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Progress of Common Bean Breeding and Research achievements in Southern Ethiopia

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Abstract: *Common bean (Phaseolus vulgaris L.) is one of the major legume crops in Ethiopia as well as in the southern region. It uses for home consumption, income generation for small-scale farmers, and to earn foreign currency for the country. The crop has a major role in the different cropping systems such as intercropping, double cropping, relay cropping and it serves as a rotational crop in the system. In contrast, there is a wide gap between the actual and the potential yield. The main constraints for low productivity are lack of improved varieties for different abiotic (e. g moisture stress & low soil fertility.) and biotic problems (diseases & insect pests).The southern region bean research program aimed to boost production and productivity via a selection of superior genotypes from aquestion of germplasms from the national program and Centro international agricultural tropics (CIAT), by hybridization, population development, and adapting released varieties from other places. Currently, the research center acquired the molecular laboratory to modernize conventional breeding and many activities were initiated to improve the problems of the released varieties genetically. The great achievement was recorded by releasing more than ten varieties in different market classes such as red speckled, small red, white beans, and other pinto beans market classes. Moreover, a great effort was carried out for the dissemination of those varieties by using wider impact, participatory variety selection, pre extension demonstration, pre-scaling –up (PED), and significant impact were created to replace the old varieties and to increase the productivity and the production of the crop as well. Generally, the research contributes to increase food security, income, and the livelihood of small-scale farmers*

Keywords: *Common bean, Phaseolus vulgaris, varietal development, convectional breeding*

1. INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) the most popular low land pulse producing in Ethiopia. It was introduced around the 16th century in Ethiopia. A continuous increase in area and volume of production has been noticed due to the growing demand for the local and export market. The crop has a different seed size, seed color, and growth habit as well. As bush beans (type I and type II) are widely produced as a sole or intercrop for a local and international market. The other types are the climbing beans (type III) mainly produced around homestead gardens and along the fences and sometimes intercropped with maize/pigeon peas. The crop can be grown with a minimum amount of agricultural inputs like fertilizers and it is among the suitable grain legume crops for crop rotation in the maize/sorghum-based cropping systems. Since it is the main pulse crop grown in the lowland areas of the country, the crop serves as a good rotational crop for other cereals and contributes to soil fertility. Common beans also fit into various cropping systems (mono-cropping, sequential/ relay-cropping, double-cropping, mixed-cropping, and inter-cropping).

Common bean is a short-season annual crop, which is under production in both main and short (*belg*) growing seasons. It is produced by over 4 million smallholder farmers in Ethiopia. In the 2015/16 (2008 E.C.) cropping season, the area covered by common bean was 357,299 and 306,335 hectares of land in main and *belg* seasons, respectively (CSA, 2016). Moreover, in the same year, private farmers (large scale) covered 10,212 hectares of land with a common bean. Thus, a totally of 673,846 ha of land was covered by beans with a total annual production of 845 thousand metric tons, mainly from three regions (Oromiya, SNNP, and Amhara) of the country where the Oromiya region alone covers 50% of the total production followed by Southern Nation Nationality and Peoples (27%) and Amahara Regional States (20.1%) (CSA, 2015).

Nutritional quality is related to the composition of the bean. Common bean is a source of proteins, vitamins (thiamine, riboflavin, niacin, vitamin B6 and folic acid), and dietary fiber (14-19%) (Particularly soluble fiber), minerals (Ca, Fe, Cu, Zn, P, K, and Mg) and unsaturated fatty acids. Recent studies show that dietary fiber can protect against cardiovascular diseases, diabetes, obesity, colon cancer, and other degenerative diseases (Arvanitoyannis et al. 2007)

Beans can be consumed as a grain and by mixing with different carbohydrate sources such as millet, sorghum, maize, enset, and cassava. There are also traditional recipes used by many peoples such as like *kurkufa (*cabbage and boiled bean mashed mixture) and *fossese (*maize flour and boiled bean mashed mixture) (Teamir *et al*., 2003). Mostly *Nifro*, *Sambosa*, *shiro* and *kik* are the main recipes in different parts of the countries. The straw is also used for animal fodder as feed. Further, it has higher crude protein (5.5%), natural digestible fiber (56.1%) digestibility, and lower fiber contents than cereal straws (Tolera, 2016).

In addition with common bean used as the income source of farmers, it is the main hunger break at belg season just at the planting of meher plantings when the food scarcity reached a peak. Because of the short growing period of beans, it allows the production of the crop two times a year. Common bean has been one of the leading exportable pulse crops in Ethiopia for the last four decades (Ferris and Kaganzi, 2008), Ethiopia being the leading exporter of common bean in Africa. The major bean market class for export is small white pea bean, but currently, other bean market classes such as small red, sugar bean, pinto, and cream beans are also exported to Europe, the Middle East, and Asia (Ministry of trade unpublished report).

According to Ethiopian Revenue and Costumes Authority (2018), common bean export earnings increased by three folds from 19 million USD in 2005 to 240 million USD in 2018, the quantity exported being 43 thousand MT in 2005 and 250 thousand MT in 2018.

The southern region bean breeding program was started at Hawassa Agricultural Research Center four decades ago, the objective being an improvement of livelihood of smallholder farmers through generation and promotion of high yielder, disease tolerant/resistant bean and adaptable varieties suitable for the export market and local consumption. This paper review progresses and achievements of past bean breeding efforts, a collaborative program with centers like CIAT, and other regional research programs like Pan Africa Bean Research Program (PABRA) and East and Central Africa Bear Research Network (ECABREN).

2. Improvement of Common Bean in Southern Ethiopia

Sources of genetic variation

The breeding program aims to avail the variability as a source of working germplasms from different sources for our trait of interest. The regional program executing different experiments by introducing the germplasms from the Center of international agricultural tropics (CIAT) by targeting different constraints, by hybridization of the released varieties with introduced donor parents for different traits (such as Common bacterial blight(CBB), angular leaf spot(ALS), Anthracnose, etc…).In addition, many varieties were released with the collaboration of the national program.

The breeding scheme we are following for the last 30 years is almost the adoption of the national program, for the introduced genotypes after observation nursery they have been grouped into a different market class based on seed size, seed color, and the unique trait they have. Then the selected around 15 -25 genotypes have been advanced into a preliminary regional Variety trial (PRVT) mostly in two locations with a simple lattice design for one year only Randomized Complete Block design (RCBD) for two or three years all the necessary yield and major disease evaluation have been done.

From the multi-environment trials, varieties with outstanding performance have been identified based on yield and quality traits as compared to the standard checks. The candidate varieties are proposed and verified for release, after being assessed by the National Variety Release Committee (NVRC). The NVRC evaluates the varieties not only for their biological performance but also for legal requirements including uniformity, distinctness, and stability. In several cases, however, when such established cultivars are not available, the bean breeding program also makes an accelerated agronomic and adaptive evaluation from which better performing varieties are presented to the NVRC for registration of candidate cultivars.

Variety development

From all sources acquired germplasms evaluated and passed through at different stages of starting from Observation nursery, preliminary Variety trial, and multi-location yield trials have been conducted to select the superior genotypes which are distinct, uniform, and stable too and reach for the last stage of verification trial to register as a Variety. From the introduced germplasms Seven varieties have been released by the selection of the best genotypes for the different traits with a different market class. Four varieties also released by hybridization which were targeted different traits. From those achievements, the improvement of old variety Red wolayta by Hawassa Dume was a great success with high yield, multiple disease resistance for common bacterial blight(CBB) and Angular leaf spot(ALS) with erect growth habit with small red bean market class which have a high demand in the region. The breeding scheme was as follows:

Hawassa Dume

Five single crosses were attempted in meher 2001 season. The materials were advanced to F_5 by the modified - pedigree method. 25 F_4 families' outperformed checks in grain yielding potential and disease resistance in 2003 main season were advanced to F_5. In the 2004 belg season, the $F_{2:5}$ seeds were divided into equal halves and planted at Awassa and Amaro to attempt a single plant selection at each location. At F_5 within and between family segregation for important traits was observed. 400 single plants were selected from best-performing families and planted in plant-to-row at Amaro in 2004 main season. All families expressed resistance to moderate resistance reaction to CBB, ALS, rust, and web blight under natural infestation both in F_4 and F_5 generations. The ECA regional nursery constituting the best performing 100 lines constructed for evaluation in Kenya, DRC, and Tanzania in 2005. In 2005 belg the 100 lines including checks were evaluated at Amaro. The best performing 34 lines evaluated in advanced multi-location yield trial at four locations in 2005 mehre and six locations in 2006 meher season.

Waju (ETAW-01-L-1-7A)

Waju is the breeding line obtained from SARI bean breeding program. The line was developed from single crosses of Omar x Ayenew. Omar is an early maturing farmer's variety obtained from Melkassa agricultural research center (MARC). It has a type II growth habit with white rounded seeds and is susceptible to all bean diseases that are common in the country. Ayenew (GLPX 92) is an early maturing, high yielding, large-seeded, and pinto cream bean variety with type III growth habit, originally introduced from CIAT and released by Haromaya University. Ayenew is moderately resistant to anthracnose and common bacterial blight [8]. The objective of this crossing was to improve Omar for anthracnose and common bacterial blight tolerance. Waju was developed with a single pod bulk method till F5 generations at Hawassa research center and after F5 single plant selection was employed. At F5:7 generation, nurseries were evaluated at two locations, Hawassa and Kokate This genotype was selected at Hawassa. Then Waju was evaluated in a multi-location evaluation trial at eleven environments.

Tatu (ETAW-01-L-7-6K)

Tatu is the breeding line obtained from SARI bean breeding program. The line was developed by backcrossing of Brown speckled with Melke ((Brown speckled x (Brown speckled x Melke)). Brown speckled is large seeded with type II growth habit and high yielder. It is susceptible to disease and bean stem maggot. Melke is the red speckled, large-seeded population with type IB determinate growth habit, developed by CIAT from the crossing of CAL113 x AND829. Melke was released by MARC, in Ethiopia for its higher yield and beans stem maggot tolerance [9]. The crossing program was initiated to improve the commercial variety Brown speckled for BSM tolerance and improving other agronomic traits. Tatu was developed with a single pod bulk method till F5 generations at Hawassa research center and after F5 single plant selection was employed. At F5:7 generation, nurseries were evaluated at two locations, Hawassa and Kokate. This genotype was selected Kokate. Then Tatu was evaluated in a multi-location evaluation trial at nine environments. Small red beans were also released for the commercial production/export market (Table 2). The release and promotion of commercial bean types of different seed colors and sizes are considered a shining success of the national bean improvement program. The recent release of the large white beans has been the first of its kind in the bean variety development history of Ethiopia. The release of food types for local

consumption was also a great achievement not only because of their magnificent role in food and nutrition security but also because of their earliness and adaptation in areas with terminal drought/short production season (*belg*) and fitness in a double-cropping system. For example, two of these varieties, namely Adda and Dursitu, need only two months for maturity and they have regional market demands mainly in Kenya and Uganda.

Table1. *Hawassa Research center Released varieties From 1999-2017*

Name of the Variety	Year of release	Seed color	Yield qt (Farmers Field)	Yield qt (Research Field)	Seed source
Tabour	1998/99	Creamy	15	25	Hawassa
Omo-95	2003	Small red	17	25	Hawassa
Ibado	2003	Red speckled	16	24	Hawassa
Wajo	2007	White	18	24	Hawassa
Tatu	2007	Speckled	14	25	Hawassa
Remeda	2007	Red kidney	15	23	Hawassa
SCR-26	2017	Small red	17	25	Hawassa
DAB-277	2017	Red speckled	15	23	Hawassa
SARI-1	2006	Small red	18	26	Hawassa
Hawassa Dume	2001	Small red	24	30	Hawassa
Batagonia	1999	Creamy	20	25	Hawassa

Technology promotion

In addition to Variety development the regional bean research program with a collaboration with other partners has been engaged in a multiplication of early generation seed to catalyze common bean seed system and promotion of bean varieties to the end-users in different approaches through the wider impact project, small packs pre- extension demonstration (PED), pre-scaling up and large scale multiplication and distribution of the improved varieties with their full packages. The role of key partners NGOs, Cooperatives, and unions during this activity is far amount important because to decentralize the system into different areas and reach the end-users. Initially the fund of the different donors East and central Africa bean research network (ECABRN), Pan-Africa bean research alliance (PABRA), wider impact project, Tropical legume I, II, III Have been played significant role designing the system, creating Innovate approaches, through training, Funding and sharing an experience from different countries.

Enhancing seed production:

Early generation seed demand is increasing for the last ten years because of the establishment of many seed-producing cooperatives and unions, different NGO demands have been increased because of climate change and relief seed scarcity, therefore these leads to an increase in the research centers pre-

basic and basic seed multiplication amount. The formal and informal seed systems are the main ways of the new varieties dissemination**,** However, the informal system shares more than 90% of the system. Although the formal seed sector started about six decades ago, the commercial seed sector supplies less than 10% of the country's seed demand per year (Zewdie *et al*., 2008; CSA, 2010). For instance, the share of the formal seed sector was 2.8% in the 2010 main growing season (CSA, 2010). The volume of production in tones increasing from 2012 parallel with the number of beans exported in USD (Figure 1.). Figure1. Showed that there has been a slight decline in the year 2016 both in production and export as well.

The regional production of common bean in comparison of other legume crops vary from region to region, however, the first crop is faba bean almost in all region expect SNNPR within 2008

2018 years.

(Figure 2.).This implies that bean is by far important than other legumes in the southern region.

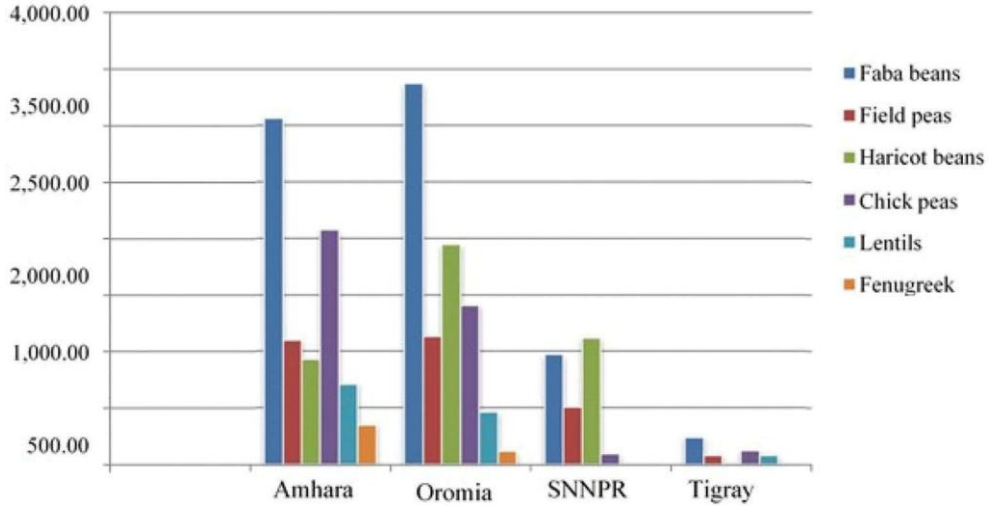

Figure1. *The average volume of production (in 000 quintals) of the top four-grain legume-producing regions inEthiopia (2019) during the last 11 years (2008–2018).* ***(Source: Getachew)***

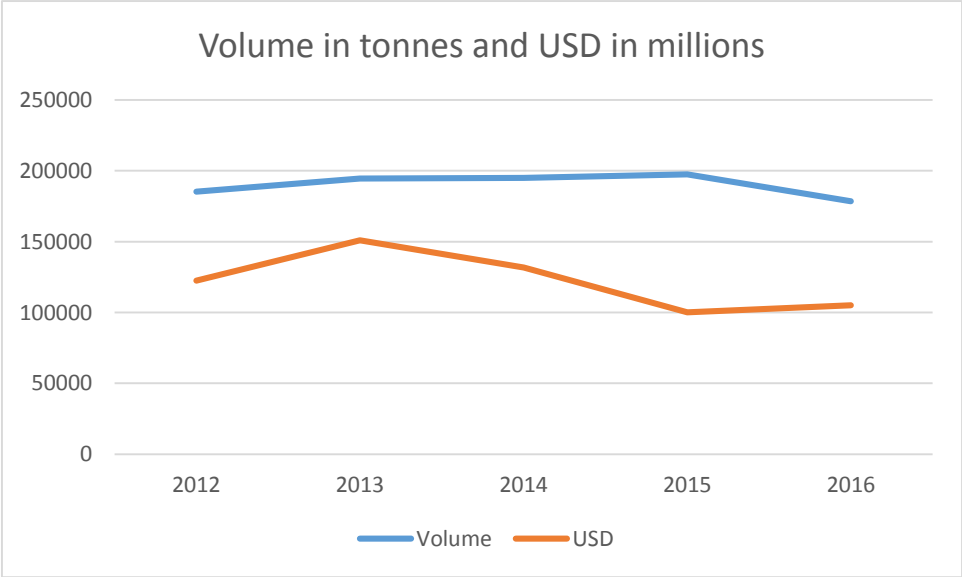

Figure2. *Common bean production and Export in USD for the period 2012 to 2016 (Source: modified from CSA, 2012 to 2016)*

Challenges and opportunities

Common bean research is one and the most advanced research program in the southern region and contributes many technologies' to change the livelihood of smallholder farmers, however, there are also many challenges to be tackled to increase productivity and production of the crop.

From those constraints lack of resistance varieties of bean bruchid and bean stem maggot, a lack of varieties that adapted mid-altitude, and lack of a varieties for irrigation and mechanization.

In addition shortage of other agronomic and management technologies helps to improve the packages. The market fluctuation and the presence of many actors in the market chain for smuggling of the product illegally inhabit the farmers to earn reasonable income for their produce.

3. SUMMARY AND CONCLUSIONS

The Southern Agricultural Research Institute (SARI) with Hawassa research center have been developed many varieties in different market classes. Moreover, much information has been generated regarding basic genetic information generation and many working populations for different constraints developed. Unlike technology generation, the promotion of the technologies has been also executed with a support of a government, CIAT, and other NGOs to push into the end-users and significant achievements recorded.

There is also good progress in molecular breeding to accelerate, support, and modernize the Variety development for specific constraints such as for common bacterial blight, angular leaf spot, and others. Many elite genotypes have been developed, evaluated, and selected for verification.

The plan will be in addition with technology generation improving the released variety defect with support of molecular techniques and availing enough amount of early generation seed for the promotion of newly released varieties and others.

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