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# Genetic progresses from over three decades of faba bean (*Vicia faba* L.) breeding in Ethiopia

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**Abstract**

Eleven faba bean (*Vicia faba* L.) varieties released between 1977 and 2007, and two promising genotypes, were evaluated to estimate the genetic progresses made in 33 years of faba bean breeding in Ethiopia. The study was conducted at eight environments during 2007 and 2009 cropping seasons in a randomized complete block design with four replications. Records taken on grain yield, seed size and chocolate spot (*Botrytis fabae*) severity were subjected to statistical analysis. Combined analysis of variance revealed highly significant differences among the genotypes and the test environments for all traits, the G × E interaction effects being significant for grain yield and seed size. Regression of mean performance at all environments on year of varietal release showed positive relationship for grain yield (r = 0.48) and seed size (r = 0.80**) but negative for chocolate spot (r = -0.60*). The annual rates of genetic progresses were 8.74 kg ha$^{-1}$, 8.07 g 1000 seeds$^{-1}$ and -0.27% for grain yield, seed size and chocolate spot, respectively. The average cumulative gains over 33 years of breeding was, therefore, 288.4 kg (8.1%) for grain yield, 266.3 g (51.12%) for seed size and -8.9% for chocolate spot severity. Seed size showed the most dramatic response to breeding for the last 33 years may be because of a lesser polygenic nature of this trait and better availability of best donor parents as compared to grain yield. The relatively slower responses of grain yield and chocolate spot to breeding may be associated with the polygenetic nature of the former and shortage of good donor parents for the later. The prior release of an exceptionally stable and better adapted variety, CS20DK, in 1977 might also seemingly undermined progresses of later efforts. It is, therefore, strategically advisable that breeding efforts in the future should give due attention to building on the shortcomings of widely adapted varieties like CS20DK.

**Keywords:** Chocolate spot, economic traits, faba bean, genetic progress, relative genetic gain.

## Introduction

Faba bean (*Vicia faba* L., 2n = 2x=12) is an old world grain legume of the family *Leguminasae* (Purseglove, 1968). It is believed that faba bean was introduced to Ethiopia soon after its domestication around 5000 B.C. (Telaye et al., 1994), and the country is now considered as one of the secondary centers of genetic diversity (Bond, 1976; Mekbib et al., 1991). Faba bean is one of the major pulses grown in the highlands of Ethiopia (Jarso and Keneni, 2006), which is the second largest faba bean producing country in the world next to Peoples Republic of China (Haciseferogullari et al., 2003; Jarso and Keneni, 2006). Currently, faba bean in Ethiopia occupies 31% of the total 1,863,445 ha of land cultivated to pulses, the corresponding annual production being 34% of the total 2,751,031 tons of pulses produced in the country (CSA, 2013). The crop has a great economic merit in Ethiopia (Keneni et al., 2006), providing a cheap source of protein (Telaye et al., 1994; Haciseferogullari et al., 2003; Jarso and Keneni, 2006) in human diet and animal feed, source of alternative cash income to the farmers and foreign currency to the country (Keneni et al., 2006; Ayele and Alemu, 2006). Faba bean is also one of the most efficient fixers of atmospheric nitrogen (Lindemann and Glover, 2003; Jarso and Keneni, 2006) and used as a suitable rotation crop with cereals (Gorfu and Feyisa, 2006). Despite the significant economic and ecological importance, however, the productivity of faba bean has been lower and highly variable as compared to many cereals (Buddenhagen and Richards, 1988). The lower productivity of the crop in Ethiopia is mainly attributed to certain yield limiting factors including biological limitations of the crop, particularly the inherently low yielding potentials of the indigenous cultivars, susceptibility to biotic and abiotic stresses such as diseases, insects, weeds, moisture deficit, high soil acidity, waterlogging and frost (Mekbib et al., 1991; Bekele et al., 2006; Jarso and Keneni, 2006). Faba bean breeding in Ethiopia was started in the 1950's with the prime objectives of improving grain yield, seed size and resistance to important diseases, particularly chocolate spot (*Botrytis fabae*) (Keneni et al., 2006). From the hitherto breeding efforts in Ethiopia, a number of improved faba bean varieties have been developed and released for general production under different recommendation domains, including the mid and high altitude agro-ecologies and the waterlogged vertisol areas. Understanding of the amount of genetic progresses realized through past crop breeding efforts is absolutely essential to improving the efficiency and effectiveness of future breeding endeavors (Waddington et al., 1986; Evan, 1993; Ustun et al., 1999). The accurate estimation of genetic progress realized from long-term breeding efforts is a difficult task but various procedures may be used. Among the available procedures, the performance of genotypes in common environments regressed over years of varietal release of a given crop as a continuous quantitative variable provided the most direct estimate of genetic progress from breeding and has widely been used in different crops (Cox et al., 1988). For example, genetic progresses using the same procedure were reported in barley (Martintello et al., 1987), groundnut (Mozingo et al., 1987), sunflower (Pereira et al., 1999), wheat (Brancourt et al., 2003; Shearman et al., 2005 and Osmar et al., 2007; Parveen and Khalil, 2011), soybean (Morrison et al., 2000; Ustun et al., 2001; Jin et al., 2010; Liu et al., 2012) and maize (Sergio et al., 2006. Genetic progresses achieved over time from breeding of different crops in Ethiopia have also been studied using the same procedure and documented in haricot bean (Bezawuletaw et al., 2006), maize (Worku and Zeleke, 2007), and barley (Fekadu et al., 2011). Very recently, Keneni et al. (2011) reported the magnitude of genetic progress breeding chick pea for seed size and grain yield in association with changes in resistance to adzuki bean beetle (*Callosobruchus chinensis*). However, information on the amount of genetic progresses made over time from breeding faba bean in Ethiopia is scanty. Therefore, the current study was designed to estimate the amount of breeding progresses made over-time in grain yield, seed size and chocolate spot resistance of faba bean in Ethiopia.

**Results and Discussion**

***Performance of the genotypes***

Highly significant differences ($p \leq 0.001$) were observed among the faba bean genotypes and the test environments for all traits (Table 3). The genotype by environment (G × E) interaction effects were also highly significant for grain yield and seed size ($p \leq 0.01$). The observed non-significant interaction effect for chocolate spot resistance revealed that the environments were distinct in favoring or disfavoring the chocolate spot disease buildup but different genotypes more or less showed similar pattern of response to the different environments in terms of chocolate spot severity.

The environmental main effect accounted for 71.8% of the total variation in grain yield, which is mainly attributed to the large differences among the test environments. On the other hand, genotype and G × E interaction effects accounted only for 4.8% and 10.9% of the total variation in grain yield, respectively. This study clearly showed that the environments were distinct, and the genotypes responded differently to the different environments in terms of grain yield. G × E interaction effects were also observed to be "cross-over" type for grain yield; i.e., frequent changes in rank orders were observed among the performances of the genotypes across the environments (Fig 1). Previous reports also showed that tremendous levels of G × E interaction effects exist in faba bean in different sets of environments in Ethiopia (Keneni et al., 2002, Keneni and Jarso, 2002; Jarso and Keneni, 2004; Keneni et al., 2006). Observation of high G × E interaction effects for grain yield and seed size in the current data set should not be surprising as the genotypes evaluated here have different genetic backgrounds (Table 2). The average grain yield for 13 faba bean varieties tested in 8 environments are presented in Table 4. The average environmental grain yield across genotypes ranged from the lowest of 1729 kg ha$^{-1}$ at Holetta in 2007 to the highest of 4638 kg ha$^{-1}$ at Assasa in 2007, with a grand mean of 3410 kg ha$^{-1}$ (Table 4). The highest yield of 6649 kg ha$^{-1}$ was obtained from variety 'Degaga' at Kulumsa in 2009, while the lowest was 1198 kg ha$^{-1}$ from one of the oldest varieties 'Kuse-2-27-33' at Bekoji in 2007 (Table 4). The faba bean variety, Degaga, with grain yield of 3822 kg ha$^{-1}$ and the recently released variety Tumsa, with grain yield of 3701 kg ha$^{-1}$, stood the best in terms of average grain yield across environments (Table 4). However, grain yield performances of these varieties were not significantly different from the average grain yield performance of 3559 kg ha$^{-1}$ by one of the oldest varieties, CS20DK. Varieties released immediately after CS20DK, for example NC-58 and Kuse-2-27-33 were the least performers for both grain yield and seed size, indicating that the production of these varieties may no more be feasible. Seed size increased dramatically from 450 g for one of the oldest variety, NC-58, which was selected from landraces to 763 g for the recently released variety, Moti (Table 4). Chocolate spot disease severity scores of the genotypes across the environments ranged from moderately resistant to moderately susceptible reaction (28.5 – 48.8%) (Jarso et al., 2008) (Table 4). The smallest disease severity value of 28.5% was recorded on the recently released large-seeded variety Tumsa followed by Gebelcho (34.8%), whereas the largest value of 48.8% was recorded on one of the old varieties, Bulga-70 (Table 4). This indicated that older varieties were more susceptible to chocolate spot than the recently released ones.

***Genetic progress in grain yield***

A linear regression equation showed that a positive relationship ($r = 0.48$) existed between mean grain yields and years of varietal releases (Fig 2). This showed that past faba bean breeding efforts in Ethiopia have resulted in an average grain yield increment of only 288.42 kg ha$^{-1}$ or an annual rate of genetic progress of 8.74 kg ha$^{-1}$ (0.26% ha$^{-1}$ year$^{-1}$) using the oldest variety, CS20DK, as a reference (Table 5). The genetic progresses made in grain yield from faba bean breeding in Ethiopia is much lower than the progresses made in grain yields from breeding of other crops like barley (1.34% ha$^{-1}$ year$^{-1}$) (Fekadu et al., 2011), and haricot bean (3.24% ha$^{-1}$ year$^{-1}$) (Bezawuletaw et al., 2006) more or less during the same period. In other countries, reports also showed higher annual yield increases of 0.58% ha$^{-1}$ year$^{-1}$ from breeding soybean in Northeast China (Jin, et al., 2010), 0.45% ha$^{-1}$ year$^{-1}$ from breeding soybean in Canada (Morrison, et al. 2000) and 0.39% ha$^{-1}$ year$^{-1}$ from hundred years of barley breeding in England (Riggs, et al., 1981). The lower genetic progresses made from faba bean breeding in Ethiopia may be attributed to the exceptionally stable and better adaptation of the reference variety, CS20DK. For instance, when the second oldest variety, NC-58, was considered as a reference instead of CS20DK, the average genetic progress value was estimated to be 466 kg ha$^{-1}$ (as compared to 288 kg ha$^{-1}$ for CS20DK) or an annual genetic progress of 14.11 kg ha$^{-1}$ (0.46% ha$^{-1}$ year$^{-1}$; $r = 0.68^{**}$) (Table 5). Therefore, it appears that faba bean breeders in Ethiopia have been seemingly "stranded" to bring about a drastic change through breeding by their own earliest success when CS20DK was released as a pioneering variety. Very low yield gain was also reported in Western USA from soya bean breeding, which was explained in terms of the "attainment of yield 'plateaus'" (Egli, 2008). It can be witnessed that genetic progress in grain yield from faba bean breeding considering another old variety, NC-58, as the reference base showed higher yield gains of 23.34% for the

**Table 1.** Description of the 5 locations used to evaluate 13 faba bean cultivars.

| Locations | Geographical position | | Altitude (m.a.s.l.) | Average rainfall (mm) | Temperature ($^0$C) | | Agro-ecologies |
|---|---|---|---|---|---|---|---|
| | Latitude | Longitude | | | Min | Max | |
| Asassa | 07$^0$06′12″N | 39$^0$11′32″E | 2300 | 620 | 5.8 | 23.6 | THMH |
| Kulumsa | 08$^0$01′00″N | 39$^0$09′32″E | 2200 | 820 | 10.5 | 22.8 | TSmMH |
| Bekoji | 07$^0$31′22″N | 39$^0$14′46″E | 2780 | 1010 | 7.9 | 16.6 | CHMH |
| Holetta | 09$^0$04′12″N | 38$^0$29′45″E | 2400 | 975.5 | 6.05 | 22.41 | TMMH |
| Koffale | 07$^0$04′27″N | 38$^0$46′45″E | 2660 | 1211 | 7.1 | 18 | CHMH |

THMH = Tepid Humid Mid Highland, TSmMH = Tepid Sub-moist Mid Highland, CHMH = Cool Humid Mid Highland, TMMH = Tepid Moist Mid Highland, m.a.s.l. = meters above sea level.

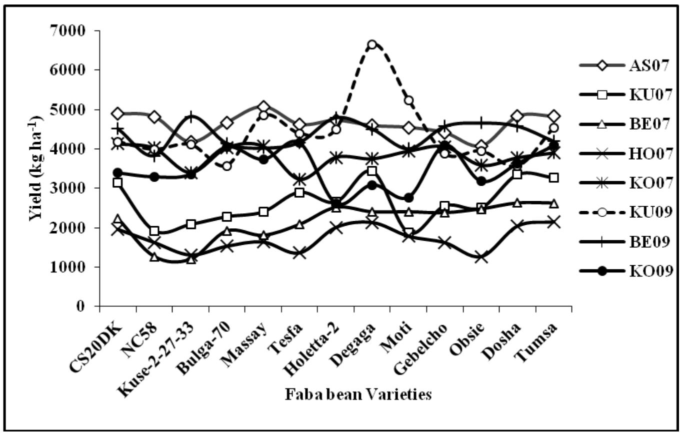


**Fig 1.** Grain yield performances of thirteen faba bean genotypes across eight environments showing the existence of relative changes in ranks (cross-overs) due to genotype by environment (G × E) interaction. Abbreviations of the test environments were as defined in Table 4.

**Table 2.** Description of the 13 faba bean cultivars used in the experiment.

| No. | Name of Varieties | Pedigree | Source | Year of release | Seed Size | Recommendation domain |
|---|---|---|---|---|---|---|
| 1 | CS20DK | CS20DK | Collection | 1977 | Small | 2300-3000 m.a.s.l |
| 2 | NC58 | NC58 | Collection | 1978 | Small | 1800-2300 m.a.s.l |
| 3 | Kuse-2-27-33 | Kuse 2-27-33 | Introduction | 1979 | Small | 2300-3000 m.a.s.l |
| 4 | Bulga-70 | Coll 111/77 | Collection | 1994 | Small | 2300-3000 m.a.s.l |
| 5 | Massay | 74TA12050 x 74TA236 | Hybridization | 1995 | Small | 2300-3000 m.a.s.l |
| 6 | Tesfa | 74TA26026-1-2 | Hybridization | 1995 | Small | 2300-3000 m.a.s.l |
| 7 | Holetta-2 | BPL 1802-2 | Introduction | 2000 | Small | 2300-3000 m.a.s.l |
| 8 | Degaga | R878-3 | Introduction | 2002 | Small | 1800-3000 m.a.s.l |
| 9 | Moti | ILB4432 x Kuse 2-27-33 | Hybridization | 2006 | Large | 1800-3000 m.a.s.l |
| 10 | Gebelcho | ILB4726 x Tesfa | Hybridization | 2006 | Large | 1800-3000 m.a.s.l |
| 11 | Obsie | CS20DK x ILB 4427 | Hybridization | 2007 | Large | 1800-3000 m.a.s.l |
| 12 | Dosha | Coll 155/00-3 | Collection | 2009 | Medium | 1800-3000 m.a.s.l |
| 13 | Tumsa | Tesfa x ILB 4726 | Hybridization | 2010 | Large | 1800-3000 m.a.s.l |

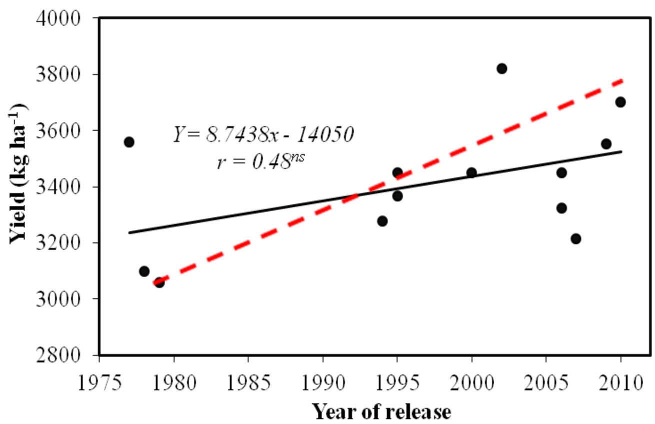


**Fig 2.** Bi-plot of grain yield (kg ha$^{-1}$) against years of cultivar release starting from 1977-2010 (broken line stands for a linear regression line using NC-58 as a reference, disregarding CS20DK).

**Table 3.** Combined analysis of variance of grain yield, seed size and chocolate spot disease of 13 faba bean cultivars evaluated over 8 environments during 2007 and 2009 cropping season.

| | Mean squares | | |
|---|---|---|---|
| Source of Variances | Grain yield (kg $ha^{-1}$) | 1000 seed weight (g) | Chocolate spot (%) |
| Environment | 80686759.7*** | 231230.86*** | 9156.14*** |
| Bloc(Environment) | 4090949.3*** | 10892.63*** | 412.02*** |
| Entry | 2341470.3*** | 514963.35*** | 1075.15*** |
| Environment*Entry | 766545.2** | 7075.88*** | $113.23^{ns}$ |
| Pooled error | 490275 | 5021 | 86.40 |

** and *** = significant at 0.01 and 0.001 probability levels, respectively; ns = non significant

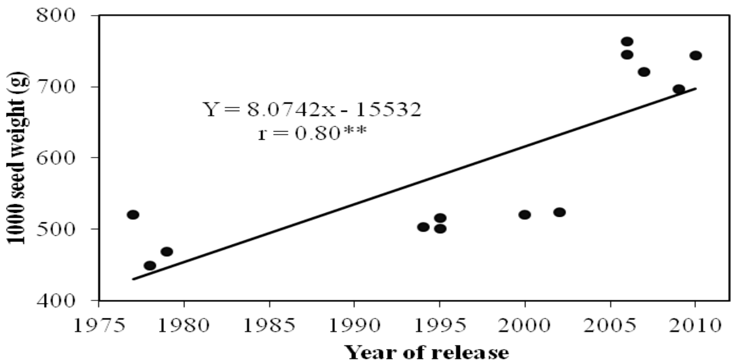


**Fig 3.** Bi-plot of 1000 seed weight (g) against years of cultivar release starting from 1977-2010.

variety Degaga and 19.45% for the variety Tumsa. These values are by far higher than 7.38% for the variety Degaga and 3.99% for the variety Tumsa when CS20DK was used as a reference (Table 6).

***Temporal changes in seed size development***

The linear regression of seed size against the years of release showed highly significant positive correlation (r=0.80**) (Fig 3). The annual rate of genetic progress from breeding faba bean for seed size in Ethiopia was estimated to be 8.07 g 1000 $seeds^{-1}$ (Fig 3), which entails that an increment of 1.55% 1000 $seeds^{-1}$ $year^{-1}$ or 266.3 g 1000 $seeds^{-1}$ (51.12%) for over three decades of breeding period was obtained (Table 5). Therefore, it was clearly revealed that better genetic progress was obtained from breeding faba bean in Ethiopia for seed size than it was for grain yield. Based on the relative comparison of different varieties for the temporal changes made through breeding, 34-47% seed size increment was obtained for recent varieties released after 2006 using variety CS20DK as the reference and 55-70% increment was obtained when variety NC58 was used as the reference (Table 6). Similar results with more dramatic increments in seed size than in grain yield, was also reported from chickpea breeding in Ethiopia (Keneni et al., 2011). This could be attributed to the fact that, while 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 since recently both at international and national levels, in response to the current move to meet the export-market demand for large seed size (EARO, 2000).

***Improvements in chocolate spot resistance***

The linear regression line between chocolate spot disease severity scores and year of varietal release clearly showed a significant negative association (r = -0.60*), indicating the temporal reduction in the severity of chocolate spot of faba bean through breeding (Fig 4). The annual rate of reduction in chocolate spot disease severity was found to be 0.27%, the total relative reduction over the last three decades of breeding being 21.5% (Table 5). The best levels of reductions in chocolate spot disease severity of 24.47% and 38.10%, as compared to CS20DK were achieved in recently released varieties, Gebelcho and Tumsa, respectively. 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 (Keneni et al., 2006; Jarso et al., 2008).

**Materials and Methods**

***Planting materials and test environments***

Thirteen faba bean genotypes including 11 varieties released from 1977 to 2007 and two promising genotypes selected from last stage of variety evaluation trial were considered as experimental materials for this study. The experiment was conducted during the main growing seasons (June-November) of 2007 and 2009. The locations include Kulumsa, Bekoji, Asassa, Koffale and Holetta in 2007 and Kulumsa, Bekoji and Koffale in 2009, making a total of eight test environments, considering each year at each location as a separate environment. The description of the genotypes and test environments in terms of geographical position, altitude, rainfall, temperature and agro-ecological zones are given in Tables 1 and 2.

***Experimental design and data collection***

A randomized complete block design with four replications was employed for the study. Seeds were sown at the rate of 5 cm plant to plant spacing and 40 cm row to row spacing.

**Table 4.** Grain yield (kg $ha^{-1}$), mean 1000 seed weight (g), and mean chocolate spot severity (%) of the 13 faba bean cultivars evaluated at 8 environments during 2007 and 2009 cropping season.

| Varieties | Mean grain yield (kg $ha^{-1}$) at each environments | | | | | | | | | Mean TSW | Mean ChS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | AS07 | KU07 | BE07 | HO07 | KO07 | KU09 | BE09 | KO09 | Mean | (g) | (%) |
| CS20DK | 4899 | 3139 | 2240 | 1962 | 4133 | 4185 | 4521 | 3394 | 3559 | 521 | 41.47 |
| NC58 | 4821 | 1926 | 1272 | 1631 | 4025 | 3989 | 3831 | 3294 | 3099 | 450 | 46.09 |
| Kuse-2-27-33 | 4180 | 2082 | 1198 | 1314 | 3401 | 4112 | 4823 | 3359 | 3058 | 469 | 47.08 |
| Bulga-70 | 4672 | 2279 | 1918 | 1534 | 4033 | 3578 | 4145 | 4057 | 3277 | 503 | 48.81 |
| Massay | 5074 | 2403 | 1807 | 1641 | 4072 | 4848 | 4024 | 3738 | 3451 | 501 | 43.81 |
| Tesfa | 4626 | 2903 | 2084 | 1366 | 3229 | 4396 | 4167 | 4167 | 3367 | 516 | 45.16 |
| Holetta-2 | 4727 | 2652 | 2517 | 2010 | 3789 | 4495 | 4795 | 2621 | 3451 | 520 | 38.91 |
| Degaga | 4596 | 3436 | 2404 | 2136 | 3753 | 6649 | 4507 | 3093 | 3822 | 524 | 39.56 |
| Moti | 4548 | 1871 | 2405 | 1787 | 3947 | 5245 | 4007 | 2776 | 3323 | 763 | 43.53 |
| Gebelcho | 4417 | 2557 | 2383 | 1624 | 4064 | 3879 | 4574 | 4102 | 3450 | 745 | 34.81 |
| Obsie | 4082 | 2504 | 2479 | 1275 | 3586 | 3949 | 4658 | 3181 | 3214 | 721 | 41.53 |
| Dosha | 4827 | 3349 | 2631 | 2047 | 3780 | 3567 | 4577 | 3636 | 3552 | 697 | 40.25 |
| Tumsa | 4830 | 3271 | 2628 | 2152 | 3902 | 4544 | 4193 | 4089 | 3701 | 744 | 28.53 |
| Mean | 4638 | 2644 | 2151 | 1729 | 3824 | 4418 | 4371 | 3501 | 3410 | 590 | 41.50 |
| LSD (0.05) | 665 | 808 | 678 | 697 | 1127 | 1519 | 1168 | 972 | 359 | 36 | 4.41 |
| CV (%) | 10.46 | 22.12 | 22.38 | 28.98 | 21.67 | 24.41 | 18.80 | 20.31 | 21.41 | 12.37 | 21.75 |

Abbreviations: AS07 = Asassa in 2007, KU07 = Kulumsa in 2007, BE07 = Bekoji in 2007, KO07 = Koffale in 2007, HO07 = Holetta in 2007, KU09 = Kulumsa in 2009, BE09 = Bekoji in 2009, KO09 = Koffale in 2009 and TSW = 1000 seed weight, ChS = Chocolate spot.

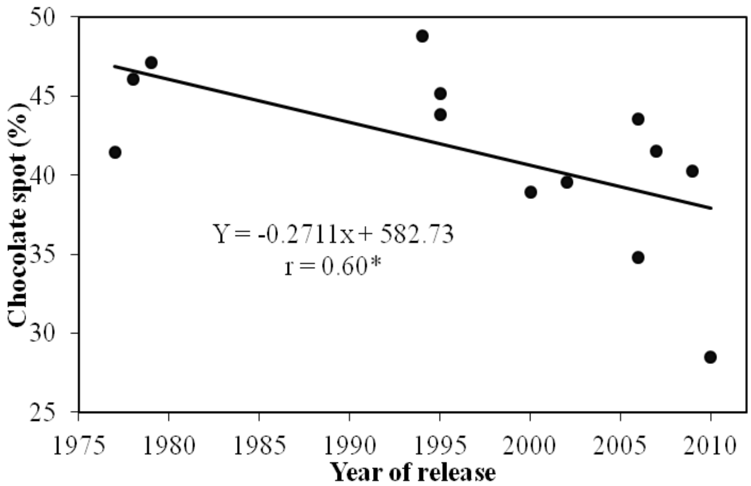


**Fig 4.** Bi-plot of Chocolate spot disease against years of cultivar release starting from 1977-2010.

**Table 5.** Relative genetic gain (RGG) compared to the oldest variety 'CS20DK' and trends in genetic progress obtained from breeding faba bean for grain yield, seed size and chocolate spot disease resistance during the last 33 years.

| Parameters | Grain yield (kg $ha^{-1}$) | 1000 seed weight (g) | Chocolate spot (%) |
|---|---|---|---|
| Mean square of regression | 130759 | 111499 | 125.66 |
| Regression coefficient *(b)*$^{a}$ | 8.74(14.11) | 8.07 | -0.27 |
| p-value | 0.104(0.001) | 0.001 | 0.032 |
| Gain in 33 years | 288(466) | 266.31 | -8.91 |
| Correlation coefficient (r) | $0.48^{ns}$(0.68**) | 0.80** | 0.60* |
| *Mean of CS20DK(NC-58)* | *3559(3099)* | *521* | *41.47* |
| RGG (%) $year^{-1}$ | 0.26(0.46) | 1.55 | -0.65 |
| Total RGG (%) | 8.1(15) | 51.12 | -21.50 |

$^{a}$ = annual rate of breeding progress; r = correlation coefficient of the traits with year of variety release, values in the parenthesis are of the second oldest variety NC-58.

**Table 6.** Temporal trends in mean performance and their percentage increments of grain yield (kg $ha^{-1}$), seed size (g) and chocolate spot (%) of faba bean varieties released during 33 years compared to the oldest varieties 'CS20DK and NC-58'.

| VARIETY | Year of Release | Grain yield (kg ha-1) Mean | % Over CS20DK | % Over NC-58 | 1000 seed weight (g) Mean | % Over CS20DK | % Over NC-58 | Chocolate spot (%) Mean | % Over CS20DK | % Over NC-58 |
|---|---|---|---|---|---|---|---|---|---|---|
| CS20DK | 1977 | 3559 | - | 14.86 | 521 | - | 15.79 | 41.47 | - | -10.03 |
| NC-58 | 1978 | 3099 | -12.94 | - | 450 | -13.63 | - | 46.09 | 11.15 | - |
| KUSE 2-27-33 | 1979 | 3058 | -14.07 | -1.30 | 469 | -9.93 | 4.29 | 47.08 | 13.53 | 2.14 |
| BULGA-70 | 1994 | 3277 | -7.93 | 5.75 | 503 | -3.41 | 11.83 | 48.81 | 17.71 | 5.90 |
| MESSAY | 1995 | 3451 | -3.04 | 11.37 | 501 | -3.78 | 11.40 | 43.81 | 5.65 | -4.95 |
| TESFA | 1995 | 3367 | -5.39 | 8.67 | 516 | -0.90 | 14.75 | 45.16 | 8.89 | -2.03 |
| HOLETTA-2 | 2000 | 3451 | -3.04 | 11.36 | 520 | -0.12 | 15.65 | 38.91 | -6.18 | -15.59 |
| DEGAGA | 2002 | 3822 | 7.38 | 23.34 | 524 | 0.65 | 16.54 | 39.56 | -4.60 | -14.17 |
| MOTI | 2006 | 3323 | -6.62 | 7.25 | 763 | 46.55 | 69.69 | 43.53 | 4.97 | -5.56 |
| GEBELCHO | 2006 | 3450 | -3.06 | 11.34 | 745 | 43.00 | 65.58 | 34.81 | -16.05 | -24.47 |
| OBSIE | 2007 | 3214 | -9.69 | 3.73 | 721 | 38.36 | 60.20 | 41.53 | 0.15 | -9.90 |
| DOSHA | 2009 | 3552 | -0.21 | 14.62 | 697 | 33.78 | 54.90 | 40.25 | -2.94 | -12.68 |
| TUMSA | 2010 | 3701 | 3.99 | 19.45 | 744 | 42.80 | 65.34 | 28.53 | -31.20 | -38.10 |

Fertilizer was applied at blanket rates of 18 kg N and 46 kg $P_2O_5$ $ha^{-1}$ in the form of DAP (Diammonium phosphate) at planting. Other agronomic practices were kept as non-experimental variables and applied uniformly to all plots. The middle two rows with net plot area of 3.2 $m^2$ were used for yield data collection. Seed size (g) was recorded as weight of 1000 random seeds. Severity of chocolate spot disease was recorded using a 1-9 rating scale, 1 being highly resistant and 9 highly susceptible. Grain yield data (g $plot^{-1}$) was converted into kg $ha^{-1}$ at 10% adjusted grain moisture content for statistical analysis.

### *Statistical analysis*

The data were subjected to analysis of variance (ANOVA) using the PROC GLM procedure of SAS version 9.0 (SAS Institute Inc., 2002) to determine the existence of significant differences between the faba bean genotypes. The following model was used for combined ANOVA:

$Y_{ijk} = \mu + G_i + E_j + GE_{ij} + B_{k(j)} + \epsilon_{ijk}$

where $Y_{ijk}$ is an observed value of genotype *i* in block *k* of environment *j*; $\mu$ is a grand mean; $G_i$ is effect of genotype *i*; $E_j$ is an environmental effect; $GE_{ij}$ is the interaction effect of genotype *i* with environment *j*; $B_{k(j)}$ is the effect of block *k* in environment *j*; $\epsilon_{ijk}$ is an error effect of genotype *i* in block *k* of environment *j*. Chocolate spot scores based on (1-9) scale were pre-transformed to percentage values, which then ARCSINE transformed for analysis of variance as suggested by Little and Hills (1978). Error mean squares from each environment were tested for homogeneity of variance to ensure that the combined analysis of variance across environments was appropriate. Separation of the main effect was done using Least Significant Difference (LSD) at 5% probability level.

The magnitude of genetic progress from breeding was estimated by regressing the mean performances of the genotypes at all environments on years of varietal release using 1977, when the first variety was released, as the base year (Cox et al. 1988) as:

$Y = bx + a$

where $Y$ = mean value of the dependent variable, $x$ = mean value of the independent variable, $a$ = the constant, and $b$ = the regression coefficient.

A straight line was fitted through the points using simple linear regression and the resultant coefficients of regression of genotype mean performances on the years of varietal release were used as estimates of the annual genetic progress calculated as:

Annual rate of breeding gain $(b) = Cov\ xy/Var\ x$,

where $x$ = year of variety release, $y$ = mean value of each character for each genotype, *Cov* = the covariance of $x$ and $y$; and *Var*= the variances of $x$ and $y$.

The relative genetic gain was calculated as a function of the regression coefficients of the respective traits and total number of years of breeding period, expressed as percentage of oldest variety in the trial.

## Conclusion

Information on the magnitude of genetic progress from breeding a crop species is absolutely essential as it enables to revise the efficiency of past approaches, define future directions and design more sound breeding strategies. The response of seed size to past faba bean breeding efforts in Ethiopia was far better than that of grain yield and chocolate spot resistance. Chocolate spot resistance also better responded to breeding than grain yield. This could be attributed to the existence of uniquely better donor parents for larger seed size and chocolate spot resistance in introduced materials from ICARDA. The lesser genetic progresses from breeding faba bean for grain yield, on the other hand, may be attributed to the more polygenic nature of the trait compared to seed size and chocolate spot and the exceptionally stable and better adaptation of the reference variety, CS20DK. It was repeatedly noted that genotypes introduced from ICARDA were found to be consistently large-seeded and resistant to chocolate spot but could not mostly be considered for direct release in Ethiopia because of inferior agronomic and adaptive performances. It is, therefore, advisable that breeding efforts in the future variety development program should give due attention to building on the shortcomings of widely adapted varieties like CS20DK to complement/supplement them.

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