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## Review Article

# Breeding Achievements of Faba Bean (*Vicia faba* L.) and its Impact in the Livelihood of Ethiopian Farmers

Mesfin Tadele

Ethiopian Institute of Agricultural Research, Holetta Agricultural Research Center, P. O. Box 2003, Addis Ababa, Ethiopia

***Corresponding author:** mesfintadele64@gmail.com

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**ABSTRACT**

Faba bean is the leading pulse category of Ethiopia in area coverage and production. Due to its high protein content the crop has a potential to substitute meat; contribute not only to the incomes of millions of smallholder farmers and also for export earnings of the country and serve as "break" crop to pests and restore soil fertility when grown in rotation with cereals and other crops. A number of biotic and abiotic factors constrained productivity of smallholder farms in Ethiopia. In response to the different constraints since 1950's the national faba bean research program contributed a lot of solutions. This paper is reviewed with the objective to quantify breeding progresses made in faba bean to improve production and productivity of the crop. Research efforts during the past five decades have been resulted release of 34 improved varieties at national (22) and regional (12) levels along with proper crop management and protection practices. The productivity of faba bean is in an increasing trend due to the use of improved technologies partially. In Ethiopia the highest breeding achievement on faba bean was recorded in seed size increment followed by chocolate spot disease resistance and grain yield. It is hardly possible to say that the technologies developed were promoted and yet have been readily accepted, fully utilized at farmers level. However, the impact of improved faba bean varieties on the livelihood of the society is encouraging. Therefore, it is important to assess the progresses realized through research for development efforts enables to improve the performance of the crop in all aspects for future research endeavors and also it indicates the gap to be bridged.

**Key words:** Grain yield, Improved varieties, Productivity, Research efforts and Seed size

## INTRODUCTION

Faba bean is mainly cultivated in the mid to high altitude areas, characterized with elevations of 1800-3000 m.a.s.l. (Mussa and Gemechu, 2006). In Ethiopia the production of faba bean is totally rainfed on nitosols and cambisol type of soils (Gemechu and Mussa, 2002) and currently on Vertisol too. It is the leading pulse category in area coverage and production. It accounted for about 0.44 million ha (27.34%) and about 0.92 million tons (30.95%) of the total pulse crops production. Oromia followed by Amhara Regional States are the largest producers and together accounted 83.20% of the country's faba bean production (CSA, 2017).

Faba bean has a versatile use and it is an important source of dietary protein to the majority of population in Ethiopia (Mulissa and Fasil, 2014), while its dry seeds, green haulm and dry straw are used as animal feeds (Sainte, 2011). The crop has a potential to substitute meat in many parts of the world where there is demand for non-animal protein sources (Crépona *et al.*, 2010). Ethiopian farmers are also aware of the role of the crop in improving soil health by fixing atmospheric nitrogen and widely use it in rotation with cereals (Sahile *et al.*, 2008). Faba bean is a source of cash to the farmers and foreign currency to the country.

Despite its diverse benefits and the availability of high yielding varieties (>3 t/ha) (MoALR. 2017), in Ethiopia the national average yield of faba bean 2.11 t ha$^{-1}$ (CSA, 2017) has remained low compared to Egypt and United Kingdom 3.47 and 3.83 t ha$^{-1}$, respectively (FAOSTAT, 2018). The low productivity of the crop is attributed by biotic and abiotic factors. However, research on this crop was started in 1950's to tackle different production constraints of the crop with the prime objectives to improve grain yield, seed size and resistance to important diseases, particularly chocolate spot (*Botrytis fabae*) (Gemechu *et al.*, 2006). Since 1950's inspite of production constraints, tremendous breeding achievement has been made in certain parameters of faba bean to increase its production and productivity in Ethiopia. Therefore, this paper was reviewed with the following objectives.

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- To quantify breeding progresses made in faba bean to improve production and productivity of the crop.

**History and Progresses of Faba Bean Breeding in Ethiopia**

Faba bean breeding in Ethiopia was started in 1950's with the establishment of Arsi Rural Development Unit followed by Debre Zeit Agricultural Research Center, the then Alemaya College of Agriculture (now Haramaya University) (Gemechu *et al*., 2006). The breeding program in Ethiopia was mainly focused to improve the economic traits like grain yield and seed size in response to the market demand and stress resistant (diseases and waterlogging).

The breeding progresses of faba bean in Ethiopia started from introduction of germplasm from abroad and performing adaptation trail in Ethiopia in multi-locations. Four varieties (Kuse 2-27-33, Tesfa, Holetta-2 and Degaga) have been released directly from introductions. Then collection of germplasms from all over the country and screening of germplasms performance has been carried out. Landrace collections, in general, are reservoirs of genetic variability and are sources of many valuable genes, especially those for adaptation (Gemechu *et al.*, 2006; Tamene, 2008).

Faba bean collections were carried out with the purpose of direct release after selection for high yield and wide or specific adaptation or to cross with exotic materials to generate superior genotypes. The varieties CS20DK, NC58, Bulga 70, Wayu and Selale were released directly from landrace collections (Gemechu *et al.*, 2006).

Hybridization of faba bean in Ethiopia started in 1980's at Holetta Agricultural Research Center to transfer chocolate spot resistant genes from exotic materials (received from ICARDA) in to adapted genotypes with good agronomic traits (Tamene, 2008; Gemechu *et al.*, 2016).. However, the recovery percent of crossing under the Ethiopian conditions ranges from 13 to 33%, which is very low as compared to 50% recovery at ICARDA under field and 50 to 70% under greenhouse conditions (Gemechu *et al*., 2006).

**Breeding Achievements of Faba Bean Research in Ethiopia**

Grain yield and seed size were the first and second priority economic traits of faba bean breeding program in Ethiopian (Asfaw *et al.,* 1994). To meet the proposed goal, research efforts during the past five decades have resulted in a release of 34 improved faba bean varieties along with proper crop management and protection practices at both national and regional levels (Table 1 and 2).

Faba bean breeding efforts in Ethiopia have resulted in average cumulative genetic gain over 33 years of faba bean breeding to be 288.4 kg/ha for grain yield, 266.3 g/1000 seeds for seed size and -8.9% for chocolate spot severity compared to the oldest variety CS20DK (Tamene *et al.,* 2015). The breeding achievements were not in the absence of constraints that hinder the production and productivity of the crop. However, different breeding progresses have been made in this crop.

**Solution for alleviate water logging problem**

Ethiopia is estimated to have 12.61 million hectares of vertisols, 63% of which is located in the highlands (Berhanu, 1985) where faba bean is the most important pulse crop occupying about 14% of the cultivated land (Getachew *et al.,* 1993). Waterlogging is a major constraint of faba bean production in the highland vertisols of Ethiopia (Gemechu *et al.,* 2001). Since 2002, to alleviate the production problems of faba bean in vertisol areas (waterlogging problem areas) by using direct selection method (screening of genotypes under water logging condition) six varieties (Selale, Wayu, Wolki, Hachalu, Didi'a, Ashebeka) have been released in Ethiopia at national level (Table 2).

**Progressive seed size increment**

The seed size of faba bean varieties is increasing from the earliest to the most recent one. The annual rate of genetic progress from breeding faba bean for seed size in Ethiopia was estimated to be 8.07g 1000 seeds$^{-1}$, which brings about an increment of 1.55% 1000 seeds$^{-1}$ year$^{-1}$ or 266.3g 1000 seeds$^{-1}$ (51.12%) for over three decades of breeding period (1977-2006) (Tamene *et al*., 2015). Seed size of faba bean increased dramatically from 476g (CS20DK, 1977) to the currently released variety 1069g (Numan, 2016). Likewise, reports indicated that 34-47% seed size increment for varieties released after 2006 using variety CS20DK as the reference and 55-70% increment as compared to variety NC58 (Tamene *et al*., 2015). The genetic progress made in faba bean for seed size is better than grain yield. Similarly more dramatic increments in seed size than in grain yield, was also reported from chickpea breeding in Ethiopia (Gemechu *et al.,* 2011). This could be attributed to the fact that, even if grain yield is the primary trait of interest and a prime objective in most of the Ethiopian crop breeding programs for the last many decades, seed size also received a special attention recently both at international and national levels, in response to the current change to meet the export-market demand for large seed size (Gemechu *et al.,* 2016).

**Improvements in chocolate spot disease resistance**

Chocolate spot disease severity scores of faba bean genotypes across the environments ranged from moderately resistant to moderately susceptible (28.5-48.8%) (Mussa *et al*., 2008). Less disease severity value of 28.5% was recorded on the recently released variety Tumsa followed by Gebelcho (34.8%), whereas the largest value of 48.8% was recorded on one of the old variety, Bulga-70 (Tamene *et al*., 2015). Likewise, performances of genotypes for chocolate spot disease were ranged between 26.17 (Tumsa) and 43.69% (NC58). Genotypes CS20DK, Tumsa, Gebelcho, Numan EH06070-3, EH09002-1, EKLS/CSR02012-2-3, EH09007-4, EH07015-7, EH09031-4 and EK05037-4 were less susceptible to chocolate spot (Mesfin, 2019). Furthermore, Gebelcho was reported as a good chocolate spot resistance and would be used as sources of resistance to chocolate spot disease in faba bean breeding (Asnakech *et al.,* 2015).

The annual rate of reduction in chocolate spot disease severity was found to be 0.27% and the total relative reduction in three past consecutive decades of breeding was 21.5%. The best levels of reductions in chocolate spot disease severity 24.47% and 38.10% were achieved in Gebelcho and Tumsa, respectively as compared to CS20DK (Tamene *et al.,* 2015).

Most farmers in Ethiopia cultivate local faba bean varieties (Thijssen *et al*., 2008). In Ethiopia, there are about 20 improved faba bean varieties which are adapted to different agro-ecology and have different disease reaction (IFPRI, 2010). Local faba bean varieties are low yielding and susceptible to both biotic and abiotic factors and highly susceptible to disease (Samuel *et al*., 2008). Generally, improved faba bean varieties are preferred by farmers for their high stable grain yield and relatively resistant to chocolate spot disease (Asnakech *et al*., 2016).

The significant reduction in the level of chocolate spot severity in recent varieties may be related to the recent modification in screening methodology that involved artificial inoculation of the breeding nurseries with virulent isolates of *Botrytis fabae* that resulted in improved precision and consistent progress from selection (Gemechu *et al.,* 2006; Mussa *et al*., 2008). Therefore, it is shown that currently released faba bean varieties are more resistant to chocolate spot disease as compared to the old and local varieties.

**Varietal development**

Improved seed is a prime background source input through which other component technologies are transferred to farmers. Sources of genetic variation for genetic improvement of this crop in Ethiopia include germplasm collections from important production complexes of the country, introduction and acquisition of genetic materials from foreign sources like ICARDA and the national crossing program of selected parents from all sources. Most of the landrace collections utilized in the breeding programs were either received from the Institute of Biodiversity or through target collections by breeders in collaboration with the Ethiopian Biodiversity Institute (Gemechu *et al*., 2016).

Faba bean breeders have been usually following a best parent by best parent hybridization technique in order to bring together desirable characters from a number of parents into a single genotype. Exotic materials, with desirable characters, but not adaptable would be crossed with the local adapted materials that lack some useful characters like diseases resistance and larger seed size. Sources of gene for desirable characters like large seed size and diseases resistant types have been identified from introductions of germplasms from ICARDA (Gemechu *et al*., 2016).

**Table 1:** Faba bean Varieties released at regional research centers and higher learning institute

| No | Variety | Year of release | Productivity (t/ha) | | 1000 seed weight | Altitude | Breeder/Maintainer |
|---|---|---|---|---|---|---|---|
| | | | Research field | Farmers' field | | | |
| 1 | Shallo | 1999 | NA | NA | NA | 1600-2600 | Sinana research center |
| 2 | Dagim | 2002 | 3.5 | ----- | 299 | 2600-3000 | Sheno research center |
| 3 | Lalo | 2002 | 3.6 | ----- | 325 | 2600-3000 | Sheno research center |
| 4 | Adet-Hanna | 2005 | 1.79-4.17 | 1.5-3.95 | 520 | 2240-2630 | Adet research center |
| 5 | Gachena | 2008 | 1.7-3.0 | 1.1-2.8 | 529 | 2000-3000 | Haramaya University |
| 6 | Angacha | 2009 | 3.0-4.0 | 2.4-3.6 | 730 | 1200-2800 | Hawassa research center |
| 7 | Bule-04 | 2012 | 3.7-4.3 | 2.0-3.0 | 1005 | 2000-2800 | Hawassa research center |
| 8 | Mosisa | 2013 | 4.0-4.8 | 3.2-4.0 | 434 | 1800-2600 | Sinana research center |
| 9 | Bobicho | 2013 | 4.41 | 2.5-3.5 | 878 | 1900-2400 | Hawassa research center |
| 10 | Ashenge$^{\Omega}$ | 2015 | 2.12-5.05 | ------ | 811 | 2200-2800 | Alamata research center |
| 11 | Mugulat | 2017 | 2.8-3.5 | 1.3-2.5 | 875 | 1900-3000 | Mekelle research center |
| 12 | Alloshe | 2017 | 4.4-5.0 | 3.5-4.1 | 698 | 2300-2600 | Sinana research center |

Source: (MoALR, 2017), $^{\Omega}$ Orobanche resistant

**Table 2:** Information on improved faba bean varieties released nationally at federal research centers.

| No | Variety | Pedigree | Year of release | Productivity (t/ha) | | 1000 seed weight | Altitude |
|---|---|---|---|---|---|---|---|
| | | | | Research field | Farmers' field | | |
| 1 | CS20DK | CS20DK | 1977 | 2.0-4.0 | 1.5-3.0 | 476 | 2300-3000 |
| 2 | NC58 | NC58 | 1978 | 2.0-4.0 | 1.5-3.5 | 449 | 1900-2300 |
| 3 | KUSE2-27-33 | Kuse 2-27-33 | 1979 | 2.0-3.5 | 1.5-2.5 | 393 | 2300-3000 |
| 4 | Kasa | Kasa | 1980 | 4.5-5.5 | 2.5-4.0 | 428 | 1900-2300 |
| 5 | Bulga 70 | Coll 111/77 | 1994 | 2.0-4.5 | 1.5-3.5 | 440 | 2300-3000 |
| 6 | Mesay | 74TA12050 x 74TA236 | 1995 | 2.5-5.0 | 2.0-3.5 | 428 | 1800-2300 |
| 7 | Tesfa | 74TA26026-1-2 | 1995 | 2.0-4.0 | 1.5-3.5 | 441 | 1800-2300 |
| 8 | Holetta-2 | BPL 1802-2 | 2001 | 2.0-5.0 | 1.5-3.5 | 506 | 2300-3000 |
| 9 | Degaga | R878-3 | 2002 | 2.5-5.0 | 2.0-4.5 | 517 | 1800-3000 |
| 10 | Selale* | Selale Kasim 91-13 | 2002 | 2.2-3.3 | 1.0-2.3 | 346 | 2100-2700 |
| 11 | Wayu* | Wayu 89-5 | 2002 | 1.8-3.2 | 1.0-2.3 | 312 | 2100-2700 |
| 12 | Moti | ILB4432 x Kuse 2-27-33 | 2006 | 2.8-5.1 | 2.3-3.5 | 781 | 1800-3000 |
| 13 | Gebelcho | ILB4726 x Tesfa | 2006 | 2.5-4.4 | 2.0-3.0 | 797 | 1800-3000 |
| 14 | Obse | CS20DK x ILB 4427 | 2007 | 2.5-6.1 | 2.1-3.5 | 821 | 1800-3000 |
| 15 | Dosha | Coll 155/00-3 | 2008 | 2.8-6.2 | 2.3-3.9 | 704 | 1800-3000 |
| 16 | Wolki* | Bulga70 x ILB 4615 | 2008 | 2.4-5.2 | 2.0-4.2 | 676 | 1800-2800 |
| 17 | Tumsa | Tesfa x ILB 4726 | 2010 | 2.5-6.9 | 2.0-3.8 | 737 | 2050-2800 |
| 18 | Hachalu* | ILB 2717 x CS20DK | 2010 | 3.2-4.5 | 2.4-3.5 | 890 | 1900-2800 |
| 19 | Gora | EH91020-8-2 x BPL44-1 | 2012 | 3.0-5.0 | 2.0-4.0 | 980 | 1800-2800 |
| 20 | Didi'a* | ILB 2717 x R878-3 | 2014 | 3.5-4.6 | 2.0-4.4 | 700 | 1800-2800 |
| 21 | Ashebeka* | N86108-5 x BPL1297-1 | 2015 | 3.0-5.0 | 2.8-4.7 | 885 | 1900-2800 |
| 22 | Numan | EH99037-5 x ILB-1563 | 2016 | 2.2-3.8 | 3.6-5.1 | 1069 | 1800-3000 |

Source: (MoALR, 2017); *****Released for vertisol areas/waterlogging problem areas, 1-18 and 19-22 released at Holetta and Kulumsa agricultural research centers, respectively.

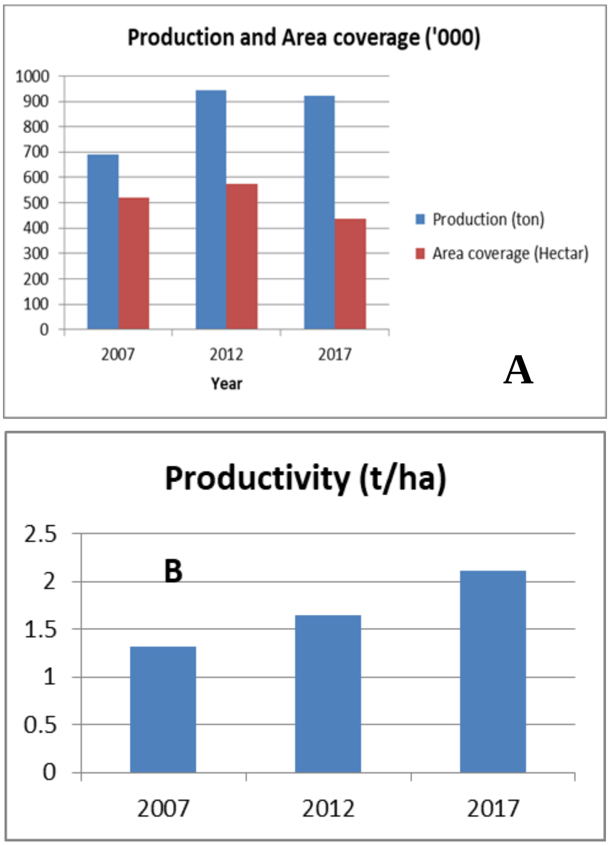


**Fig. 1:** Production, area coverage and productivity trends of faba bean in 5 years interval within the last ten years (2007-2017) (Source (CSA, 2007, 2012, 2017).

The total area occupied for faba bean production worldwide dropped by 57% (5.4 to 2.3M ha) from 1961 to 2012, but average yield has increased around 2-fold (0.9 to 1.7 t/ha) during the same time (FAO, 2014). Likewise, in the past (2005 to 2014) the yield potential and relative advantages of improved faba bean varieties over the existing husbandry method showed the potential of improving the low national average from 1.122 to 1.842 (Gemechu *et al*., 2016). The yield trend is still upward, showing how conventional breeding efforts have been successful in this crop.

Through consorted inter-institutional efforts, during the last five decades, 34 faba bean varieties have been released at national and regional level. The released varieties have special merit that makes these released varieties to be accepted by the producer (Table 1 and 2) (MoALR, 2017). They are developed and released to producers along with proper crop management and protection practices.

### Increase in Production and Productivity of Faba bean

Currently, more than 1.6 million hectares of land has been cultivated to pulses in Ethiopia and faba bean shares 0.4 million hectares. During the last ten years (between 2007 and 2017), the area under faba bean cultivation was decreased from 520,519 to 437,106 ha (16.02%) (Figure 1A), whereas the production and productivity of faba bean, during the corresponding period, was increased from 0.69 to 0.92 million ton (25%) (Figure 1A) and 1.323 to 2.109 t/ha (37.27%) (Figure 1B), respectively (CSA, 2007; 2017). Trends of productivity and total annual national production of faba bean between 2005 and 2015 in Ethiopia was progressively increasing despite the stagnation in cultivated areas as a result of improved productivity per unit area of land (Gemechu *et al*., 2016). The increase in production and productivity of the crop was due the presence of best technologies regardless of reduction in area of production.

It was reported breeding progress of 30.73 kg $ha^{-1}$ $year^{-1}$ in faba bean (Tamene, 2008). Replacing local varieties with improved ones led to increment in production of 18% in Egypt, 8% in Sudan and 42% in Ethiopia (ICARDA, 2008). Therefore, variety Wolki can increase the grain yield 70-100% as compared to a local check (ICARDA, 2010). Studies on genetic progresses from breeding of faba bean also confirmed existence of reasonable levels of yield gain over the last three decades (Tamene *et al*., 2015).

The productivity of faba bean is in an increasing trend due to the use of improved technologies. In relation to the desire, however, it is not possible to say that the technologies developed and promoted through the efforts yet have been readily accepted, fully utilized and modernized production at farm levels (Gemechu and Imtiaz, 2010). Though, the Ethiopian government is planned to increase faba bean productivity by 32.50% in 2030 (Gemechu *et al*., 2016). However, there is still a long way to go in terms of technical capacity and capability in order to exploit the high potential of this crop. Periodic assessment of the previous research achievements and understanding the amount of progresses realized through research for development efforts enables to improve the efficiency and effectiveness of future research endeavors (Gemechu *et al*., 2016).

The decrease in areas of production in faba bean attributed by appearance of new threats like parasitic weed (*Orobanche crenata*), faba bean gall (*Olpidium viciae*) and recurrent drought and erratic rain fall distribution in the northern block of the country coupled with absence of readymade technologies that overcome the negative contribution of these threats (Gemechu *et al*., 2016).

It was reported that recently, faba bean is threatening by faba bean gall locally known as "Kormid", causing up to complete crop failure over wide areas within short period of time with disastrous economic consequences (Wulita, 2015). The distribution and pattern of the disease was at accelerating speed like fire-wood within short period of time (Teklay *et al.*, 2014). The spread of this disease has been very fast and expanding from year to year in all faba bean-growing areas of the country. The disease is expanding at an alarming rate in the highland faba bean-growing areas of Amhara, Tigray, and Oromia regions and it caused up to 100% severity and loss on faba bean in the Tigray region (Endale *et al*., 2014).

Soil acidity hinders legume production more than any other crops as it affects the complex association of the legume host, the endosymbiont and the symbiosis (Graham, 1992). It is a significant problem that agricultural producers in tropical and subtropical regions are facing and limit legume productivity (Bordeleau and Prevost, 1994). It becomes a serious threat to crop production in most highlands of Ethiopia in general and in the western part of the country in particular (Hirpa *et al*., 2013). Therefore, recently, it is confirmed that soil acidity is one of the major production limiting factors of faba bean in Ethiopia Ethiopia (Mulissa and Fasil, 2014; Endalkachew *et al*., 2018).

The distribution of rainfall adversely affects crop production than the total amount received in the crop growing period as a result cultivars successful in one dry year may not perform better in the next dry season or may lead to complete crop failure. Therefore, cultivars tolerant to terminal drought may not be tolerant to drought occurring in intermediate or early season (Gemechu *et al*., 2016).

## Impact of Improved Varieties in the Livelihood of the Society

The pre-scaling up activities of technologies generated through the national Agricultural Research System brought about a considerable promise in substantially improving the agricultural productivity and production in various parts of the country (Abate, 2006). Thousands of farmers benefitted from the pre-scaling up programs particularly in Amhara, Oromiya, SNNP and Tigray regions where thousands of tons of improved seeds of faba bean was distributed and applied (Fikre *et al.*, 2011). Due to such activities small-scale farmers were able to adopt improved technologies, boost their yield and transform their agriculture. For instance, farmers participated in pre-scaling up of technologies got, on average, grain yield advantage of 61.2% from faba bean (Fikre *et al.*, 2011).

In 2005 a survey was carried out by ICARDA in Egypt, Ethiopia and Sudan on 587 households using a formal questionnaire. Faba bean, technology 'package' for combining an improved variety with several agronomic or crop management practices to maximize yield and improve input use efficiency of use from the new variety. The complete package normally gives the best results; but farmers tend to adopt the package in stages, first experimenting with one or two components, and gradually adding others. The most popular components and relative preferences varied between countries but improved variety, weed control and pest control were generally the most widely adopted components (ICARDA, 2008).

In Ethiopia, there were several positive factors or associations: availability of seed from a research organization, awareness of the role of faba bean in crop rotations and in household nutrition, access to market, farming experience. Farmers who adopted the new faba bean technologies, whether the full package or individual components, obtained significantly higher yields. Simply replacing traditional varieties with improved ones led to gains of 42% in Ethiopia. The new technologies substantially improved household food security and income. Average per capita faba bean production among non-adopters was 44 kg in Ethiopia. Among adopters, this increased by 39% a clear indication of improved food security. In Ethiopia, 3% of adopter households moved up at least one 'wealth class', while all non-adopters remained in the lowest class (ICARDA, 2008).

## Conclusion

In the past research efforts, progress made in seed size improvements of faba bean in Ethiopia was far better than that of grain yield from 476 to 1069 gram and chocolate spot resistance. This could be credited by exceptionally better parents introduced from ICARDA for larger seed size and chocolate spot resistance. The polygenic nature of grain yield attributed for less progress compared to seed size and chocolate spot. The chocolate spot severity in recently released varieties was reduced significantly due to screening of genotypes by artificial inoculation with virulent isolates of *Botrytis fabae.* The concerted efforts of federal and regional research centers resulted releases of 34 faba bean varieties that have biotic (chocolate spot and orobanche) and abiotic stress resistance (waterlogging). As a result production and productivity of the crop increased. It is evident that previous faba bean breeding efforts have resulted in the identification of desirable genotypes as released varieties or parents for further improvement. However, there is a long way to increase the production and productivity of this crop due unconditional constraints. Therefore, development of soil acidity tolerant varieties needs future attention because it becomes the major production limiting factor in the highlands of Ethiopia.

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