Net Journal of Agricultural Science
Vol. 10(3), pp. 59-65, September 2022
DOI: 10.30918/NJAS.103.22.018
ISSN: 2315-9766
Review

Progress of common bean breeding and research achievements in Southern Ethiopia

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Accepted 24 August, 2022

ABSTRACT

Common bean (*Phaseolus vulgaris* L.) is one of the major legume crops in southern Ethiopia. It is used for home consumption, income generation for emerging small-scale farmers, and to earn foreign currency for the country. The crop plays a major role in the different cropping systems such as intercropping, double cropping and 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 the lack of improved varieties for different abiotic (e.g moisture stress and low soil fertility) and biotic problems (diseases and 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 a 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 created to replace the old varieties and to increase the productivity and the production of the crop as well. This Review article has used different completed activities achievements and the ongoing activities milestones at different stages of the improvement process. The baseline information is the major breeding scheme of the improvement work in relation to the result archived in the two and three decays. Generally, the research contributes to increasing food security, income, and the livelihood of small-scale farmers.

Keywords: Common bean, *Phaseolus vulgaris*, varietal development, conventional breeding.

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INTRODUCTION

Common bean (*Phaseolus vulgaris* L.), is the most popular low land pulse producing in Ethiopia. It was introduced around the 16th century in Ethiopia (Shiferaw et al., 2017). 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 markets. 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 Berhane et al. (2017). 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) (Assefa et al., 2017).

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 the 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 to 19%) (Particularly soluble fiber), minerals (Ca, Fe, Cu, Zn, P, K, and Mg) and unsaturated fatty acids (Admassu and Rakshit, 2004). Recent studies show that dietary fiber can protect against cardiovascular diseases, diabetes, obesity, colon cancer, and other degenerative diseases.

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 people 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.

In addition to the common bean used as an income source for 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 for 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 the 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 2016 unpublished report).

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 (Ethiopian Revenue and Costumes Authority (ERCA), 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 the generation and promotion of high yielder, disease tolerant/resistant beans 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) (Amsalu, 2016).

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 executes 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 (EIAR. 2000).

The breeding scheme of Hawassa Agricultural Center 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 15 to 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 were 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 were evaluated and passed through at different stages 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 the 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 has a high demand in the region. The breeding scheme was as follows:

Hawassa dume

Five single crosses were attempted in the Meher 2001 season. The materials were advanced to F_5 by the modified - pedigree method. From the crosses evaluated, Twenty-five 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. At Amaro in the 2004 main season, 400 single plants were selected from best-performing families and planted plant-to-row. 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 constitutes 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 meher and six locations in 2006 meher season.

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

Waju is the breeding line obtained from the SARI bean breeding program. The line was developed from single crosses of Omar × 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 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. Waju was evaluated in a multi-location evaluation trial in eleven environments.

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

Tatu is the breeding line obtained from the SARI bean breeding program. The line was developed by backcrossing of Brown speckled with Melke (Brown speckled × (Brown speckled × 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 × AND829. Melke was released by MARC, in Ethiopia for its higher yield and bean stem maggot tolerance. The crossing program was initiated to improve the commercial variety Brown speckled for BSM tolerance and improve 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 these genotype was selected Kokate. Tatu was evaluated in a multi-location evaluation trial in nine environments. Small red beans were also released for the commercial production/export market (Table 1). 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 (Table 2).

Technology promotion

In addition to variety development, the regional bean research program in collaboration with other partners has been engaged in a multiplication of early generation seeds to catalyze common bean seed system and

Table 1. 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

Table 2. Comparison of Waju mean seed yield (kg/ha) with Awash-Melka and other genotypes evaluated in different environments.

Genotype	Year 1 (2006)				Year 2 (2007)					Year 3 (2008)					Overall mean
	Areka	Hawassa	Inseno	Mean	Amaro	Areka	Hawassa	Inseno	Mean	Amaro	Areka	Hawassa	Inseno	Mean	
ETAW-01-L-1-25A	1352	3957	1464	2257.6	741.4	1752	3184	3342	2254.8	2458	1353	3077	2173	2265.2	2259.4
ETAW-01-L-1-13A	1505	3947	1560	2337.3	820.4	1795	2976	3368	2239.8	2669	1324.2	3074	2169	2309.0	2291.6
ETAW-01-L-8-18A	1269	3172	1182	1874.3	786.7	1756	2828	2588	1989.6	2609	1079.6	3029	3316	2508.4	2146.8
ETAW-01-L-1-11A	1646	2503	1571	1906.6	749.4	2176	2037	2369	1832.8	2085	958.9	2518	2688	2062.4	1936.4
ETAW-01-L-8-2A	1584	3541	1781	2302	718.9	2154	2900	3253	2256.4	1866	1401.8	2765	1739	1942.9	2154.8
Waju (ETAW-01-L-1-7A)	**2197**	**3715**	**2377**	**2763**	**1054.8**	**2635**	**2697**	**3638**	**2506.2**	**2143**	**1651.2**	**2843**	**1498**	**2033.8**	**2404.4**
ETAW-01-L-1-19A	1362	3636	1363	2120.3	540.7	1482	2316	3118	1864.1	2552	930.8	2677	1600	1939.9	1961.5
ETAW-01-L-1-21A	1702	3202	1529	2144.3	658.5	1612	1529	2872	1667.8	2882	709.9	2486	1687	1941.25	1897.2
ETAW-01-L-1-2A	1504	3202	1311	2005.6	528.8	1362	1479	2780	1537.4	2913	565.9	2439	1647	1891.5	1793.7
ETAW-01-L-1-18A	1179	3322	1290	1930.3	457.6	1664	2665	2876	1915.6	1930	1033.9	2625	1873	1865.4	1901.4
ETAW-01-L-1-12K	1628	3022	1630	2093.3	596.4	1916	1934	2829	1818.8	2135	924.1	2413	1626	1774.5	1877.5
ETAW-01-L-8-5K	1332	2945	1555	1944	441.7	2076	2613	2781	1977.9	1273	1151.7	2397	1622	1610.9	1835.2
ETAW-01-L-8-3A	1667	2676	1781	2041.3	459.2	2139	1760	2725	1770.8	1468	921.5	2092	1117	1399.6	1709.6
ETAW-01-L-1-10A	1593	2148	1529	1756.6	487.3	2052	1431	2179	1537.3	1721	668.5	2069	1953	1602.8	1620.9
ETAW-01-L-1-9A	1285	2495	1184	1654.6	392.8	1614	1656	2241	1475.9	2066	571.5	2243	2095	1743.8	1622.1
ETAW-01-L-8-5A	1791	2495	1846	2044	509.2	2213	1502	2620	1711.0	1557	856.2	2028	1193	1408.5	1691.8
ETAW-01-L-1-8A	1621	2682	1551	1951.3	578	1912	1665	2543	1674.5	2143	776.8	2310	1870	1774.9	1786.5
Awash-Melka	**1156**	**3110**	**1202**	**1822.6**	**367.7**	**1536**	**2277**	**2701**	**1720.4**	**1977**	**824.6**	**2452**	**1749**	**1750.6**	**1759.3**
Average	1520.72	3098.33	1539.22		604.97	1880.33	2191.61	2823.5		2135.94	983.5	2529.83	1867.5		

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 important because it decentralizes the system into different areas and reaches 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 and III have played a significant role in designing the system, creating Innovate approaches, through training, funding and sharing an experience from different countries.

Enhancing seed production

Early generation seed demand has been increasing for the last ten years because of the establishment of many seed-producing cooperatives and unions. Different NGO demands have increased because of climate change and relief seed scarcity, therefore these lead 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. 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 tonnes increased from 2012 parallel to the number of beans exported in USD (Figure 1). 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 to other legume crops vary from region to region, however, the first crop is faba bean in almost all region except SNNPR from 2008 to 2018 years.

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

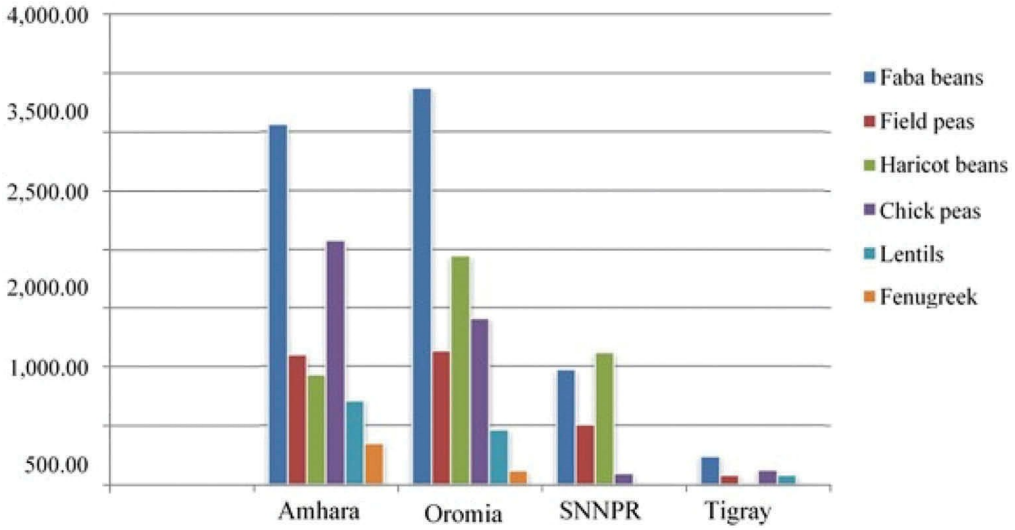

Figure 1. The average volume of production (in 000 quintals) of the top four-grain legume-producing regions in Ethiopia (2019) during the last 11 years (2008–2018) (Source: Getachew).

CHALLENGES AND OPPORTUNITIES

Common bean research is one and the most advanced research programs 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 the product illegally inhabit the farmers to earn reasonable income for their produce.

SUMMARY AND CONCLUSIONS

The Southern Agricultural Research Institute (SARI) and the Hawassa Research Center have developed many

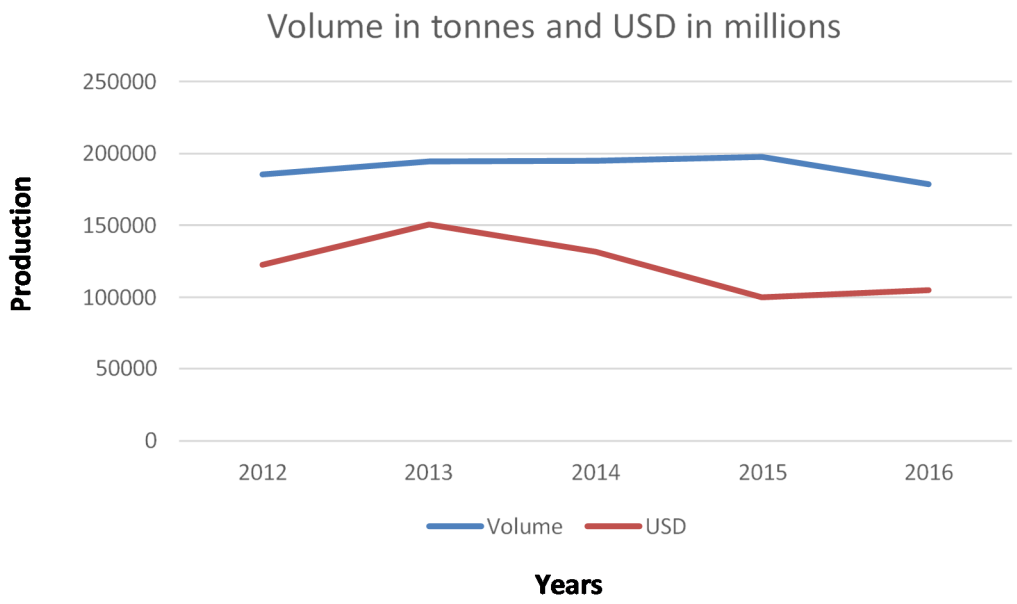

Figure 2. Common bean production and Export in USD for the period 2012 to 2016 (Source: modified from CSA, 2012 to 2016).

varieties in different market classes. Moreover, much information has been generated regarding basic genetic information generation and many working populations with 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 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 to technology generation improving the released variety defect with support of molecular techniques and availing enough amounts of early generation seed for the promotion of newly released varieties and others.

ACKNOWLEDGMENTS

We are grateful for the technical and financial support of the Southern agricultural research institute (SARI), Tropical legume III (TL III) through the International Centre of Tropical Agricultural (CIAT) Cali, Colombia, and the Pan Africa Bean Research Alliance (PABRA), Uganda.

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Citation: Alemayehu F, 2022. Progress of common bean breeding and research achievements in Southern Ethiopia. Net J Agric Sci, 10(3): 59-65.