muyra Red, Muyra White and Muyra short* are selected in the order of decreasing preference respectively.

The major criteria for selection of these varieties by the farmers are overall performance of these varieties; mainly, yield, adaptiveness, resistant to stresses, consumption qualities that includes culinary and cultural preferences regarding taste, color, consistency, size, cooking time, processing quality and aptness for preparation of traditional dishes and animal feed values. Hence, because of these preferred values, current and future breeding programs have to base itself on the enhancement of FVs by analysing characters of such germplasm.

Table 5

Table 6

FVs for the farmers' livelihood and survival: strategic importance.

Sorghum is a strategically important in the region in which farmers livelihoods is based up on. Farmers are very much dependent on FVs for food, feed, fuel wood, construction material etc., on sorghum. In this work, **Farmers' varieties are defined as varieties developed, selected and maintained by the farmers over many years of human-cum-natural selection which are adapted locally and/or widely and provide farmers with various benefits.**

In Ethiopia, the last four decades of research in cereals, legumes, oil crops and vegetables has resulted in release of over 122 varieties (Agrawal and Worede, 1996); of these only 10% have been adopted. For the same reason, the last two decades of research in Sub-Saharan Africa has resulted in release of over 40 sorghum cultivars in 23 countries (Miller *et al.,* 1996). However, the level of adoption is not appreciably high (Ahmed, *et al.,* 2000). This low level of adoption is due to lack of appropriate varieties and dissemination system that caters for socio-economic and biophysical environments of the farmers.

The bulk of sorghum production in Ethiopia is dependent dominantly on FVs. Only 12.7% of the farmers have adopted IVs of sorghum, while 87.3% of the farmers still use FVs.

There is a significant variation (Fig 3) for the level of adoption of IVs across crop ecologies where higher level of adoption (46%) in the lowlands and only 4.2% in the highlands. This actually reflects two scenarios. First, the narrow genetic base of sorghum in Ethiopian lowlands vis-à-vis the other crop ecologies. The existing genetic resources in the lowland are only just satisfactory but insufficient. Secondly, most of the formal bred varieties meet the need of the lowland farmers than the highland and intermediate farmers. The crop architecture of most modern varieties is similar with the Ethiopian lowland sorghum variety types. These scenarios are also demonstrated by the reasons for the adoption of IVs, which are mainly drought resistance and early maturity (Fig 4). These substantiate, the considerable role played by the FVs for food security in the region. Nonetheless, most of the adopting farmers have rarely replaced their varieties with IVs; instead, they used the IVs as a component of the traditional varietal mixture. Addition of IVs as a component of the varietal mixture is the commonest process. Replacement is atypical. This also partly agreed with the finding of Brush (1992) on potato and Smale, *et al.,* (1995) on maize. In eastern Ethiopia, in the year 2005, the area allocated for sorghum amounted to 188,413 ha with a total production of over 239,190 tons (CSA, 2005). Based on the on farm monitoring of 120 farmers, the mean area allocated for IVs was 0.45 *timmad* while for FVs is 4.92 *timmad* (Table 7). This also indirectly indicates the dependence farmers have on FVs in line with meeting their livelihoods.

In view of the salient contribution of FVs for food security and farmers' livelihoods, the idea of Frankel and Soule (1981) that FVs have outlived their usefulness in agricultural production and their roleshould be limited to be used as sources of genetic materials for plant improvement is invalid idea in the context of Ethiopia where FVs are more important than IVs. Nonetheless, in order to develop IVs that will have a significant role in food security, FOB has to orientate itself for identifying cultivars suitable for traditional farming systems characterized by high variability in social, economic, environmental and biological conditions.

Fig 3

Fig 4

Table 7

Farmers preference ranking for FVs

One of the challenges for FOB in centre of diversity is the problem in producing cultivars surpassing the FVs, which are many, diverse and often specifically adapted. Even farmers have different preferences for their own bred varieties. The type of varieties needed varied from one place into another and in one place for various cropping systems. Hence, it is implicit that there is a variation for yield and multiple values, which are reflected in the proportion of area allocated to each varieties. This was shown by direct matrix ranking of folk species done with focused groups (Table 8). A variation of varieties by sites is also observed where *Jorro*, *Fendisha* and *Bullo* are the prior varieties for *Lencha*, *Fendsiha* and *Likale* FA respectively. The ranking by group of farmers for multiple value, yield stability and area coverage showed that it varied by wereda. The use of varietal mixtures caters for the differential values and uses of the FVs. In sum, the ranking pointed two issues: first, the need to focus for specific (local) adaptation breeding and to make specific recommendation and, second, the genetic resources collection smallest environment and socio-economic unit should be FA.

On the same line, 17.8% of the farmers believed that other farmers have better varieties than themselves. 11.7% of the farmers have seen and heard the variety but could not get the seed. This also indicates the possibility for the farmers to change and manage varietal portfolio *via* farmer-to-farmer dissemination.

Table 8

Yield stability

One of the major problems of farmers in the region is the lack of consistent yield across years. The on farm yield is very much affected by the weather condition, as most of the sorghum production is rainfed (Fig 2, Table 9).

The yield difference between good year and bad year is very high. In bad years, the mean yield reduction due to the weather amounts to 56%. However, in times of drought there can be a complete loss of yield. As per the farmers' experiences, bad year (serious drought) happens once in three years. On the other hand, there is a significant difference in total yield and yield per *timmad* across various farm sizes (Fig 5). The yield per *timmad* decreased as land size increases while the total yield showed the similar trend with increasing land size. The different wealth groups, using land size as a wealth indicator, did not vary with the type of varieties they grow. They varied only in the field management and women of rich farmers are not often engaged in off farm activities. The age of the farmer did not affect the yield per *timmad* significantly.

Table 9

FVs have low genetic load as compared to IVs; hence, they have been on production for decades. Genetic load which is the accumulation of deleterious genes, is one of the important genetic mechanisms determining varietal stability in crop production. It is the process that commonly happens in both FVs and IVs.

Yield stability is also one of the most important criteria by the farmers for varietal selection (Mekbib, 2002, 2003). **Farmers' perceive yield stability as an adaptation to local production techniques and variable water and soil conditions in combination with a variety of characteristics related to labour, intercropping and weed competition etc.,; food availability and various other consumption purposes opted for.** Hence, it is broader than the conventional concept of yield stability.

One of the surprising differences between FAB and FOB is the variation in stability of varieties produced by both. Varieties produced in the FOB are stable to an average of ten years**.** But FVs, in hundreds, are still on production for over 50 years. Why that is FVs are more stable than IVs? Yield stability of FVs is due to the following:

a) The established varietal mixture based sorghum production confers more stability than mono-varietal culture to biotic and abiotic stresses. Varietal mixtures (ranging from 2 upto 20) on farm renders stability and minimizes genetic load for increased disease and insect epidemics.

b) Diverse cropping system (poly-cultivars, intercropping, alley cropping, mixed cropping) prevalent in the region renders diverse and stabilizing micro-crop ecologies and then more stability for sorghum and this at the end reduced disease and pest outbreak (Mekbib, 1997; Mekbib and Farley, 2000).

c) Farmers for long have bred for specific adaptation; do not practically believe in wide adaptation, as much of their effect is for local adaptation (Mekbib, 2002, 2003). The more the variety is specifically adapted, the more stable it will be for that particular area over time.

d) There are some folk species, which have low genotype by environment interaction, enabling it to yield under both stressful and optimum conditions. However, the varieties with in the folk species have high genotype by environment interaction.

e) Varietal portfolios are manipulated according to the current socio-economic and bio-physical environments of the farmers. This change in the micro-environment reduces risk (insect, diseases, and drought) and stabilizes the varietal components and crop ecosystem, and hence prolongs varietal stability.

In summary, the aforementioned farmers' strategies in complex, diverse and risk prone environments have reduced genetic load on the varieties thereby resulted in the longevity of the FVs.

Farmers' released varieties currently under production.

Despite the fact that formal recognition is not given by the National Variety Release Committee of Ethiopia to FVs, they have been selected, developed, and proven for their better performance and released by the farmers to the farmers for production and use.

As described in Fig (2), the sorghum production in Ethiopia is dominantly based on the varieties developed over years. These varieties are conserved on farm with continuous maintenance breeding. In the course of maintenance breeding and enhancement, farmers used four different levels of selection. These were: Introduction which is used across the farmers; while simple mass selection, modified mass selection, modified bulk selection, and pure line selection have been practised by 50%, 6.4%, 5.2% and 46% of the farmers respectively. Besides directional, disruptive and abruptive selection modalities are in use by the farmers for the various traits.

Of the considerable numbers of FVs being produced by the farmers using various selection schemes, for exemplification, only some are mentioned at a folk species levels; but what was compared for performance and preference rank evaluation is at folk varieties level. The detail on the infra-specific folk taxonomy is described in Mekbib (2006). A folk species has folk varieties, a folk variety has subvarieties. Folk species is farmers' taxonomic unit of classification of the particular crop. Farmers use botanical, technological, use and agro-ecological criteria in their taxonomic system. For example, *Muyra* folk species has many varietal forms based on seed colour, height, panicle morphotypes etc. In the comparative performance study (Table 3,4,5,6), three varietal forms of *Muyra* folk species has been used. These are: *Muyra Long and Short* and then in the *Muyra Long* we have *Muyra Long Red* and *Muyra Long White* types.

There is a variation in the range of folk species adaptation. Folk species *Abdelota, Cherchero, Daslee, Fendisha, Harkebasse, Jeldi, Mureta, Muyra*, and *Wegere* are grown in the highland and intermediate and lowland areas. Wide adaptation is through the varietal forms of each folk species. While others such as *Aday, Beker, Daddu, Dulla, Firelemi, Kereyu, Kirmi,* and *Kuffanzik* are ecologically adapted to the lowlands while *Alasherif, Alegrad, Bele Melik, Eja, Marur, Merulae, Suta,* and *Toge*, are adapted to the intermediate altitudes. These varieties have been in the farmers' field for over four decades. The variation among naming connotes geographical, genetical and ecological diversity (Mekbib, 2006).

In conclusion, FVs did not persist because of marginal conditions, poor accessibility, traditional farming system, but due to better multifaceted performance vis-à-vis IVs.

Conclusions and recommendations

Comparison of FAB and FOB

Even if the contribution of FAB have been considerable over the last half century, to make it sustainable it entails congenial role with FOB. In order to have the synergism, weakness and strength of FOB and FAB are outlined in Table (10). The major weaknesses of FAB are the lack of focus on non-yield related traits and mono-cropping and mono-variety system based selection environments, which resulted in limited achievement and adoption; on the contrary, that of FOB weaknesses are the lack of sufficient germ plasm for lowland crop ecologies.

Integrated Plant Breeding (IPB)

As per the outlined weaknesses and strength and to develop the ideotypes (Table 11), both FAB and FOB need to be integrated (Fig 6) to improve the productivity of sorghum in Ethiopia. Integrated Plant Breeding (IPB) has to be used in centres of crop origin and diversity as the scenario demands. Many years of FAB needs to be enhanced by FOB. The integration has to be made at the all steps of the cycles of breeding: from setting objectives and goals up to appropriate technology development and disseminations. As an example, the first stage for integration of FOB and FAB is in setting of objectives and goals. It has to be undertaken with the participation of stakeholders from FAB, FOB, consumers and industrialists in the development of multi-purposive varieties (for food, feed etc.,) with specific adaptation of diverse seed types. This will be followed by selection of genotypes using the criteria of various stakeholders. IPB will continue in the cyclical fashion for development of acceptable varieties. The proportionate role and share of FAB and FOB at each stage has to be worked out depending the prevalent crop production system and growing environment. The integration modality has taken into account the retrospective, current and prospective aspects of sorghum breeding in Ethiopia and hence, it is practically implementable.

Table 10

Fig 6

Sorghum ideotypes suggested for the highland, intermediate and lowland crop ecologies in eastern Ethiopia

The concept of ideotype was proposed by Donald (1960) as an approach in plant breeding, sometimes called analytical approach. Donald thought is based on the knowledge of crop physiology and morphology to construct a plant type that was theoretically efficient. This actually encouraged breeders and physiologists to collaborate in way that improve the efficiency of selection for yield (Passioura, 1981). Donald's ideotype is critically discussed and enunciated by Marshall (1991) and Hamblin (1993). However, the ideotype concept is with problems, some of them are lack of suitable genetic variants and interrelationships among traits (Hamblin, 1993). The other limitation of Donald's definition of ideotype, is its pure dependence on morpho-physiologic characters. But this can not be supported in the era of participatory plant breeding where socio-economic and cultural criteria are equally important. Hence, a new concept for ideotype is given here. **Ideotype is redefined as a variety endowed with ideal morpho-physio-genetic traits to give high values (yield + non yield products) at specific biophysical environments and is acceptable by the farmers socio-economically**. According to this definition, the following ideotypes are suggested (for the coming 5-10 years) for the respective sorghum growing environments.

Table 11

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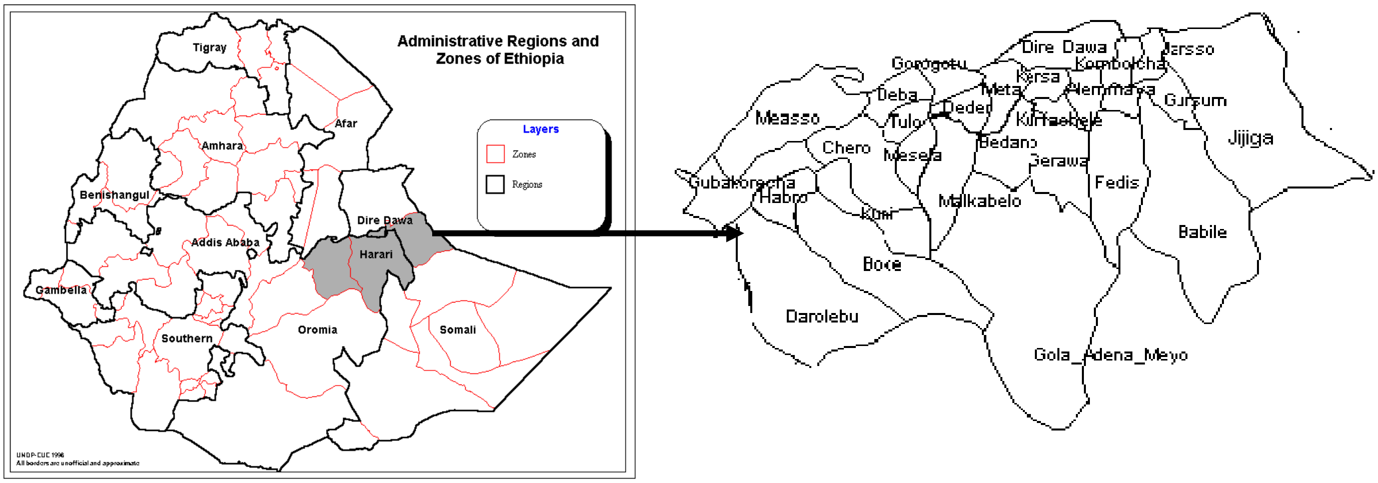

Figure 1. Position of the study sites in Ethiopia and detail map of the *weredas* of eastern Ethiopia.

Table 1. Characteristics of major crop ecologies in eastern Ethiopia

Ecology	**Climate**	**Altitude M asl**	**Ave. Ann. Temp**	**Ave. Ann. Rainfall**
Lowland	Warm semiarid	<1700	20-27.5^{0}c	200-800 mm
Intermediate	Cool and subhumid	>1700-2100	17.5-20^{0}c	800-1200 mm
Highland	Cool and humid	>2100	11.5-17.5^{0}c	1200-2200 mm

Table 2. Descriptions of test sites used for preference evaluation

Test sites	Altitude (M asl)	Soil type (FAO Classification)
Babile	1650	Regosol
Kitto	1706	Regosol
Hirna	1710	Fluvisol
Fedis	1832	Regosol
Aweday	1960	Verticambisol
Aweberkelle	1960	Verticambisol
Dawe	1980	Regosol
Alemaya	1980	Regosol, Fluvisol, Vertisol
Kersa	1990	Fluvisol
Kombolcha	2150	Regosol
Kulubi	2230	Verticambisol
Chelenko	2243	Verticambisol

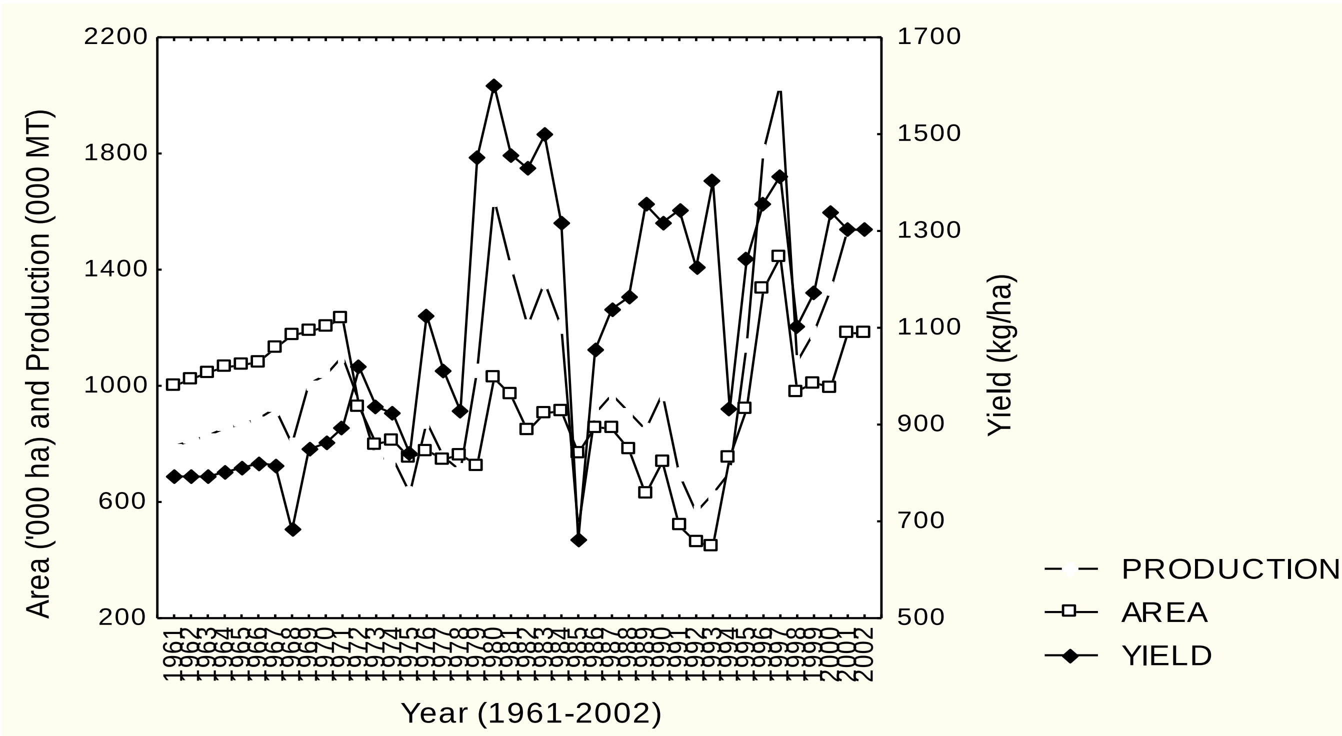

Fig 2. Area, production and yield of sorghum in Ethiopia from 1961 to 2002.

Table 3. The mean performance of IVs and FVs for two years and sites at Alemaya

Varieties	Variety type	Seed color	Seed size	Grain Yield (kg/ha)	Plant height (cm)	Biomass (Kg/ha)	TKW
ETS 3235	IV	White	Large	3336	168	14511	29.72
*ETS 2752**	IV	White	Large	3605	254	16832	27.20
*Al 70**	IV	White	Large	4673	261	20754	25.38
Chirro*	IV	Light Brown	Large	4675	239	25244	27.22
Awash 1050	IV	White	Medium	2611	192	8664	27.52
IS 9302	IV	Light Brown	Small	1361	155	6568	23.25
IS 9323	IV	Light Brown	Small	1144	151	5884	23.89
Red Muyra L	FV	Light Red	Large	4074	243	21768	29.34
White Muyra L	FV	White	Large	4460	259	22532	32.51
Red Wegere	FV	Red	Large	4498	234	24341	29.43
White Wegere	FV	White	Large	3368	261	16643	25.14
Red Fendisha	FV	Red	Small	4354	286	31915	22.92
White Fendisha	FV	White	Small	4355	269	35716	21.86
Short muyra	FV	Light red	Large	3163	162	16528	27.52
			Mean	3461	222.43	17901	26.51
			F-test	**S**	**S**	**S**	**S**

IV=Improved Varieties; FV=Farmers' Varieties, TKW=Thousand Kernel Weight
*= formally released FVs of eastern Ethiopia
S=Significant at P=0.05 and NS=Non significant at P=0.05

Table 4. Group comparisons of FVs and IVs for yield and yield related traits

Plant traits	Farmer Varieties	Improved Varieties	**F-test**
Plant height (cm)	245.0	202.9	S
Biomass (kg/ha)	24168	14065	S
Grain yield (kg/ha)	4039	3058	S
TKW	26.96	26.32	S

S and NS; significant and Non-significant difference respectively at 5%
NB: Due to less senescent nature of FVs at physiological maturity, the total biomass is higher than the IVs.

Table 5. Direct matrix ranking of FVs and IVs for yield and food values at various sites in eastern Ethiopia

Varieties	Varietal type	Kitto	Aweday	Kombolcha	Kersa	Kulubi (M)	Kulubi (F)	Awe-berkelle (M)	Awe-berkelle (F)	Fedis	Hirna	Dawe	Chel-enko	Babile	Total score	Mean rank	Men rank	Women rank	Overall Rank
ETS 3235	IV	1	11	8	5	10	9	8	9	11	9	3	3	3	90	6.92	72	18	5
ETS 2752	IV	13	7	4	3	4	4	6	2	5	11	12	12	2	85	6.54	79	6	4
Al 70	IV	2	9	7	6	11	7	9	8	1	7	11	11	11	100	7.69	85	15	9
Chirro	IV	10	10	12	4	6	5	6	11	2	4	9	9	9	97	7.46	81	16	6
Awash 1050	IV	6	12	9	6	12	10	7	7	12	8	10	10	10	119	9.15	92	27	10
IS 9302	IV	9	14	14	8	13	14	11	13	13	14	13	13	13	162	12.46	135	27	11
IS 9323	IV	14	13	13	11	14	13	10	14	14	13	14	14	14	171	13.15	144	27	12
Red Muyra Long	FV	8	8	3	1	3	1	5	4	6	2	4	4	4	53	4.10	48	5	2
White Muyra	FV	7	3	5	2	1	2	1	1	4	1	7	7	7	48	3.69	45	3	1
Red Wegere	FV	13	4	11	4	7	8	3	3	3	5	2	2	2	67	5.15	56	11	3
White Wegere	FV	11	6	10	7	8	6	2	5	7	6	8	8	8	103	7.92	92	11	7
Red Fendisha	FV	12	1	6	10	9	11	9	12	10	10	5	5	5	105	8.10	82	23	8
White Fendisha	FV	5	2	1	9	2	3	4	6	9	3	1	1	1	48	3.69	39	9	1
Short muyra	FV	4	5	2	7*	5	12	9	10	8	12	6	6	6	85	6.54	63	22	4
No.of farmers		n=10	n=11	n=11	n=15	n =11	n=17	n=9	n=12	n=15	n=11	n=15	n=17	n=14					

IV=Improved Varieties; FV=Farmers' Varieties; M=Male; F=Female; *Mean rank was used to substitute the missing data; the lower the value the higher preference rank

Table 6. Pair wise ranking matrix values of FVs and IVs at Babile, Hirna and Chelenko,

Varieties			Babile, Lowland (N=14 farmers)		Hirna, Intermediate (N=11 farmers)		Chelenko, Highland (N=11 farmers)	
			Frequency of pair wise ranking values	Rank	Frequency of pair wise ranking values	Rank	Frequency of pair wise ranking values	Rank
ETS 3235	IV	1	8	4	6	7	5	8
ETS 2752	IV	2	9	3	3	8	9	5
Al 70	IV	3	5	7	7	6	7	6
Chirro	IV	4	5	7	8	5	10	4
Awash 1050	IV	5	3	8	8	5	3	10
IS 9302	IV	6	1	9	0	11	3	10
IS 9323	IV	7	0	10	1	10	0	12
Red Muyra L	FV	8	9	3	12	2	13	1
White Muyra	FV	9	13	1	13	1	12	2
Red Wegere	FV	10	6	6	9	4	1	11
White Wegere	FV	11	7	5	5	7	7	6
Red Fendisha	FV	12	2	8	7	6	4	9
White Fendisha	FV	13	13	1	10	3	6	7
Short muyra	FV	14	10	2	2	9	11	3

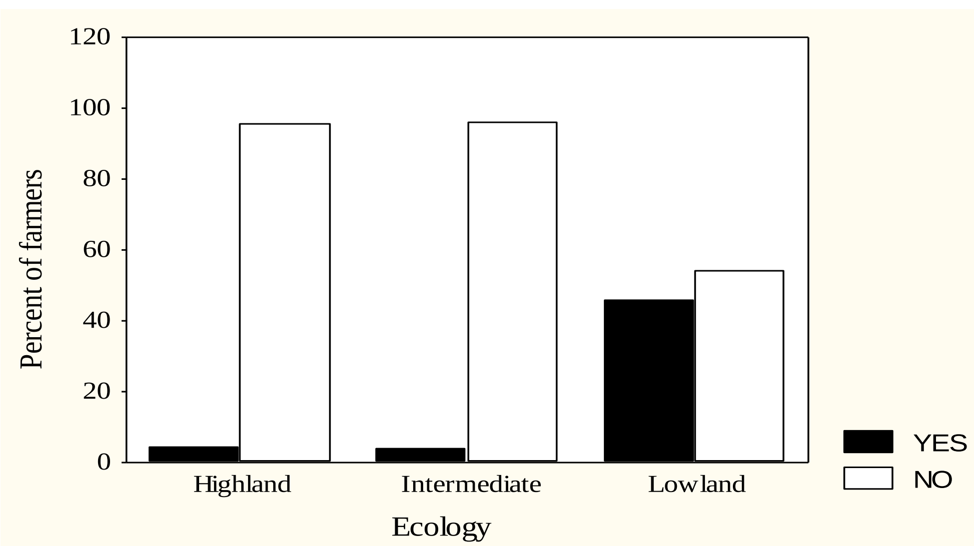

Figure 3. Percent of adoption of IVs in the different ecologies.

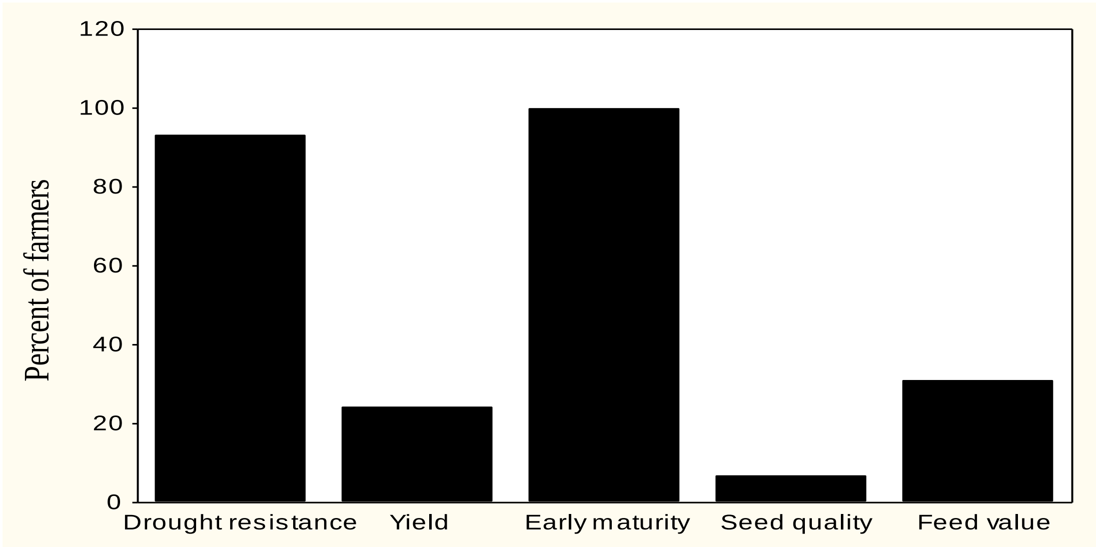

Fig 4. Reasons for adoption of improved varieties in eastern Ethiopia

Table 7. Relative importance of FVs and IVs in five weredas of eastern Ethiopia

Wereda	Ecology	No. of farmers growing*			Yield	
					FV^{NS}	IV*
		FVs	IVs	Both		
Alemaya	Intermediate	20	0	0	9.95	0.0
Hirna (Highland)	High	20	0	0	6.20	0.0
Hirna (Intermediate)	Intermediate	20	0	0	7.40	0.0
Girawa	Highland	20	0	0	7.60	0.0
Dire Dawa	Lowland	20	5	5	11.63	2.65
Babile	Lowland	20	7	7	8.78	0.55

*=Significant at 5% and NS=Non Significant at 5%; *timmad*=0.25ha

Table 8. Direct matrix ranking of FVs* in different crop ecologies

Girawa at Lencha FA, Highland N=30				Alemaya at Fendisha FA, Intermediate N=28				Babile at Likale FA, Lowland N=31			
Varieties	Multiple value	Yield Stability	Area coverage	Varieties	Multiple value	Yield Stability	Area coverage	Varieties	Multiple value	Yield Stability	Area coverage
Fendisha long	3	3	4	*Fendisha*	1	1	1	*Bullo*	1	1	1
Jorro	1	1	1	*Muyra*	2	3	2	*Chamme*	2	2	2
Gebabe	2	2	2	*Wegere*	3	4	3	*Wegere*	5	5	5
Muyra	5	5	3	*Fitibile*	4	2	4	*Kuffakassa*	3	3	3
Merturasse	4	4	5					*Shirdon*	4	4	4

(1=high, 5=low); FA=Farmers' Association

*=these are FVs identified in each study area. This is to show the farmers variation for preferences to their own developed varieties. The ranking was made in groups by voting system.

Table 9. Yield performance (qt/*ha*) under good and bad weather conditions

Ecology	**Yield in good years ***	**Yield in bad years***
Highland*	10.93	3.30
Intermediate*	15.65	4.52
Lowland*†	18.11	4.49
Total	14.22	4.02

*=Significant variation for yield with in each group and among groups
†=the yield data does not include ratoon crop yield

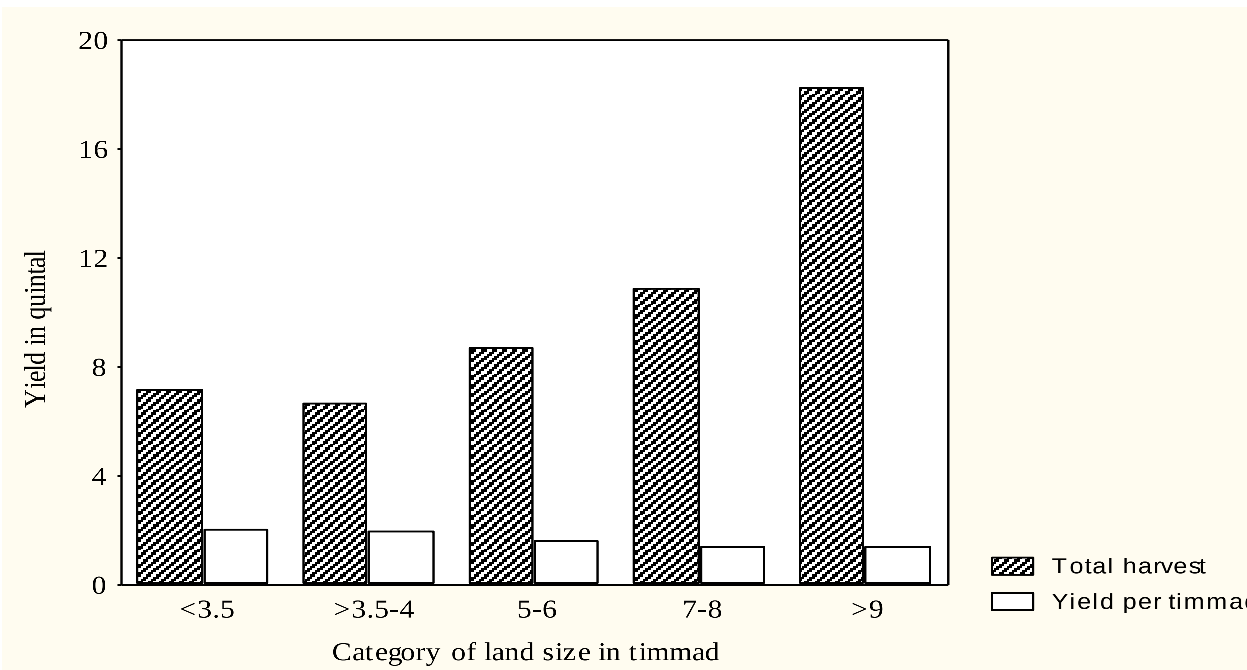

Fig 5. Total harvest and yield per *timmad* for different farm sizes

Table 10. Balance sheet for FOB and FAB

Criteria for comparison	Formal breeding (FOB)	Farmer breeding (FAB)	Remark
Genetic diversity	High	High for Intermediate and Highland areas	FAB constrained by the lack of early maturing germplasm
Selection criteria	Yield and yield related traits	Yield, yield related and non-yield related traits	FAB is featured by multiple selection criteria
Adaptation	Wider	Local and specific	Sometimes cropping system specific
Dominant Selection method	Pedigree breeding, pure line, modified mass selection	Mass selection, modified pure and bulk selection	
Selection environment	Mono-cultivar	Poly-cultivar; Multiple cropping system based	
G x E evaluation	3-4 sites per year	One site over many years	
Maintenance breeding	High	High	
FVs enhancement	Low	High	
Achievements	Low	High	
Adoption	Low	High	

Table 11. Suggested sorghum ideotypes for the crop ecologies in eastern Ethiopia

Characters	**Highland**	**Intermediate**	**Lowland**
Race*	B, BC, BG	DC, DB, D, C	Durra, DC, C
Panicle type	Lax to semi-lax	Semi-lax to Semi-compact	Semi-compact to compact
Plant height	Intermediate	Tall	Short
Seed size	Small to medium	Medium to large	Medium to large
Seed color	Red, White, Straw, Brown	Red, White, Straw	Red,White, Straw
Maturity (in mths)	Early (6-8)	Intermediate (5-6)	Very early (3-5)
Stalk sweetness	sweet	sweet	sweet
Endosperm texture	Corneous, Floury	Corneous, Floury	Corneous, floury
Grain subcoat	No	No	No
Plant color	tan	tan	tan
Grain luster	lustrous	lustrous	lustrous
Basal tillers	yes	no	yes
Stay green	yes	yes	yes

*According to Harlan and deWet (1972) sorghum race classification. *Crop Science*. 12:172-176. *D*=Durra; *C*=Caudatum; *B*=Bicolor; *G*=Guinea. *DC*=Durra-Caudatum, *GC*=Guinea-Caudatum, *DB*=Durra-Bicolor, *BC*=Bicolor-Caudatum, *BG*=Bicolor-Guniea.

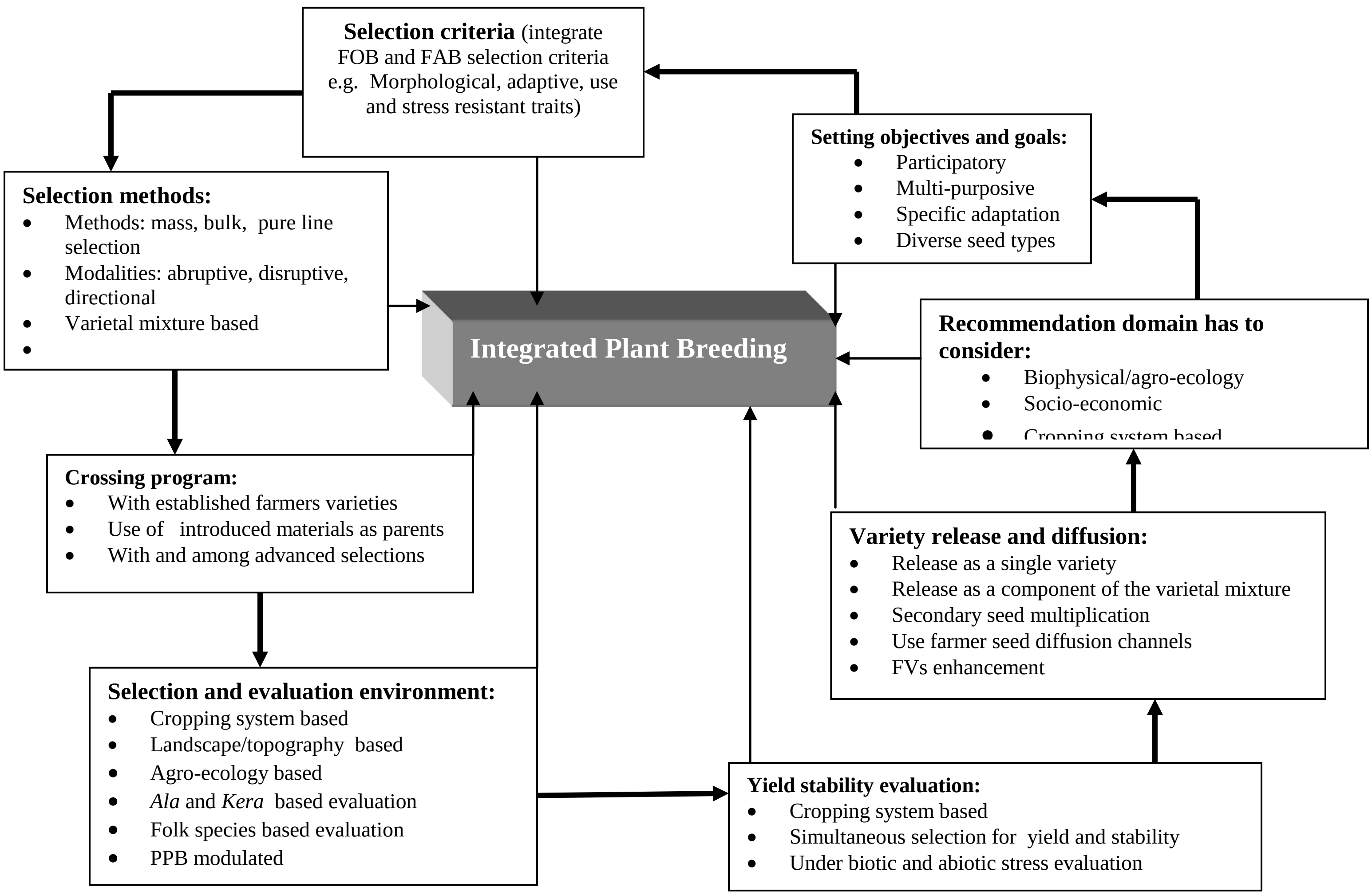

Fig 6. An Integrated Plant Breeding (IPB) Scheme