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Varietal and Seed Replacement As a Means to Improve Crop Productivity in GTP I: The Case of Major Cereals in Some Districts of Southern Ethiopia

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Abstract
Cereals are major food crops in area coverage and total production in Ethiopia; thus share the largest proportion compared to other grain crops such as pulses and oil crops. It has been realized that the productivity of cereals is too low compared with potential productivity of the crops. Surveys on identification of crop production constraints indicated that limited access to crop production technologies such as suitable and better yielding crop varieties and improved management practices have been identified as some of the major constraints that pinpointed as causes for low productivity. This study was aimed to improve crop productivity at farm levels through intensive and massive crop varietal and seed replacement. During GTP-I of Ethiopia, participatory on farm evaluation of technologies which were available for major cereal crops such as maize, tef, barley and wheat in different districts of Southern Ethiopia was done as first phase of this study to identify the most suitable ones for different agro-ecologies. Identified technologies were multiplied at large scale in the next phase to disseminate widely to users in pre-scaling up program. In four rounds, a total of 883quintals (88300kg) of seeds from different selected crop varieties were disseminated to cover 1272 ha of land there by more than 5066 farmers in different districts were directly benefitted in improving productivity at their farm levels.
Keywords: Cereals, Varietal and seed replacement, Crop technologies, Pre-scaling up

1. INTRODUCTION

In Ethiopia, a total land area of 11,822,786.19 hectares was covered with all grain crops i.e. cereals, pulses and oilseeds (**CSA, 2010)**. However, the largest proportion (81.97%) of land was owned by only cereals. The same report indicates that a total production of 177,613,365.84 quintals (which is 87.29% of the production from all grains) was obtained from only cereals.

The image of the production area (in hectares) and the total production (in quintals) from all grain crops at Southern Nations Nationalities and Peoples Region (SNNPR) is an analogous to that of the country's level. In SNNPR, among total land size of 1,066,825.51 hectares planted by all grain crops, cereals owned 859,340.71 hectares with a total production of 14,801,477.56 quintals. However, pulses and oil crops owned only 202,224.44 and 5,260.36 hectares with the total production of 2,724,166.37 and 25,979.42 quintals, respectively.

Thus, it can be realized that cereals are grain crops which constituted the major food crops for the majority of the country's as well as the region's (SNNPR's) population and they are the leading ones both in terms of the area they are planted and volume of production obtained at both nationaland regional levels (http:// **ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/126747).** These crops are also served as a source of income at household level and are contributor for the country's foreign currency earnings.

Crops like tef, maize, wheat, barley, sorghum, finger millet and oats with regional productivity (q/ha) of 11.18, 23.45, 18.65, 17.74, 16.26, 11.23, 9.56, respectively are cereals grown in different agro-ecologies of SNNPR (CSA, 2010). From this regional productivity list, it can be realized that the productivity of all crops is too low which is less than half of the potential productivities which would have been obtained through using improved production techniques.

The survey report which was conducted at Southern Agricultural Research Institute (SARI-Ethiopia) level in 2008 (unpublished), also confirmed that the yield obtained from the local cultivars is too low. Although several improved varieties on many of the cereals are released so far (MOA. 2014), lack of such improved crops varieties and associated improved management practices at majority of farm levels particularly at the remote districts of the region are some of the major causes for low productivity in the crop production systems i.e. farmers in many remote areas of SNNPR even do not know the existence of the new crop varieties.

To resolve this specific agricultural productivity constraint, several works have been done at regional level. During the first Growth and Transformation Program (GTP I) of Ethiopia, massive aggressive movement to test suitability of the existing technologies in different cereal crops with special focuses to bread wheat, tef and food barley has been carried out in different agro-ecologies and subsequently the best technologies were pre-scaled up in some localities of the region. Even though only few districts with limited number of technologies were reached during GTP I, a considerable improvement in crop productivity was realized in the target areas. For instance, **CSA (2015)** reported yield increment in crops like tef, maize, wheat and sorghum with regional productivity (q/ha) to 13.7, 32.23, 24.37 and 21.19, respectively in SNNPR. This improvement has mainly been

achieved through replacement of seeds of well adapted crop verities through pre-scaling up programs.
Therefore, it has been learnt that exploitation of specific high yielding and competitive varieties is the best means for escalating agricultural production. In other words, it can be restated that the new crop varieties and quality seeds are the most viable means to improve crop production. Thus, productivity rate is directly proportional to the seed replacement rate thereby reinforcement of agriculture through a high and intensive seed replacement rate. (**Brennan and Byerlee, 1991**)

To improve crop's productivity up to its potential, continual identification of the best and suitable crop technologies appeared to be essential. This can be achieved, through adaptability tests and generation of the new technologies. Those identified technologies should be demonstrated and pre-scaled up to hasten replacement of seed and the seed-carried crop technologies.

In this study, series of activities on different cereal crops such as maize, tef and barley are dealt; and the report of the same kind of study on bread wheat (**Mathewos and Ashenafi, 2014**) is well referred and acknowledged so that it will help to view approaches for productivity improvement so that it helps understand the significance of seed replacement in enhancing productivity of crops with special focus to major cereals in some districts of Southern Ethiopia.

2. MATERIALS AND METHODS

Preliminary surveys have been conducted to interview farmers, development agents and experts in each district so as to analyze crop production constraints in the areas. Low productivity of farmer varieties and no or limited access to improved crop technologies in the target districts was one of the pinpointed crop production constraints. At each locality it was realized that farmers have been using their cultivars year to year and few areas used to receive new crop varieties which no longer better than the farmers' one. In such cases it is important to pay attention to the significance of the interaction between genotype and environment. Although it is not cost effective, evaluation of available crop technologies for each environment will help identify varieties suitable for specific conditions thereby it will boost productivity through seed and variety replacement.

Before designing to replace seeds of crop varieties in the study areas it was found important to evaluate available crop technologies including locally known to be grown so as to identify the best fitting ones with regard to better productivity.

Maize, tef, barley and wheat were selected cereal crops in which available crop varieties were evaluated against local cultivars in a participatory approach.

Three major activities (stages) such as experimentation, seed multiplication and pre-scaling up were used as a road and bridge to reach at yield improvement at farm levels which in turn led farmers to boosted yields through crop varietal and seed replacements.

Several crop varieties have been released at national and regional research institutions. However, genotype x environment interaction (Breese, 1969) hinders growers to adopt varieties directly to environments where no tests were conducted during the processes of research to release a particular variety. Therefore, to identify suitable crop variety to specific area, it is mandatory to conduct adaptability testing experiments for intended crop varieties and in a specific environment. Thus, experimental stage was the most important stage to make out "which will win where".

To conduct experiments for adaptability tests, potential districts and varieties which were needed to be included in the experiments were identified for maize, barley, tef and wheat. Experiments for maize were conducted in Boloso sore, Kindokoisha and Gofa districts; maize varieties under test vary for each district according to original agro-ecological based recommendations. Tef adaptability test was done in Konta special district. The same kinds of experiments were conducted in five districts, namely Konta, Gumer, Damotgale, Yem and Hadero-tunto.

Farmers were selected to host experiments on each crop. For all crops, the treatments (varieties) were arranged in RCB design; and 10m x 10m plot size was used and each trial hosted farmer for all crops were considered as replications. Farmers' varieties for all crops have been included in the respective experiments to see how extent the yield advantage was due to new crop varieties.

As it was reported for wheat by Mathewos and ashenafi (2014), for other crops (maize,tef and baley) varietal performance evaluations, mainly farmer criteria, were used as keys for marking best varieties for specific agro-ecology. Pair-wise ranking was employed to identify better productive crop varieties. Representative Farmers Training Centers (FTCs) and farms of members under different Farmers Research Groups (FRGs) were major spots to evaluate crops' varieties. All available improved management practices for each crop were considered during adaptability tests. Although there was no specific recommendations, fertilizers 100 and 50 kg/ha DAP and urea, respectively (with split application of Urea) were used for all crops. Seed rates of 25, 125, 30 and 150 kg/ha were used for maize, barley, tef and bread wheat, respectively. As it was indicated by Mathewos and Ashenafi (2014) on wheat SAS software was utilized for ANOVA and to test significance in performance of grain yield among different crops' varieties (SAS, 2001). As indicated by the same report, for

specific adaptability study and consecutive intervention, each trial in each district was used as an independent entity to select best technology for each district.

3. RESULTS AND DISCUSSION

3.1. Experimental stage

3.1.1. Maize (for Mid-altitude and lowlands)

In this study, different maize varieties were evaluated in different districts based up on original agro-ecological based recommendations.

The varieties were evaluated for different parameters; such as number of cobs per plant, number of seeds per cob, marketability and grain yield. They also were ranked based on all criterions.

In Boloso Sore district, BH-540, BH-543, BH-670, BH-660 and local check were evaluated on five farmers' fields. Pioneer was used as local check in all localities as it has been well known and adopted in the areas; and BH-670 significantly out yielded all other varieties under test. This variety was also ranked first using pair wise comparison using farmers' criterion.

Table 1. Grain yield (Quintal/hactare) recorded on five farmers (F) fields

Maize varieties	Grain yield (Quintal/hectare): 1quintal equals 100kg						
	F1	F2	F3	F4	F5	average	Rank
BH-540	29c	18c	14c	26c	16b	21c	3
BH-543	25d	14d	12c	21d	10d	16d	5
BH-660	32b	23b	25b	30b	25a	27b	2
BH-670	42a	31a	29a	41a	25a	34a	1
Local	22e	15d	23b	21d	13c	19c	4
CV	15	11	12	10	12	14	

Table 2. Overall rank given for maize varieties based on farmers' criteria

	BH-540	BH-543	BH-660	BH-670	Local
Number of cobs per plant	2	2	2	1	2
Number of seeds percob	3	4	2	1	2
Marketability	1	2	1	1	1
Sum of rank	5	8	5	3	5

In Gofa district, BH-540, BH-543 and and local check were evaluated on nine farmers' fields. It was realized that the check, Pioneer, significantly out yielded other varieties followed by BH-540. Overall rank given to varieties based upon different farmers' crieteruon showed that the check ranked first; and it was followed by BH-540 (Table 3 and 4).

Table 3. Grain yield (Quintal/hectare) recorded on five farmers (F) fields

Maize varieties	Grain yield (Quintal/hectare)										
	F1	F2	F3	F4	F5	F6	F7	F8	F9	average	Rank
BH-540	50b	42b	56a	63a	32b	64a	60a	58a	55b	53a	2
BH-543	48c	28c	50b	38c	24c	33c	48c	44b	18c	37b	3
Local	60a	52a	55a	44b	54a	52b	54b	56a	70a	55a	1
CV	15	12	10	13	13	14	11	13	18	13	

Table 4. Overall rank given for maize varieties based on farmers' criteria

	BH-540	BH-543	Local
Number of cobs per plant	2	3	1
Number of seeds per cob	2	3	1
Marketability	1	2	1
Sum of rank	5	8	3
Overall rank	2nd	3rd	1st

In Kindo Koisha, maize composite varieties such as Melkasa 2, Melkasa 3, Melkasa 4, Melkasa 5, Melkasa 6, Melkasa 7 and local were evaluated on eight farmers' fields. Although variation in productivity was observed among the varieties under test, the grain yields recorded from all test maize varieties were generally low due to a high moisture stress during experimentation. However, significant differences in grain yield among the varieties were observed and the local check (pioneer) significantly out yielded all composites under test; the check also ranked first in pair-wise comparison using different parameters (Table 5).

Table 5. Grain yield (Quintal/hectare) recorded on five farmers (F) fields

Grain yield (Quintal/hectare)										
Maize varieties	F1	F2	F3	F4	F5	F6	F7	F8	average	Rank
Melkasa 2	15c	7c	12b	5b	9d	8b	11b	9d	10bc	4
Melkasa 3	24a	11a	10b	3b	24a	8b	13b	12b	13b	2
Melkasa 4	10d	8c	8c	3b	20b	7b	9c	10c	9c	5
Melkasa 5	20b	7c	6c	3b	20b	6c	15a	11c	11b	3
Melkasa 6	15c	6c	16a	3b	10d	4c	6d	13b	9c	5
Melkasa 7	15c	6c	11b	3b	14c	5c	14a	12b	10bc	4
Local	26a	13a	18a	12a	24a	12a	16a	14a	17a	1
CV	11	12	14	10	11	10	14	13	15	

3.1.2. Tef

Tef varieities such as Koye, Kuncho, Ginbicho and local were evaluated in two FRGs called Cheka bocha and Medayeja in Konta Special District. Four voluntary farmers were selected to host the experiments and mange the trials according to recommendations.

The yield performance and the farmers view on each variety are indicated in the Tables 6 and 7. FRGs of Konta special woreda, it appeared that a tef variety called kuncho took the first lead in its productivity and preferred by almost all farmers due to its better productivity and other important parameters. Therefore, the production of Kuncho should be widened to enhance tef productivity at farm level and should be made adopted widely through designing scaling up program in the area.

Table 6. Grain yield (Quintal/hectare) recorded on four farmers (F) fields

	Grain yield (Quintal/hectare)						
Tef varieties	F1	F2	F3	F4	average	Rank	
Koye	17a	18b	12b	13b	15b	2	
Kuncho	19a	22a	19a	16a	19a	1	
Ginbicho	5c	7c	10c	11c	11c	3	
local	10b	9c	9c	11c	10c	4	
CV	10	14	10	10	11c		

Table 7. Overall rank given for wheat varieties based on farmers' criteria

	Koye	Kuncho	Ginbicho	Local
Seed emergence	2	1	2	2
Resistance to diseases and pests	2	1	2	3
Resistance to lodging	1	2	3	3
Tillering capacity	2	1	3	2
Marketability	1	1	1	2
Sum of rank	8	6	11	12
Overall rank	2^{nd}	1^{st}	3^{rd}	4^{th}

3.1.3. Barley

To improve barley productivity, use of improved varieties has been one of the strategies. Thus, to identify suitable variety for barley producing areas, testing of existing barley varieties was believed to be an essential. Therefore, on farm trial using an improved barley variety, HB1307, including the most popular or local variety was conducted on fields of five farmers in each district such as Konta, Gumer, Yem, Hadero Tunto and Damotgale. The experiments were conducted in FRGs and/or on-farms in the localities. Except in Damotgale, the yield performance and the farmers view on each variety were observed to be in a similar fashion where HB-1307 out yielded the local cultivar; and it ranked first for different parameters. However, the local cultivar significantly out yielded the improved one in Damotgale where the local cultivar was also found to be the winner of the improved one in all other parameters.

Table 8. Grain yield (Quintal/hectare) recorded on five farmers (F) fields

Barley varieties	Average grain yield (Quintal/hectare)				
	Konta	Hadero Tunto	Yem	Gumer	Damotgale
HB-1307	23	32	29	23	18
local	17	24	24	13	28

Table 9. Overall rank given for barley varieties based on farmers' criteria in Konta, Hadero Tunto, Yem and Gumer

	HB-1307	Local
Seed emergence	1	2
Resistance to diseases and pests	1	2
Resistance to lodging	1	2
Tillering capacity	1	2
Marketability	1	2
Sum of rank	5	10
Overall rank	1st	2nd

3.1.4. Bread wheat

To improve bread wheat productivity at farm levels, similar approaches mentioned for other cereals indicated earlier were followed; and this was reported by Mathewos and Ashenafi (2014). The following tables (Table 10 and 11) adopted from the same report described outputs from adaptability tests at different districts.

Table 11. Average grain yield (quintal/hectares) of bread wheat varieties evaluated at different FRGs in five districts

	Grain yield (quintal/hectare): 1quintal equals 100kg					
	Damot Gale	Konta		Kedida-Gamele	East Badewacho	Soro
Bread wheat varieties	Sha-Sha-Gale FRG	Cheka-Bocha FRG	Medayeja FRG	Gesh-Gola FRG	Waira- Lalo FRG	Sigeda FRG
Digalu	41 a	35 a	39 a	40 a	34 a	36 a
Tay	37 a	33 a	33 b	34 b	35 a	35 a
Merrero	23 c	19 c	19 b	25 c	31 b	19 c
Galema	33 b	29 b	33 b	33 b	32 b	28 b
Simba	30 b	29 b	29 b	29 c	28b	26 b
Kubsa	31 b	28 b	31 b	30 b	30 b	27 b
local	17 d	21 c	13 d	20 d	25 c	18 c
CV	12.07	11.34	5.38	5.92	5.20	16.03

(Adopted from Mathewos and Ashenafi, 2014)

Table 12. Overall rank given based on farmers' criteria in Damot Gale, Konta and Kedida Gamela Woreda

	Digalu	Tay	Merrero	Galema	Simba	Kubsa	Local
Seed emergence	1	1	2	1	2	1	2
Resistance to diseases and pests	1	2	4	4	3	4	3
Resistance to lodging	1	2	3	1	1	1	3
Tillering capacity	1	2	2	2	3	2	2
Marketability	1	1	2	1	2	3	3
Sum of rank	5	8	13	9	11	11	14
Overall rank	1st	2nd	5th	3rd	4th	4th	7th

(Adopted from Mathewos and Ashenafi, 2014)

3.2. Breeder and pre-basic seed multiplication

The process of identification of suitable technologies for each agro-ecology and each crop was considered as the first phase for this study. To reach as many as possible farms with the best fitting crop production technologies, the quality seed (**Boyd and et al, 1975**), which is known to carry the intended crop technologies need to be multiplied at large scale. Therefore, the selected varieties of targeted cereals were multiplied at stations of research center, farms of schools and different churches. All procedures for quality seed production were strictly followed (Ahmed, 1985); and breeders and quality controlling agencies were major actors during seed production. A total of 2561 quintals (256100kg) of seeds from different crops' varieties were produced and made ready for further pre-scaling up program.

Table 13. Breeder and pre-basic seeds produced at different farms from 2001 to 2004 EC (Ethiopian Calendar)

Crops	Varieties	Land size (ha)	Grain yield (Quintal)	Seed class	Year (E.C.)
Wheat	Tay	2	62	Pre-basic	2001
	Digalu	1	34	Pre-basic	2001
	Simba	0.25	8	Breeder	2001
	Merero	Plot	2	Breeder	2001
	Sulla	Plot	3	Breeder	2001
	HAR-604	0.25	8	Breeder	2001
F.Barley	HB-1307	1	19	Basic	2001
Tef	Kuncho	6	96	Basic	2001
	DZ-Cr-37	6	85	Basic	2001
Wheat	HAR-604	16	293	Pre-basic	2002
	Kubsa	14	251	Basic	2002
	Digalu	1	12	Pre-basic	2002
	Tay	0.25	7	Pre-basic	2002
Tef	Kuncho	45	420	Basic	2002
	Quncho	22	220	Pre-basic	2003
	DZ-Cr-37	5	50	Pre-basic	2003
Wheat	Digalu	9	225	Basic	2003
	Tay	2	50	Pre-basic	2003
	Kekeba	3	75	Pre-basic	2003
	Dendaa'	0.75	18	Breeder seed	2003
Food barley	HB-1307	4	80	Pre-basic	2003
Tef	Quncho	26	233	Pre-basic	2004
	DZ-Cr-37	11	111	Pre-basic	2004
Wheat	Digalu	1	15	Pre-basic	2004
	Danphe	4	118	Pre-basic	2004
	Kekeba	1	26	Pre-basic	2004
Food barley	HB-1307	2	40	Pre-basic	2004

4. Pre-scaling up of cereal technologies

The goal of this work was to take suitable crop technologies to more farms there by to enhance production and productivity in those targeted areas. As indicated in earlier sections, suitable technologies were identified through participatory on farm evaluation of available crop technologies; the selected ones were multiplied in a large scale to go for widened dissemination of better ones. Pre-scaling up activities were done in four rounds as of 2003/2004 EC. Below is a table showing pre-scaling up of the most preferred cereal technologies (improved varieties with associated management practices) during the first round of GTP -I to different districts in SNNPR, Ethiopia. During the first round, 261 Quintals of seed was disseminated to cover 373 ha of land; and 1492 farmers were benefited from the program. In four rounds a total of 883quintals (88300kg) seed was disseminated to cover 1272 ha of land there by more than 5066 farmers in different districts were directly benefitted from the work.

Table 14. Pre-scaling up activities done in different districts of SNNPR

Zone	Destricts/FRG	Ceeals included in Pre-scale up	Varieties	Amount of seed (quintal)	Area coverage	Farmers participated
Wolyta	Damotgale, Boloso Sore, Mokanisa FRG, Boloso Bombe, Hmbo & Offa	Wheat	Galema, Digalu, Tay, Simba,	110	62.86	250
		Tef,	Kuncho	35	50	200
			DZ-Cr-37	50	33.33	133
Konta	Konta	Wheat	Galema and Digalu	44	25.14	100
		Tef	DZ-Cr-37	10	33.33	133
		Barley	HB-1307	25	20	80
Dawuro	Mareka	Wheat	Galema and Digalu	26	14.86	60
		Tef	Kuncho	14	46.67	190
		Barley	HB-1307	16	12.8	50
Hadya	Wairalalo FRG	Tef	Kuncho &Dz-Cr-37	16	53.33	213
Kembata	Geshgola FRG	Tef	Kuncho & Dz-Cr-37	16	53.33	213
	Ojoje watershed	Tef	Kuncho	9	30	120
			Total	261	373	1492

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