Uganda Journal of Agricultural Sciences, 2004, 9:594-605 ISSN 1026-0919

Development of sorghum varieties and hybrids for dryland areas of Ethiopia

G, Geremew., Asfaw Adugna, T., Taye, T., Tesfaye, B., Ketema[1]., and H. S., Michael[2].

Sorghum and Millet breeders, Melkassa Agricultural Research Center, P.O.Box 436, Nazareth, Ethiopia
[1]Associate professor and Sorghum and millet breeder, Alemaya University, P.O.Box 138, Alemaya, Ethiopia
[2]Sorghum Breeder, Sirinka Agricultural Research Center, Woldia, Ethiopia

Abstract

A study was conducted to scrutinize the development of sorghum (*Sorghum bicolar*) varieties and hybrids that have been carried out for the dryland areas of Ethiopia in the past 35 years (1969-2003). The experiments were conducted at the three major research centers and sub-centers representing the dryland areas of the country, viz., Melkassa, Mieso and Kobo. Over the years a number of activities have been executed to identify sorghum varieties and hybrids that can give relatively better yield and escape drought. The identified better performing varieties have been tested on farm and released for commercial production. Hitherto, a total of 11 varieties have been released by the national sorghum research program for commercial production in the dryland areas. Of these, 9 are on the current recommendation list. Additionally, two hybrids will be released in the near future. Despite the efforts made to improve sorghum production and productivity the improved varieties are not still well adopted by the local farmers.

Key words: Commercial production, drought, Sorghum bicolar

Introduction

Sorghum (*Sorghum bicolar)* grows over a wide range of latitudes from 0 to 45° North and South of the equator (ICRISAT, 1991). Because of its drought resistance, sorghum is the crop of far excellence for dry regions and areas with unreliable rain fall. It is a staple food in the drier parts of tropical Africa, India and China. Sorghum is grown in Ethiopia in 12 of the 18 major agro-ecological zones. It is one of the important indigenous food crops and is only second to *tef* as *injera* (leavened local flat bread) making cereal. In the dryland areas of Ethiopia which covers 66 per cent of the total area, it is the major cereal crop grown. In these areas crop production is mainly rain-fed. Because of the low amount, uneven distribution and erratic nature of the rainfall crop production is seriously affected in these areas. A number of constraints have been standing on the way towards sorghum production. The major problems that check sorghum production in the dryland areas of the country include: lack of early maturing varieties that can escape drought, poor soil fertility, poor stand establishment due to reduced emergence in characteristically crusty soils, insect pests like the spotted stalk borers (*Chilo partellus*) and birds. Research has been underway to alleviate these problems. The purpose of this paper is therefore; to review the work done so far in Ethiopia to develop sorghum varieties and hybrids for moisture stressed areas.

Materials and methods

Moisture stressed sorghum growing areas
The moisture stressed areas in Ethiopia are more extensive in southern, southeastern, eastern and northeastern part of the country. Sorghum is the major cereal crop grown in Konso and Derashe in the south, Miesso, Asebot and Babile areas in the east, North Shoa (Shoa Robit), Wello, Raya valley, Sheraro and Humera areas in the north and more recently the Jijiga plains in the east (ICRA, 1992). The livelihood of the population is mainly dependent on sorghum in these areas.

The moisture stressed areas in Ethiopia are grouped into 7 agro-ecologies: A1, A2, SA1, SM1, SM2, M1, M2 (MoA, 1998) (Table 1). According to Adejei-Twum (1987) and Reddy and Kidane (1993) the main constraint to the productivity of crops in the semi-arid areas of Ethiopia is inadequate, unreliable and erratic distribution of rainfall. There is a high coefficient of variability with regard to quantity, onset and cessation of rainfall. In addition highly unpredictable dry spells may occur at vegetative and grain formation stages of crop growth.

Table 1. Charactersitics of moisture stressed sorghum testing sites in Ethiopia

Existing Centers/ Sub-centers	Agro-ecologies	Environmental variables			
		Altitude (m.a.s.l)	Annual Rain-fall (mm)	Annual Temperature (^{0}C) Minimum	Maximum
Melkassa	SM2(SM2-5), Sub-moist, mountains and plateau, tepid to cool	1550	770	12.6	28.6
Miesso	SM1 (SM1-1) Hot to warm sub-moist plains	1470	713.4	13.8	30.4
Werer	A1 (A1-1) Arid plains, hot warm	750	560	18.7	33.8
Sirinka	M2 (M2-5), Moist mid highlands, tepid to cool	1920	1064.9	13.6	26
Kobo	SM1(SM1-3), Sub-moist hot warm lowlands	1500	617.3	15.6	29
Mekele	SM2 (SM2-5), Sub-moist mountains and Plateau Tepid to cool	1970	469.2	12	26
Sheraro	SM1(SM1-4), Sub-moist hot warm lowlands	1010	-	-	-
Abergelle	SM1(SM1-4), Sub-moist hot warm lowlands	1450	-	-	-
Babile	SM1(SM1-7) Hot to warm sub-moist mountains	1650	600	-	(21)
Jijiga	A2 (A2-7), Arid mid highlands, Tepid cool	1650	550	-	(21)

Source: MoA (1998)

Indigenous and exotic germplasm acquisition and evaluation

Sorghum breeding program has been diversifying the germplasm base through acquisition and evaluation of germplasm from indigenous collections and exotic sources. In moisture stressed areas the growing period is short and therefore the genotype to be developed for these areas should be early maturing. But, such early maturity sorghum genotypes are not readily available in the indigenous collections. As a result, exotic germplasm have been acquired from other national programs as well as international institutions. A large number of exotic germplasm have been introduced from international organizations. The germplasm have been evaluated on a quarantine field at Melkassa Research Center on non replicated observation plots of size two rowsx5 m x 0.75m.

Hybridization and population improvement

Alternative to introduction of germplasm from abroad generation of variability from planned hybridization between selected parents and population improvement schemes have been carried out the overall objective being to identify superior genotypes which can tolerate/resist various stress factors in moisture stressed areas. To enhance the probability of obtaining transgressive segregants of economic worth, large numbers of crosses are made every year. Hybridization work is done at the national coordinating centre, Melkassa using hand emasculation.Population breeding that uses recurrent selection was initiated by sorghum improvement program at Melkassa to develop superior half sib genotypes for moisture stressed areas. For this purpose two populations that are based on ms3 genetic male sterility gene were introduced from Texas A & M University. These were TP24 white and TP24 brown. For this seeds from a large number of early maturing genotypes out of the various trials have been sampled and bulked and used as pollinators. The female carried the ms3 genetic male sterile gene and the pollinators are planted in every other row to effect random mating. The sterile plants were tagged during flowering and harvested. These were usually head rowed at Melkawerer off season nursery to select superior plants to ensue the next cycle. Superior S1s have been evaluated for yield performance in a RCBD with three replications on plots of size 5 m x 0.75 m x 5rows.

Evaluation and selection of segregating generations

The F_1s that are resulted from the hybridization work are out grown in the off-season at Werer irrigated research station. These F_1s are usually space planted on a single row plot. Starting from the F_2 segregating generations have been grown and selected each year at each testing site. Each generation grown at two or more testing site representing a similar adaptation zones has been pooled to form planting material for the following season. But very recently it has been started to grow all the F_2 populations at Melkassa (the coordinating center) and the selections in the successive generations are grown as F_3 at Melkassa, Mieso and Kobo. Finally, when the genes are fixed the selected lines from each testing site have been pooled and tested for yield across various moisture stress testing sites (Melkassa, Mieso, Kobo, Sheraro, Abergelle and Jijiga). Variable numbers of the segregating populations are involved every year. The common plot sizes are 10 m x 0.75 m x 4 rows for the F_2 and 5 m x 0.75 m x 2 rows for generations starting from F_3.

Hybrid development and evaluation

Sorghum hybrids development has been going on for many years. The hybrids are evaluated at three stages. The first and preliminary stage of evaluation is called initial screening of hybrids (ISH). At this stage, a large number of the newly developed hybrids are evaluated for their sterility reaction and their overall agronomic desirability on a two non-replicated observation rows. The second stage is called advanced sorghum hybrids trial (ASHT). At this stage a few hybrids that were advanced from ISH are evaluated based on their performance using RBD with 3 replications at two or three test locations. This is equivalent to the pre-national variety trial in the case of open pollinated varieties evaluation. The hybrids advanced from ASHT are evaluated in the next and last stage of evaluation, elite sorghum hybrids trial (ESHT). This stage is equivalent to the national variety trial for open pollinated varieties evaluation. The hybrids are organized into a RBD with four replications on plots of size 5mx0.75mx5rows and are sent to the test locations all over the country. Based on their multi-location performance and yield stability, the best hybrids are selected and proposed for release after on farm verification.

Evaluation for seedling emergence

Poor stand establishment is common in sorghum fields due to poor emergence and seedling vigor (Martin *et al*., 1976). There are several environmental factors (soil type, moisture, crusting, compaction, depth, diseases and insect pests, temperature) that influence seedling emergence. In Ethiopia among the environmental factors soil crusting is the most important one that causes poor seedling emergence in sorghum fields (Tilahun and Teshome, 1987) and poor stand establishment is a serious problem in moisture stressedsorghum growing areas of Ethiopia (Yilma and Abebe, 1986). In addition, there are also plant characteristics (viability, size, source, coleoptile and raddicle length) that can influence emergence. Yilma and Abebe (1990) reported the presence of variation with respect to seedling emergence through soil crust. Experiments were carried out on pots and in the field to identify genotypes with reasonable seedling emergence at Melkassa, Mieso and Wolenchiti in 2003. A total of 44 genotypes were involved in 2 color groups, 21 white and 23 red/brown.

Performance test

Since 1969 a number of variety trials have been executed in two or more testing sites to identify better performing varieties for moisture stressed areas. The trials have been organized based on maturity groups. Earlier, our variety development program has been focused on identifying early maturity sorghum varieties. But farmers have been found to be reluctant to grow early maturity sorghum varieties in good rainy seasons during which time they can also harvest good yield from their local cultivars. Therefore, an alternative activity had been initiated to identify long cycle indigenous sorghum cultivars that are planted in April and resist the dry spell during May and resume growth in June and harvested in November/December. This has been designed to suit into the bimodal nature of rains in most moisture stresses areas of the country. Overall, the trials for performance evaluation of the test varieties use RCBD with 3 replications for pre-national and 4 replications for the national variety trials. The plot size in both cases is 5 m x 0.75 m x 5 rows. Data are recorded from the middle 3 rows only. The best varieties selected from the national variety trial are tested on farm on a plot of size 10mx0.75mx13rows ($100m^2$).

On-farm evaluation of early and medium maturity sorghum varieties

Mulatu and Belete (2001) studied farmers' response to released early and medium maturing sorghum varieties around Babile (Eastern Ethiopia). It was a kind of farmers' participatory variety selection. During evaluation the points considered were stalk length/thickness/strength, maize stalk borer tolerance, covered kernel smut resistance, number of ineffective tillers, performance under sub-optimal soil fertility conditions, early maturity to escape drought, seed size, head type, taste and quality of grain, ease of dehulling and grinding, weevil resistant and stalk type (juiciness). Based on these criteria eight varieties and the local check were evaluated by farmers.

Integrated striga management (ISM)

Striga is the major parasitic weed causing severe damage on the production of maize, sorghum and millet. In areas of high *striga* infestation 65-100% yield loss is prevalent (Ejeta et al., 1993). Many reports in highly infested areas of Ethiopia support this. In Ethiopia two *stariga spp., Striga hermontica* and *Striga asiatica*, were identified as economically important sorghum production bottlenecks. So far two resistant sorghum varieties and related management technologies that suppress the effect of *Striga* infestation were recommended. However, there was little effort in disseminating the improved technologies to the users. Due to this reason a pilot project aiming at introducing the improved technologies to farmers and other stakeholders and making the seed accessible to farmers is being undertaken in collaboration with INTSORMIL in four regions of the country. This pilot project involves three activities: Package demonstration, Seed multiplication and Popularization.

Results and discussion

Indigenous and exotic germplasm acquisitions and evaluations

In 1986 from out of 419 indigenous lowland sorghum genotypes grown by Plant Genetic Resources Center of Ethiopia (PGRC/E) at Melkassa only 4 were advanced for further testing (IAR, 1986). A total of 1,244 local collections were acquired and evaluated but no better performing genotype was found (Yilma and Abebe, 1987). As a result, exotic germplasm were acquired from other national programs as well as international institutions. Yilma and Abebe (1987) reported that from 1976 to 1986 a total of 16,483 exotic germplasm were received from international institutions and evaluated at testing sites that represent moisture stress areas of the country. In all the cases the genotypes were evaluated on non replicated double row plots having 5m length and 0.75m inter-row spacing. A close to 11% of these introductions was initially advanced for further testing. Some of the selected genotypes have been utilized for various sources of desirable genes for yield, maturity, plant height, pest resistance and good grain quality. In addition, most of the selections from exotic sorghums have been purified and promoted to preliminary and national yield trials. From 1976-1986 alone, entries derived from exotic sorghums constituted 60% of the total entries included in low elevation variety trials.

Five early maturing varieties, viz., Dinkmash 86 (81 ESIP 47), Seredo, 76 T_1#23, Kobomash 76 and Melkamash 79 were released from 1976 to 1986. These were derived from among the various introductions (Yilma and Abebe, 1987). Only one variety (Gambella 1107) was released from indigenous germplasm as far as the lowland agro-ecologies are concerned (Table 2). Again, from 1987 onwards several genotypes were acquired from abroad and local institutes as well. It was reported by IAR and EARO (1987-2001) that a total of 2,052 exotic and 1,405 indigenous sorghum genotypes were received and tested. Twenty five per cent from exotic and 8.6% of the indigenous genotypes were advanced. Varieties like MEKO-1, Teshale, Birhan and Yeju were selected from the exotic germplam and recently released for commercial production. Table 3 shows the early maturity sorghum germplasm introduced and selected from 1999 to 2003. The selected germplasm are now being tested at different stages of evaluation.

Hybridization and population improvement

From 1976-1986 a total of 429 parents were involved resulting 5,327 crosses. Similarly, from 1987-2001 a total of 335 parents were utilized resulting in 1,120 crosses. Relatively larger numbers of crosses were made towards the development of high-yielding and stable genotypes for moisture stressed areas than either for intermediate or high altitude areas. Yilma and Abebe (1987) reported the development of six populations using genetic male sterility sources. Out of the 6 populations 4 were discarded due to narrow genetic base, poor adaptation and performance. Two populations, early white and early brown were improved. The former serves as sources of early maturing materials for drought prone areas where good quality sorghum is preferred whereas the latter is maintained to serve as good sources of lines for bird prone moisture stressed areas. According to the above authors considerable amount of genetic variation in grain yield was observed. Among S_1 progenies derived from early white population the S_1 selection improved the grain yield by 27 per cent (Table 4). As it can be clearly seen from the table the top ranking S_1 progenies produced two to three times higher yields than the check varieties Gambella 1107 and 76T_1#23.

Evaluation and selection of segregating generations

In the process of development of genotypes through hybridization, the F1 crosses have been sown in the off-season at Werer and the resulting F2 seeds planted and tested in the main seasons at the eventual areas of release. The total number of populations, families and lines grown and advanced in 2003 alone are summarized in Table 5.

Hybrid development and evaluation

Earlier, very good performing hybrids involved yellow endosperm pollinators and well known A-lines from Texas A & M and ICRISAT were ready for release. However, during the political unrest in the country in 1991 when the research center was looted all the seeds were destroyed. Thereafter, the effort was resumed to develop other better performing hybrids. Consequently, two high yielding early maturing hybrids are on the pipe line for release (Table 6). Moreover, the result of the elite sorghum hybrids evaluated at Melkassa, Mieso and Kobo in 2003 main crop season is presented in Table 7. The analysis of variance for individual locations showed non significant differences among the genotypes at Melkassa and at Mieso. However, the combined ANOVA revealed that eleven hybrids were significantly superior to the standard check variety, Teshale.

Table 2. Characteristics of sorghum varieties released for moisture stressed areas

Varieties	Year of Released	Maturity Group	Days to flowering	Plant height (cm)	Yield (q/ha)	Seed color	Status*
Gambella 1107	1976	Medium	80-90	150-200	30-50	White	1
Melkamash 79	1979	Medium	70-80	109-140	30-45	White	2
Dinkmash	1986	Early	63-90	103-160	20-50	White	2
Kobomash 76	1986	Early	77-88	109-140	25-35	White	2
76T1 #21	1976	Early	70-75	120-140	20-30	White	2
76T1 #23	1976	Early	60-70	120-140	25-45	White	1
Seredo	1986	Early	65-75	110-140	20-40	Brown	1
Meko-1	1998	Early	61-92	157-177	22-33	White	1
Teshale	2002	Early	65-76	169-200	26-52	White	1
Yeju $^{+}$	2002	Early	75	150-210	50	White	1
Abuare^{+}	2003	Early	67-80	134-156	38	White	1
P 9403 (Abshir)**	2000	Early	83	110-140	14-24	White	1
P 9401 (Gobye)**	2000	Early	80	110-140	14-27	White	1

*/ Status = 1 currently in the recommendation list and 2 = Obsolete; = Released by Sirinka Agricultural Research Center for north eastern part of the country; **= Sorghum varieties resistant to *striga*

Table 3. Sorghum germplasm introduced and selected from 1999 to 2003 by year

Year of introduction	Germplasm type	Number of entries introduced	Number of entries selected	Source
1999	Sorghum varieties/lines	-	-	INTSORMIL
	Sorghum hybrids	419	126	INTSORMIL
	Total	419	126	
2000	Sorghum varieties/lines	25	18	INTSORMIL
	Sorghum hybrids	-	-	-
	Total	25	18	
2001	Sorghum varieties/lines	1417	277	INTSORMIL
	Sorghum hybrids	219	14	INTSORMIL, ICRISAT
	Total	1636	291	
2002	Sorghum varieties/lines	208	54	INTSORMIL
	Sorghum hybrids	266	43	INTSORMIL
	Total	474	97	
2003	Sorghum varieties/lines	70	40	INTSORMIL
	Sorghum hybrids	838	177	INTSORMIL
	Total	908	217	
	Grand total	**3462**	749	

Table 4. Grain yield of three top-yielding S_1 progenies derived from TP24 white population and the two check varieties tested at Melkassa, 1986.

Progeny	Grain Yield (q/ha)
86MWTP24(w)-S1-22	69
86MWTP24 (w)-S1-109	59
86 MWTP24(w)-S1-60	48
Gambella 1107 (check variety)	24
761#23 (check variety)	21
Min.	13
Max.	69
Mean (C1)	30
Mean (C0)	24
SE ±	7
Change/ cycle (%)	27
CV (%)	34

Source: IAR, 1986

Table 5. Number of entries grown and selected from the dryland sorghum segregating generations in 2003 crop season at representative sorghum growing areas.

Generation	Testing site	Number of entries Grown	Selected*
F2	Melkassa	20	17 (96)
F3	Melkassa	77	37 (54)
	Mieso	77	40 (71)
	Kobo	77	20 (41)
F5	Melkassa	177	71 (102)
	Mieso	177	71 (114)
	Kobo	57	25 (51)

*Figures in parentheses indicate the number of heads selected

Table 6. Agronomic characteristics of dryland sorghum hybrids to be proposed for release

No.	Variety	Grain yield (q ha^{-1})	Days to flowering	Plant height (cm)
1.	ICSA-15 x 3443-2-op	5.1	74	213
2.	ICSA-15 x ICSR-161	4.6	77	171
3.	Meko (Check)	3.4	73	150

Table 7. Grain yield (q/ha) performance of elite sorghum hybrids tested at Mieso (MI), Kobo (KB) and Melkassa (MS) in 2003

Entry No.	Hybrids	MI	KB	MS	Mean
1	P-9501 A x ICSR 14	46	66	45	52
2	ICSA-21 x ICSR 50	48	77	45	56
3	ICSA-22 x M - 4850	44	64	37	48
4	ICSA-90003 x M – 170	40	80	35	52
5	ICSA-90003 x M – 240	44	69	44	52
6	ICSA-15 x M – 5568	47	69	41	53
7	P-9534 A x KCTENT # 17 DTN	47	75	32	51
8	ICSA-15 x ICSR – 14	48	65	42	52
9	ICSA-34 x ICSR – 14	43	75	38	52
10	ICSA – 90003 x SDSL 89426	41	71	40	50
11	ICSA – 34 x 98 MW 6001	41	56	32	43
12	ICSA – 34 x 98 MW 6002	47	69	37	51
13	ICSA – 34 x MW 6100	44	60	34	46
14	ICSA – 34 x P – 984108	46	60	46	50
15	ICSA – 21 x 98 MW 6001	45	50	39	45
16	ICSA – 21 x 98 MW 6002	40	68	38	49
17	ICSA – 21 x 98 MW 6100	39	63	45	49
18	Teshale (standard check OPV)	37	61	29	42
LSD (0.05)		NS	11.67	NS	6.71
CV (%)		18.55	12.38	22.05	16.71

Evaluation for seedling emergence

Yilma and Abebe (1990) reported the presence of variation with respect to seedling emergence through soil crust. This investigation revealed the presence of considerable difference in field emergence despite high laboratory germination. However, there was no significant correlation with seed weight (r = 0.24 ns). Tables 8 and 9 show the results of the pot and field emergence tests carried out in 2003 at Melkassa, Mieso and Wolenchiti. The field emergence of the white kernel group ranged from 35% (meko) to 81% (IS6961). For this group the highest pot emergence was 96%. Only 3 genotypes had pot emergence of 90%. From the red and brown kernel group 6 genotypes showed >80% field emergence and 8 of them had pot emergence of 90%.

Performance Tests

So far 11 varieties have been identified from early and medium maturity variety trials and released for commercial production (Table 2). Of these 9 are on the current recommendation list. In addition, recently, several varieties have been identified from long cycle sorghum variety trials (Table 10). Since there is no appropriate standard check for this particular trial the local check was used. As a result 8 varieties showed more yield than the local check. Table 11 shows the performance of early maturing sorghum varieties in 2003 at Melkassa, Mieso and Kobo. In this particular trial, 2 varieties that had location mean grain yield of 56q/ha each significantly out yielded the standard check, Meko (that had grain yield of 48q/ha).

On-farm evaluation of early and medium maturity sorghum varieties

Among the 8 varieties evaluated, the farmers selected 76 T1 #23, Meko-1 (M36121) and Gambella1107 as their first, second and third choices, respectively. The farmers gave local names: Aba-Biya (community survivor), Lubu-Kebei (life saver) and Kubsa (hunger fighter) to Meko-1, 76T1#23 and Gambella 1107, in that order.

Integrated *Striga* management (ISM)

Within a limited life of the pilot project it was possible to bring impact in *striga* prone areas of the country where in some the land was totally abandoned. The number of farmers involved and input distributed in 2002 and 2003 crop season are indicated in Table12.

Regional variety adaptation trials

At the end of the regional adaptation trial some varieties (76 T1 #23, Seredo, and Gambella 1107) have been recommended for the test areas. Similarly, the performance test of intermediate and highland varieties studied at Srinka research center indicated that the highland varieties like ETS 2752, AL 70 and Chrio were late and it was not possible

Table 8. Percent of field & Pot seedling emergence for the White sorghum lines tested in 2003 at Melkassa, Mieso and Wolenchiti

		Field Emergence (%)				Pot emergence (%)		
Entry#	Genotype	MS	MI	WOL	Mean	MS	WOL	Mean
1	IS – 24259	58	71	43	57	78	85	81
2	BTX – 629	78	82	60	73	92	88	90
3	SPV – 245 x 1(146 x 3541)-27 x Framida – 7 – 1	78	81	48	69	88	88	88
4	ICSV – 745	62	82	45	63	78	79	79
5	(9372 x IS – 10485)	78	92	65	78	79	94	86
6	IS 6762 x 557	69	82	47	66	85	84	84
7	23209 x 96 x IS 6762	76	68	39	61	75	62	69
8	(3443 x 25 V – 1) – 5	73	67	52	64	91	83	87
9	SPV – 245 x P – 967083	60	71	46	59	77	72	74
10	IS – 2342 x M – 66145	64	81	59	68	95	87	91
11	(148 x E – 3541) – 4 –1 x CS 3541-Derive	79	84	53	72	89	80	85
12	IS-19614 x (148 x E – 35 – 1) – 1x (SV – 4) – 5 –3 – 4 – 4 – 10 – 2	76	81	41	66	82	88	85
13	(SC – 423 x CS 3541) E – 35 – 1) – 2-1x - RS/R – 20 – 8614 - 2	70	86	75	77	96	95	96
14	DJ 1195 XN – 13	69	81	65	72	73	92	83
15	M – 90411	80	88	67	78	85	88	86
16	(148 x E – 3541) – 4 -1 x CS 3541 – Derive – 5 – 4 – 2 – 1	73	71	60	68	89	89	89
17	IS 6961	83	93	68	81	74	90	82
18	(148 x E – 35- 1) x CS 3541	72	87	58	72	89	78	84
19	Mpoma white	78	85	61	75	92	78	85
20	Mera	68	84	61	71	90	86	88
21	Meko	39	49	17	35	70	38	54
C.V. (%)		17.92	12.84	24.66	17.83	12.95	12.55	12.76
LSD(0.05)		20.88	16.82	21.90	19.64	NS	16.99	12.19

Table 9. Percent of field & Pot seedling emergence for the Red & Brown sorghum lines tested in 2003 at Melkassa, Mieso and Wolenchiti

Entry#		Field Emergence (%)				Pot mergence (%)		
		MS	MI	WOL	Mean	MS	WOL	Mean
1.	90 MW 5402	79	77	55	71	78	89	83
2.	Seredo	80	84	73	79	89	94	92
3.	PGRC/E # 69442	85	87	70	81	98	72	85
4.	PGRC/E # 69475	77	78	73	76	90	73	81
5.	ACC # 69447	83	94	72	83	90	83	86
6.	PGRC/E # 69441	69	89	64	74	88	88	88
7.	PGRC/E # 69447	79	91	74	81	91	93	92
8.	Red Moechema	74	90	64	76	84	83	83
9.	IS 777	80	78	61	73	93	79	86
10.	P 898012 x (148x (E-35-1) -4 -1x –3541 derive – 5 – 4 – 2 –1	69	81	63	71	82	83	82
11.	IS 776	82	84	70	79	93	90	92
12.	SC – 103	74	82	53	69	78	87	82
13.	IS 2284	82	90	73	81	91	94	93
14.	5D 135/13/1	72	73	63	69	93	89	91
15.	ICSV 1018 BF	65	97	64	75	77	93	85
16.	SR – 306 Framida – 055	76	86	80	81	96	90	93
17.	IESV 93035 – SH	69	81	66	72	83	87	85
18.	IESV 93041 – SH	83	87	71	81	97	70	83
19.	IESV 94009 – SH	74	88	57	73	92	91	92
20.	IS 6524	72	91	60	74	86	94	90
21	SC – 52	45	64	28	46	67	73	70
22	Ruffe	46	27	22	31	44	51	47
23	Meko	29	55	22	35	49	38	43
C.V. (%)		13.45	16.09	23.8	17.64	7.73	13.62	11.01
LSD (0.05)		15.81	21.36	23.80	11.72	13.39	23.06	12.96

Table 10. Mean performance of long cycle sorghum lines at Melkassa and Mieso Dryland conditions in 2003

1	Killite	36
2	Mishinga Adi	36
3	Abolla	41
4	Degalite (red)	29
5	Birmash	34
6	Degalite Yellowish	46
7	ETS-0738	27
8	ETS-3502	38
9	90 BK 4241	28
10	ETS 0601	40
11	ETS 789	43
12	Merahabette coll. # 9	35
13	Merahabette coll. # 10	42
14	Merahabette coll. # 11	27
15	Abay Gorge coll.# 1	45
16	Abay Gorge coll. # 2	45
17	Wollo coll. # 1	44
18	Wollo Tenglle # 1	34
19	Woldia coll. # 1	36
20	Local check	39

to take any yield and other agronomic data under Sirinka conditions. However, the intermediate varieties Bakomash, 85MW 5340 and Birmash gave reasonable yield (Table 13). The lowland varieties Yeju, Birhan (for *Striga* resistance) and Abuare have been released from such regional testing. Similarly the result of the regional variety trial that was executed by Mekele Agricultural Research Center at Sheraro and Aberegelle is given in Table 14.

Problems associated with early maturing sorghum varieties

In spite of the strong research efforts exerted by the national and regional research institutes, the improved sorghum varieties are still not well assimilated into the farming community. This can be traced back to one or more of the following causes: improved varieties are sensitive to sowing depth, susceptibility to soil crusts which results in poor stand establishment, the farmers preference to their own local cultivars in good rainy season, lack of aggressive extension work to reach the end users, unavailability of enterprises involved in seed production and high bird damage particularly of white seeded and high quality varieties.

Table 11. Grain yield performance of the varieties included in early maturity white sorghum national variety trial in 2003 at Melkassa, Mieso and Kobo

		Grain yield (q/ha)			
Entry#	Identification	MS	MI	KB	MEAN
1.	97MW 6038	43	46	48	45
2.	97MW 6085	32	39	54	41
3.	97MW 6009	35	48	46	43
4.	SDSL 89426	51	56	35	47
5.	WSV 387	47	55	65	56
6.	ISV–5	45	50	49	48
7.	MR– 812	44	49	56	50
8.	ADIV– 150	37	41	50	43
9.	SDSL-2690–2	62	63	43	56
10.	P–89002	39	42	55	45
11.	DR–14	45	51	57	51
12.	99 MW 4066	41	47	45	44
13.	99 MW 4074	36	43	39	39
14.	99 MW 4075	34	53	48	45
15.	97 MW 6015	33	49	46	43
16.	97 MW 4067	34	46	34	38
17.	99 MW 4067	41	46	50	46
18.	MEKO	41	48	54	48
LSD (0.05)		12.59	7.75	14.85	6.91
C.V. (%)		21.66	11.32	21.57	18.57

Table 12. Number of farmers involved and input distributed from 2002-2003 for ISM activities

			Input distributed		
Year	No. of farmers	Area (Ha)	Seed (q)	Fertilizer (q)	Tie-ridger
2002	472	174.40	34	137.25	90
2003	1340	497.71	60	126.00	12
Total	2812	672.11	94	263.25	102

Table 13. Mean values for grain yield (q/ha), days to flowering, plant height (cm) and days to maturity for medium maturity sorghum varieties tested in 1996 and 1997 at Srinka

Variety	Grain yield	Days to flowering	Plant height	Days to maturity
Bakomash 80	21	113	165	155
85MW5340	20	108	165	152
Birmash	23	118	172	151
Local check	19	130	282	181
Mean	21	117	196	160
LSD (5%)	NS	3.28	12.0	9.7
CV (%)	289.9	2.6	5.6	5.6

Table 14. Mean values for plant height (cm), days to maturity and grain yield (q/ha) of 14 sorghum varieties tested under regional variety trial at Sheraro and Abergelle (1999-2001).

	Abergelle			Sheraro		
Varieties	Plant height	Days to Maturity	Grain yield	Plant height	Days to Maturity	Grain yield
IS 77	183	113	17	194	103	15
Seredo	153	114	19	166	102	20
ACC. #69447	152	115	20	156	104	15
91Mk7011	128	109	19	110	97	17
ICSV 111 Inc	150	115	11	145	98	16
ICSV - 219	136	118	13	135	99	15
90MW5250	159	116	16	150	101	16
SKN4841x(EC-64734x E-35-1) - 2-2-2	134	118	15	120	98	15
SE82 - 022	139	115	16	121	98	13
(82LSPY-2#5) x 81ESIP46	180	116	18	173	102	19
90MW5344	138	118	13	123	97	13
CR:35:5	135	119	19	135	106	20
76T1 #23	140	113	14	135	96	13
Local Check	189	123	13	192	101	15

Conclusion

From the experience of the national sorghum improvement program exotic germplasm has been found to be better in the development of early maturing sorghum varieties and hybrids than the indigenous germplasm for the dry lowland areas of Ethiopia. As far as the utilization of indigenous germplasm in the dryland areas of the country is concerned the efforts made to develop long cycle sorghum varieties that can withstand the dry spell in May is a good option. Not withstanding the costly and cumbersome operation it involves hybridization was and continues to be a good source of variability. The better performance of sorghum hybrids in yield and earliness than the open pollinated varieties drags the interest of the researchers and the farmers. Pipe-line hybrids gave as much as 1.7 ton ha^{-1} more yields over the best standard check variety and this indicates the potential of hybrid sorghum for production in the dryland areas of Ethiopia.

The significant variability that was observed among sorghum genotypes tested for seedling emergence was valuable to identify and utilize in future breeding program to incorporate this trait into the high yielding background. The ultimate output of any breeding program should be to bring about significant impact in the farming community. To this end the on farm evaluation of released sorghum varieties was found to be important tool for the farmers in the dryland areas of the country to help acquainted with these varieties. Although there was no economic analysis done to study the adoption rate of the *striga* resistant sorghum varieties, observations from the demand and the increased area under these two varieties revealed significant impact in the *striga* prone areas where the pilot project has been operating.

Future Direction

Investigations will continue to identify variability for seedling emergence in our sorghum genotypes towards improving stand establishment. Side by side to developing early and medium maturing varieties we need to continue on identifying long cycle indigenous sorghum cultivars that can perform better in the moisture stressed areas. As a national program germplasm supply to higher learning institutions, federal and regional research centers will be continued to curb biotic (*Striga*, bird, insect pests and disease) and abiotic (moisture stress, poor stand establishment and low soil fertility) stresses. Moreover, collaboration with local and international institutions will be strengthened.

References

Adjei-Twum, D.C., 1987. Effects of plant density and tillage on growth and grain yield of sorghum under dryland conditions in a semi- arid area in Ethiopia. *Journal of Agricultural Sciences*, 108, 395-401

Ethiopian Agricultural Research Organization, 1997-2001. Ethiopian Sorghum Improvement Program progress reports 1997-2001.

IAR (Institute of Agricultural Research). 1986. Ethiopian Sorghum improvement Program Progress Report for the period 1986.

IAR (Institute of Agricultural Research)., 1987-1996. Ethiopian Sorghum improvement Program Progress Reports for the periods 1987, 1988, 1989, 1991, 1992, 1995 and 1996.

ICRA (International Center for Development Oriented research in Agriculture., 1997. Strengthening farmer participatory research and development in Jijiga zone: The case of moisture stress reduction in the plains and soil fertility management in the hills. *Working document series,* 60 Jijiga Ethiopia.

ICRISAT (International Crop Research Institute for the Semi-arid Tropics)., 1991. Annual Report for year 1990. The cereals program (semi-formal publication).Patancheru, A.P.502324, India.

Maritin, J.H., Leonard, W.H. and Stamp, D.L., 1976. Principles of field crop production. 3rd Ed., Macmillan Publishing Co. Inc., New York.

MOA (Ministry of Agriculture)., 1998. Agro-ecological zones of Ethiopia. *Natural Resources Management and regulatory Department*. Addis Ababa.