Genetic Progress for Yield and Yield Components and Reaction to bean Anthracnose (*Colletotrichum lindemuthianum*) of Large-Seeded Food Type Common Bean (*Phaseolus vulgaris*) Varieties in West Shoa Zone, Ethiopia

Solomon Bekele [1], Firew Mekbib[2], Gemechu Keneni[3], and Birhanu Amsalu[4]

[1] Bako Agricultural Research Center, P. O. Box 03, Bako, Ethiopia
[2] Haramaya University, P.O.Box 138, Dire Dawa, Ethiopia
[3] Holeta Agricultural Research Center, P. O. Box 31, Holeta, Ethiopia
[4] Melkasa Agricultural Research Center, P.O.Box 436, Melkasa, Ethiopia

Abstract: Fourteen common bean (*Phaseolus vlgaris* L.) varieties that were released in Ethiopia from 1997 to 2012 as large-seeded food type common bean varieties were evaluated with the specific objectives to: (1) estimate the genetic progress made in 15 years of common bean breeding in Ethiopia; (2) assess changes in associated traits in the genetic improvement of common bean varieties released in Ethiopia; and (3) assess the reaction of common bean varieties to bean anthracnose [*Clletotrichum lindemuthianum* (Sacc. and Magnus) Briosi and Cavara]. The study was conducted at two locations, Bako and Gute during 2014/2015 main cropping season in a randomized complete block design (RCBD) with three replications. Days to 50% flowering (DF), Days to 90% maturity (DM), Grain filling period (GFP), Hundred Seed weight (HSW), Biomass yield (BMY), Grain yield per plot (GY), Harvest index (HI), Biomass production rate (kg/ha/day), Seed growth rate (kg/ha/day), Grain yield per day (kg/ha/day) and Anthracnose (1-9) scale data were collected on plot basis and Plant height, Number of pods per plant, Number of seeds per pod, Number of seeds per plant and grain yield per plant data's were collected on plant basis. Statistical data analyses were performed for biomass yield, grain yield, seed weight, harvest index and bean anthracnose severity. Combined analysis of variance showed highly significant differences among the common bean varieties and between test environments for hundred seed weight. The VXL interaction of seed weight did not show significant difference among the varieties. Regression analysis of mean performance at both environments on year of varietal release showed positive relationship for seed weight (r = 0.08), biomass yield (r = 0.04) and anthracnose disease severity (r = 0.10) but negative relationship for grain yield (r = -0.38), and harvest index (r = -0.37). The highest overall locations mean average of grain yield was 2679.5 kg ha^{-1} for Ayenew and the lowest was 1050.2 kg ha^{-1} for GLP-2, the grand mean being 1806 kg ha^{-1}. The annual rates of genetic progresses were 12.7 kg ha^{-1} (0.13% ha^{-1} year^{-1}), -48 kg ha^{-1} (-0.39%), 0.68 g 100 seed^{-1} year^{-1} (0.34% 100 seed^{-1} year^{-1}), -0.004% and 0.39% for biomass yield, grain yield, seed weight, harvest index and anthracnose disease severity, respectively. Generally, the grain yield was reduced in the period of genetic improvement, due to the consistent performance of the reference variety Gofta. Stepwise regression indicated that grain yield day^{-1} (82.5%) and days to mature (21.8%) explained more for the variation of grain yield; but, seed size (-40.2%) was more important cause for grain yield reduction than bean anthracnose (-9.3%). It could, thus, be concluded that the yield of large seeded food type common bean varieties were reduced due to anthracnose and its large seeded for the last fifteen years (1997- 2012) of breeding; in future also managing the disease; especially, anthracnose disease will be crucial and Ayenew (26.79.5 kg ha^{-1}), Gofta 2627.1 kg ha^{-1}) and Fedis (2180.6 kg ha^{-1}) are recommended for production in the study areas.

Keywords: Anthracnose disease severity; canning type; Colletotrichum lindemuthianum; common bean; genetic progress; large-seeded; Phaseolus vulgaris; relative genetic gain; stepwise regression.

1. Introduction

Common bean (*Phaseolus vulgaris* L., 2n = 22), also referred to as dry bean, is an annual leguminous plant that belongs to the genus *Phaseolus,* with pinnately compound trifoliate large leaves. In Ethiopia, it is most likely that the Portuguese introduced the crop in the 16th century (Wortman, 1997). Common bean is grown throughout Ethiopia and is increasingly an important commodity in the cropping systems of smallholder producers (the average farm size for smallholder farmers is between 0.25 to 0.5 hectares) for food security and income. Common bean has also health benefits being rich in protein content (about 23% for dried shelled beans and about 6% for green beans) and serving as a good source of iron and zinc (both of which are key elements for mental development). The area covered by common bean production in Ethiopia was 113,249.95 ha and 244,049.94 ha for white and red common bean respectively with total area of 357,299.89 ha and total

*Corresponding Author. E-mail: slmnbkl092@gmail.com

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production of about 540,238.94 tons/ha and national average yield was 1600 kg/ha (CSA, 2016). Common bean is mainly grown in Eastern, Southern, South Western and the Rift valley areas of Ethiopia (CSA, 2016). Beans need up to four months of warm weather and are not frost tolerant. They do poorly in very wet or humid tropical climates because of susceptibility to bacterial and fungal diseases. They need well-drained soils with a pH between 6.5 and 7.0 and are sensitive to deficiencies or high levels of minerals in the soil (Broughton *et. al.*, 2003).

There is a wide range of common bean types grown in Ethiopia, including white, mottled, red, and black varieties. The most commercial varieties are pure red and pure white colored beans and these are becoming the most commonly grown types with increasing market demand (Ferris and Kaganzi, 2008). To support both the growth in domestic and export bean markets, the Ethiopian Institute of Agricultural Research (EIAR) has developed a range of high yielding, multi-disease resistant bean varieties. They are major sources of proteins in the lowlands where they are consumed as Nifro, Wasa, Shirowat, Soup and Samosa. Currently, according to the Ministry of Agriculture report on crop variety registered book in 2014, around 50 common bean varieties are under production; additionally, five new varieties (SER 119, SER 125, Tatu, Waju and Ramada) that were released in 2014 are now under production (MoA, 2014).

Common bean production is constrained by several biotic and abiotic environmental stresses. Biotic (field and post-harvest pests and plant diseases) and a biotic (drought, excessive rain/flooding, poor soil fertility, heat and cold stressors) factors are known to cause significant reductions in grain yields (Wortmann *et al.*, 1998). Bean anthracnose [*Colletotrichum lindemuthianum* (Sacc. & Magnus) Briosi & Cavara] poses a major constraint on the production of dry bean in Ethiopia. Bean anthracnose develops early in the growing season and produces brown to black lesions along the veins of the lower leaves. Rain spreads the spores of *C. lindemuthianum* to neighboring plants and further up into the canopy onto the stems and pods, resulting in the formation of brown to black sunken lesions on which the spore-bearing acervuli are formed. A study by Tesfaye B (1997) stated that yield loss up to 62.8% due to anthracnose was recorded in Ethiopia on susceptible cultivars of common bean like Mexican-142, Awash-1 and Awash Melka.

Yield refers to the mass of product at final harvest, for which dry matter content should be specified. Yield potential is the yield of a cultivar when grown in environments to which it is adapted, with nutrients and water non-limiting and with pests, diseases, weeds, lodging, and other stresses effectively controlled. This definition of yield potential is based on the notion that there are yield genes and stress-resistance genes and that a yield potential measurement attempts to measure only the effects of the yield genes. In measuring progress in genetic yield potential, complications can arise as a result of the possibility of interactions between cultivar and growing conditions (Evans and Fischer, 1999).

Knowing the information on genetic progress achieved by a crop over time from a breeding program is absolutely essential to develop effective and efficient breeding strategies by assessing the efficiency of past improvement works in genetic yield potential and suggest on future selection direction to facilitate further improvement (Waddington *et al.*, 1986; Donmez *et al.*, 2001; Many investigators did the genetic progress of common bean and they clarify its positive response; but, they don't did by classifying according to its seed size and my study reveals negative to their response regarding genetic progress. The focus of this genetic progress work has been on the large-seeded food type common bean varieties with the specific objectives to estimate the genetic progress made in improving yield potential of common; bean varieties; to assess changes in associated traits in the genetic improvement of common bean varieties released in Ethiopia; and to assess the reaction of common bean varieties to bean anthracnose in Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area

The field experiments were carried out at two locations, i.e. Bako and Gute, West Shoa Zone of Oromia Regional State, located 250 and 316 km, respectively, to west of Addis Ababa. The weather (temperatures and relative humidity) and edaphic conditions of the test locations are summarized and tabulated hereunder (Table 1).

Table 1. Description of the test locations for geographical position and physic-chemical properties of the soils.

Parameters		Locations	
		Bako	Gute
Geographical position	Latitude	09o6'N	09o5'30,N
	Longitude	37o09'E	36o42'0'E
	Altitude (m.a.s.l.)	1650	1918
Edaphic characters	Soil type	Utisols	Nitosols
	Soil pH	4.8-5.8	4.5-5.5
Weather characters	Minimum T.(oC)	13.5	25
	MaximumT. (oC)	28.5	30
	Mean T. (oC)	21.0	27.5
	RH (%)	48.4	57.3
	ARF (mm)	1067.1	1350

*T** = temperature; ARF = Annual rainfall

Source: Meteorological Data of Bako Agricultural Research Center (2014)

2.2. Treatments/Experimental Materials

Fourteen large-seeded food type of common bean varieties that released between 1997 and 2012 from different Agricultural Research Centers in different regions of Ethiopia were used. Seeds of the common bean test varieties were obtained from Bako, Melkasa, and Sirinka Agricultural Research Centers and Haramaya University. The detailed descriptions of the common bean varieties used in the experiment are summarized and depicted in a tabular form hereunder (Table 2).

Table 2. Descriptions of the large-seeded food type common bean varieties used in the study at Bako and Gute, West Shoa Zone in 2014/15 main cropping season.

S. No.	Varieties	Year of release	Maturity Days	Yield (kg ha^{-1})	Crosses/ seed source
1	Gofta	1997	79.2	2627.1	HU
2	Ayenew	1997	82.8	2679.5	HU
3	Melke	1998	85.0	1928.7	Cross 14 MARC/EIAR
4	Ibado	2003	82.0	1464.8	SARI
5	Red kidney	2007	77.7	1473.2	MARC/EIAR
6	Kufanzik	2008	78.8	2079.8	HU
7	Loko	2009	84.0	1630.4	BARC
8	GLP- 2	2011	81.2	1050.2	MARC/EIAR
9	Morka	2011	85.8	1633.8	MARC/EIAR
10	Hirna	2012	87.3	1455.4	HU
11	Hundane	2012	84.8	1825.9	HU
12	Babile	2012	82.3	1707.4	HU
13	Tinike	2012	85.5	1549.2	HU
14	Fedis	2012	85.7	2180.6	HU

Note: MARC = Melkasa Agricultural Research Center, EIAR = Ethiopian Institute of Agricultural Research, HU = Haramaya University, BARC = Bako Agricultural Research Center, SARI = Sirinka Agricultural Research Institute.

2.3. Experimental Design and Field Management

The experiments were conducted at Bako and Gute during the 2014 main cropping season.A plot of 6.4 m^2 consisting of 4 rows of 4 m length with 0.4 m spacing between rows was used. A distance of 0.5 m was maintained between plots and 1 m between blocks. A seed rate of 100 kg ha^{-1} was used; 160 and 40 seeds were administered to each plot and each row, respectively. The two middle rows were used for data collection. The treatments were arranged in a randomized complete block design (RCBD). Fertilizer was applied at the rate of 100 kg ha^{-1} diammonium phosphate (18 kg N ha^{-1}, 46 kg P_2O_5 kg ha^{-1} and 0 k) and all other crop management practices were carried out as recommended.

2.4. Data Collection

2.4.1. Collected data on plot basis

Days to 50% flowering (DF): Number of days from planting to the date on which 50% of plants on the two middle rows produced at least their first flowers.

Grain filling period (GFP): The number of days between days to flowering and days to physiological maturity.

Days to 90% physiological maturity (DM): The number of days from planting to the stage when 90% of the plants in a plot have reached physiological maturity, i.e., the stage at which pods lost their pigmentation and began to dry.

Biomass yield (BMY): Determined by weighing the total air-dried above ground biomass yield of plants in the two middle rows.

Hundred Seed weight (HSW): Weight of 100 seeds were counted from each plot and weighted.

Grain yield per plot (GY): Grain yield in kilogram of plants from the two middle rows and adjusted to 10% moisture level and then it was converted to kg ha^{-1}.

Harvest index (HI): Proportion of dry grain yield to the aboveground biological yield (biomass yield) was calculated as follows:

$$HI = \frac{\text{Grain yield}}{\text{Biomass yield}} \quad (1)$$

$$\text{Biomass production rate (kg ha}^{-1}\text{ day}^{-1}) = \frac{\text{Above ground biomass yield}}{\text{Days to physiological maturity}} \quad (2)$$

$$\text{Seed growth rate (kg/ha/day)} = \frac{\text{Grain yield (Kg/ha)}}{\text{Days to grain filling period}} \quad (3)$$

$$\text{Grain yield per day (kg/ha/day)} = \frac{\text{Grain yield (kg/ha)}}{\text{Days to physiological maturity}} \quad (4)$$

Bean anthracnose severity: Bean anthracnose severity (1-9 scales) was pre-transformed into percentage values and then percentage values were Arcsine transformed for statistical data analysis (Little and Hills, 1978).

2.4.2. Collected data on plant basis

Plant height (cm): The plant heights of five randomly taken plants from each of the two middle rows were measured from the ground level to the tip of the plant at physiological maturity and expressed as an average of heights of five plants per plot.

Number of pods per plant: The number of pods per plant was counted from five randomly taken plants from the middle two rows and expressed as an average for each plot.

Number of seeds per pod: Number of seeds was counted from five random pods from each of five randomly taken plants per plot and expressed as an average of five plants per plot.

Number of seeds per plant: It was determined by multiplying the number of pods per plant and number of seeds per pod.

Grain yield per plant (g): The average seed yield in grams obtained from five randomly taken plants in each plot.

3.5. Statistical Data Analysis

All the measured variables were subjected to analysis of variance (ANOVA) following Gomez and Gomez (1984). The General Linear Model (GLM) of SAS Statistical Package Version 9.2 Software **(SAS, 2009)** was employed for the analysis. The following model was used for computing the analysis of variance.

For over location Anova = $p_{ijk} = \mu + b_i + v_j + l_k + (vl)_{jk} + e_{ijk}$ (5)

Where p_{ijk}= phenotypic observation on variety j in block i at location k (i = 1…B, j = 1…V, and k = 1…L) and B, V and L stand for number of blocks, varieties and location, respectively, μ = grand mean, b_i= the effect of block i with in location k, v_j = the effect of variety j, l_k = the effect of location k, $(vl)_{jk}$ = the interaction effect between variety and location, and e_{ijk} = error.

For individual location ANOVA = $Y_{ij} = \mu + V_i + B_j + e_{ij}$ (6)

Where: Yij = observed value of variety i in block j, μ= grand mean of the experiment, Vi = effect of variety i, Bj = effect of block j, eij = error effect of variety i in block j. Least significant difference (LSD) was used to separate treatment means when analysis of variance showed significant differences at 5% probability level.

Least significant difference means for significantly different interaction effects were separated by SAS model (P = 0.05). The homogeneity of error mean squares between the two locations was tested by F-test on variance ratio and combined analyses of variance were performed for the traits whose error mean squares were homogenous (when the error mean square of one location less than by three-fold the error mean square of the second location) using PROC GLM procedure of SAS. The annual rate of genetic gain achieved from past breeding efforts in grain yield and the associated agronomic traits was calculated by regressing the mean performance of each variety on the year of release (expressed as the number of years since 1973) for that variety. The relative annual gains achieved over the years of releases in different characters were determined as the ratio of annual genetic gain, which was estimated from regression to the corresponding estimated values of the oldest variety and expressed as percentage.

$$\text{Annual rate of gain (b)} = \frac{CovXY}{VarX} \quad (7)$$

Where X = the year of variety release, Y = the mean value of each character for each variety, Cov = covariance and Var = variance.

Correlation coefficients among all characters were calculated using means of each character as:

$$\text{CC between X and Y } (r_{xy}): \frac{Cov(X,Y)}{\sqrt{Var(X)Var(Y)}} \quad (8)$$

Where: CC = Correlation coefficient; r_{xy} = correlation coefficient between X and Y, Cov(X, Y) = covariance between X and Y, Var (X) = variance of X and Var (Y) = variance of Y.

Stepwise regression analysis was carried out on the varietal mean using PROC STEPWISE in MINITAB to determine those traits that contributed much to yield variation among varieties by using grain yield (response) as dependent variable and the other characters (predictors) as independent variable.

3. Results and Discussion

3.1. Analysis of Variance

The combined analysis of variance of large-seeded food type of common bean varieties showed that variety by location interaction was highly significant (p≤0.01) differences for seed growth rate, yield (gram plant^{-1}), grain filling period and days to 50% flowering and significant (p≤0.05) for grain yield per day, number of seeds per plant, number of seeds per pod and number of pods per plant (Table 3).

3.2. Performance of the Varieties

The combined mean performance of hundred seed weight ranged from the lowest 25.63 g for Ayenew to the highest 51.65 g for Fedis variety, the grand mean being 40.7 g (Table 4). This clearly indicated that common bean varieties released as large-seeded food type in Ethiopia so far had significant variation for seed weight trait to be exploited in the future breeding programs.

3.3. Genetic Progresses from Breeding

3.3.1 Grain Yield

There was an average reduction by 720.9 kg ha^{-1} (5.94%) in grain yield for large-seeded food type of common bean varieties for the past 15 years (Table 5) or an annual rate of genetic reduction by 48.06 kg ha^{-1} (0.39% ha^{-1} year^{-1}), computed using the first released variety, Gofta, as a reference (Table 5 and Figure 1). This is in contrast with the finding of Kebere *et al.* (2006) who reported that the average relative annual gain in grain yield of haricot bean varieties since 1972 was 3.24% year^{-1}, or about 84.24% for the whole period of 26 years and barley (1.34% ha^{-1} year^{-1}), (Fekadu *et al.*, 2011).

Table 3. Mean squares from the combined analysis of variance of 14 large-seeded food type of common bean varieties evaluated over two locations in West Shoa during 2014 main cropping season

Characters	Source of Variations					Mean	CV (%)	R^2
	Location (1)	Replication (2)	Variety (13)	VxL (13)	Error (26)			
Days to Flowering (DF)	**	NS	**	**	0.96	36.3	2.7	0.94
Days to Maturity (DM)	**	NS	**	NS	4.59	83	2.6	0.79
Plant Height (PH)	**	NS	**	*	102.59	57.3	17.66	0.84
Number of Pods per Plant (NPPP)	**	NS	**	*	4.9	10.7	20.6	0.69
Number of Seeds per Pod (NSPP)	**	NS	**	NS	0.27	4.2	12.6	0.58
Number of Seeds per Plant (NSPPT)	**	NS	**	*	133.92	44.3	26.1	0.63
Pod Length (PL)	**	NS	**	NS	0.55	10.6	7.0	0.84
Grain Filling Period (GFP)	NS	NS	**	**	6.62	47.7	5.4	0.6
Yield in Gram per Plant (YGPT)	**	*	**	**	25.24	18.4	27.3	0.69
Hundred Seed Weight (HSW)	**	*	**	NS	17.54	40.7	10.3	0.85
Biomass Production Rate in kg ha^{-1} day^{-1} (BMPR)	**	*	**	NS	242.3	68.2	22.8	0.78
Seed Growth Rate in kg ha^{-1} day^{-1} (SGR)	**	**	**	**	65.8	37.9	21.4	0.84
Grain Yield per Day in kg ha^{-1} (GYD)	**	**	**	*	21.84	22	21.3	0.85

Several similar reports indicated high increases in grain yields of some crops in other countries, like Northeast China where high annual yield increase of 0.58% ha^{-1} per year was obtained from breeding soybean (Jin, *et al.*, 2010); Canada where 0.45% ha^{-1} per year increase was obtained from breeding soybean (Morrison, *et al.*, 2000); and England where 0.39% ha^{-1} per year increase was realized from barley breeding for over hundred years (Riggs, *et al.*, 1981). On the other hand, the finding of the present study is in agreement with the investigation by Egli (2008) who stated that very low grain yield, which was explained in the "attainment of yield plateaus", was also obtained from soya bean breeding in western USA. Previously, it was reported that cultivar seed size and yield potential of common bean were negatively associated (Peter. *et. al.*, 1994). Here in the current study, among large-seeded food type common bean varieties, Gofta and Ayenew were released in the same year, 1997; but, the variety Gofta was chosen as a reference variety to compare and contrast with the other tested common bean varieties since it has an advantage over the variety Ayenew for its high yielding potential when it was released and has been extensively distributed to the farmers by its hosting institution, Haramaya University.

Non-consistent gradual reduction of yield of this large-seeded food type of common bean varieties across recently released varieties (Table 6) implies that common bean breeding in our country needs future attention for better responses through different breeding strategies, like crossing. For example, if we compare the mean grain yield (2627.1 kg ha^{-1}) (Table 6) of Gofta, which is one of oldest released common bean varieties, and the mean grain yield (1050.2 kg ha^{-1}) of GLP-2, the recently released variety, the mean grain yield of the latter was less by 1576.9 kg ha^{-1} (59.1%) than the grain yield of Gofta. On the other hand, the mean grain yield (1455.4) kg ha^{-1}) of Hirna variety, the most recently released variety, was less by 1171.7 kg ha^{-1} (44.6%) than the mean grain yield (2627.1 kg ha^{-1}) of Gofta variety (Table 6). Only the variety Ayenew, which was released in the same year 1997, exceeded by 52.4 kg ha^{-1} (2%) the mean grain yield (2679.5 kg ha^{-1}) of the variety Gofta. The possible main reasons for the lower genetic progresses made for these large-seeded food type common bean varieties were the stability and better adaptation of the first released variety, Gofta (Table 6). Therefore, to bring the drastic change for large-seeded common bean varieties through breeding, the Ethiopian researchers are advised to apply rigorous breeding strategies like earlier study when Gofta and Ayenew varieties were first released and to come up with other promising varieties both in yield and disease resistant.

Table 4. Mean performance of the varieties from combined analysis for hundred seed weight of large-seeded food type common bean varieties at Bako and Gute, West Shoa, in 2014/2015 main cropping season.

S.No.	Large-seeded food type common bean varieties	100 Seed weight (g)
1	Gofta	29.36
2	Ayenew	25.63
3	Melke	42.76
4	Ibado	44.63
5	Red kidney	47.78
6	Kufanzic	30.26
7	Loko	46.05
8	GLP-2	45.91
9	Morka	43.63
10	Hirna	45.03
11	Hundane	42.13
12	Babile	37.01
13	Tinike	38.01
14	Fedis	51.65
	Mean	40.7
	LSD (5%)	4.8

Table 5. Annual relative genetic gain (ANRGG) and average relative genetic gain (ARGG) in % compared to the oldest variety Gofta of large-seeded food type common bean variety. Trends in genetic progress obtained from breeding common bean for biomass yield, grain yield, seed size, harvest index and anthracnose severity during the past 15 years

Characters	Characters						
	Mean square of regression	Regression coefficient (b)	P-value	Coefficient of determination (R^2)	Gain in 15 years kg ha^{-1}	ANRGG year^{1} (%)	ARGG (%)
Biomass yield (kg ha^{-1})	75081.9	12.7	0.86	0.004	190.5	0.13	2.04
Grain yield (kg ha^{-1})	1059099	-48	0.02	0.38	-720.9	-0.39	-5.94
Seed weight (g)	215.52	0.68	0.05	0.28	10.2	0.34	5.16
Harvest index (%)	0.008	-0.004	0.021	0.37	-0.06	-1.11	-16.61
Bean anthracnose severity (%)	71.5	0.39	0.26	0.107	-5.85	-0.07	-1.10

3.4 Associations of Characters

The correlation coefficient is the measures of degree of symmetrical association between two traits and it is used for understanding the nature and magnitude of association among yield and yield components. Association between any two traits or among various traits is of very importance to make desired selection of combination of traits (Ahmad *et al*., 2003). Therefore, the correlated characters for each other of large-seeded food type of common bean varieties are tabulated hereunder (Tables 7).

Table 6. Mean performance and their percentage increase in biomass yield (kg ha^{-1}), grain yield (kg ha^{-1}), seed weight (g), harvest index (%),and bean anthracnose severity (%) of large-seeded food type common bean varieties released during the past 15 years compared to the first released variety Gofta.

Varieties	Year of release	Characters												
		Grain yield			Seed weight			Harvest index		Biomass yield			Anthracnose severity	
		Mean weight (kg ha^{-1})	Increase over Gofta variety Kg ha^{-1})		Mean Weight (g)	Increase over Gofta variety (g 100^{-1} seeds, %)		Mean Index (%)	Increase over Gofta variety (%)	Mean Yield (kg ha^{-1})	Increase over Gofta variety (Kg ha^{-1})		Mean severity (%)	Reduction from Gofta variety (%)
Gofta	1997	2627.1	-	-	29.36	-	-	0.39	-	5416.7	-	-	10.14	-
Ayenew	1997	2679.5	52.4	2	25.63	-3.73	-12.7	0.34	-12.8	6041.7	625	11.5	18.54	-82.8
Melke	1998	1928.7	-698.4	-26.6	42.76	13.4	45.6	0.27	-30.8	6302.1	885.4	16.3	13.48	-32.9
Ibado	2003	1464.8	-1162.3	-44.3	44.63	15.27	52	0.27	-30.8	5364.6	-52.1	-1	11.85	-16.8
Red kidney	2007	1473.2	-1153.9	-44	47.78	18.42	62.7	0.30	-23.1	4166.7	-1250	-23.1	11.85	-16.8
Kufanzic	2008	2079.8	-547.3	-20.8	30.26	0.9	3	0.30	-23.1	5052.1	-364.6	-6.8	23.7	-133.7
Loko	2009	1630.4	-996.7	-38	46.05	16.69	56.8	0.28	-28.3	5156.3	-260.4	-4.8	10.14	-
GLP-2	2011	1050.2	-1576.9	-59.1	45.91	16.55	56.4	0.29	-25.7	3385.4	-2031.3	-37.5	20.28	-100
Morka	2011	1633.8	-993.3	-37.8	43.63	14.27	48.6	0.30	-23.1	5468.8	52.1	1	11.85	-16.8
Hirna	2012	1455.4	-1171.7	-44.6	45.03	15.67	53.4	0.23	-41.1	7864.6	2447.9	45.2	36.9	-263
Hundane	2012	1825.9	-801.2	30.5	42.13	12.77	43.5	0.28	-28.3	6406.3	989.6	18.3	20.3	-100.2
Babile	2012	1707.4	-919.7	-35	37.01	7.65	26	0.30	-23.1	4947.9	-468.8	-8.7	13.57	-33.8
Tinike	2012	1549.2	-1077.9	-41.1	38.01	8.65	29.5	0.24	-29.5	6250	833.3	15.4	15.2	-49.9
Fedis	2012	2180.6	-446.5	-17	51.65	22.29	75.9	0.27	-30.8	7500	2083.3	38.5	16.9	-66.7

Table 7. Correlation coefficients (r-values) of yield and yield related traits of large-seeded food type common bean varieties.

Characters	DF	DM	PH	NPPP	NSPP	NSPPT	PL	GFP	YGPT	SW	HI	BMPR	BMY	SGR	GYD	GY	ANSIV
DF	-	0.59	0.17	-0.19	0.05	-0.17	0.07	-0.35**	-0.15	-0.10	-0.34**	-0.26*	-0.19	-0.32**	-0.41**	-0.36**	-0.19
DM		-	0.01	-0.01	-0.01	-0.03	0.01	0.54**	0.13	0.20	-0.50**	0.08	0.19	-0.32**	-0.33**	-0.23*	0.08
PH			-	0.45**	0.01	0.44**	0.12	-0.16	0.17	-0.33**	0.29**	0.34**	0.32**	0.48**	0.45**	0.45**	0.18
NPPP				-	0.15	0.91**	0.24*	0.14	0.75**	0.04	0.28**	0.29**	0.27*	0.42**	0.43**	0.44**	0.04
NSPP					-	0.42**	-0.17	-0.07	0.22*	-0.24*	0.29**	-0.33**	-0.33**	-0.04	-0.05	0.06	-0.16
NSPPT						-	0.12	0.14	0.78**	-0.04	0.34**	0.16	0.15	0.36**	0.37**	0.38**	0.01
PL							-	-0.07	0.29**	0.48**	-0.17	0.25**	0.24*	0.07	0.06	0.06	0.07
GFP								-	0.30**	0.34**	-0.22*	0.37**	0.43**	-0.02	0.05	0.12	0.29**
YGPT									-	0.39**	0.03	0.22*	0.23*	0.18	0.20	0.23*	0.03
SW										-	-0.49**	0.31**	0.33**	-0.17	-0.14	-0.10	0.02
HI											-	-0.11	-0.18	0.66**	0.65**	0.60**	-0.25*
BMPR												-	0.99**	0.62**	0.65**	0.68**	0.39**
BMY													-	0.56**	0.59**	0.64**	0.40**
SGR														-	0.99**	0.98**	0.00
GYD															-	0.99**	0.03
GY																-	0.04
ANSEV																	-

Note: ** and *, highly significant at $p \leq 0.01$ and significant at $P \leq 0.05$ respectively; and Values with no asterisks are insignificant;
DF = Days to 50% flowering, DM = Days to maturity, PH = Plant height (cm), NPPP = Number of pods plant^{-1}, NSPP = Number of seeds pod^{-1}, NSPPT = Number of seeds plant^{-1}, PL = Pod length (cm), GFP = Grain filling period, YGPT = Yield gram plant^{-1}, SW = Seed weight (g), HI = Harvest index (%), BMPR = Biomass production rate(kg ha^{-1}), BMY = Biomass yield (kg ha^{-1}), SGR = Seed growth rate (kg ha^{-1}), GYD = Grain yield (day^{-1} kg ha^{-1}), GY = Grain yield (kg ha^{-1}+, ANSEV = Anthracnose severity (%)

The association of characters of large-seeded food type common bean varieties ranged from -0.50 to 0.99 (Table 7). Grain yield was negatively associated with days to flowering (r = -0.36**) and days to physiological maturity (r = -0.23), while it was positively correlated with plant height (r = 0.45**), number of pods per plant (r = 0.44**), biomass yield (r = 0.64**), biomass production rate in kilogram per day (r = 0.68**), number of seeds plant^{-1} (r = 0.38**), seed growth rate in kilogram per day (r = 0.98**), grain yield in kilogram per day per hectare (r = 0.99**), harvest index (r = 0.60**) (Table 7). Similarly, correlation between grain yield with grain yield per day (White and Izquierdo, 1991), with grain yield per day and biomass production rate were highly correlated (Waddington *et al*., 1987; Teklu, 1998).

Some authors also stated that grain yield was related positively with biomass yield; for instance, Kebere *et al.* (2006) on haricot bean; Laing *et al.* (1984) and Salado-Navaro *et al*. (1993) on soybean; and Teklu (1998) on tef, obtained similar results. But, the findings of these authors indicated that grain yield showed no association with harvest index on their respective studied crops; this contradicts with the present finding. On the other hand, other authors reported that grain yield had positive association with both biomass yield and harvest index (Riggs *et al*., 1981; Waddington *et al*., 1987; Perry and D'Antuono, 1989) and their findings are in agreement with the current study.

In another case study, Tarekegne (1994) stated that no relation between grain yield and biomass yield and positive association between grain yield and harvest index were reported on bread wheat. According to Kebere *et al.* (2006), seed growth rate, grain yield per day and biomass production rate were positively associated with grain yield. As Kebere *et al.* (2006) stated, there was no correlation between grain yield and plant height; but the present finding stated that there was strong association between grain yield and plant height and supported with the finding of Riggs *et al.* (1981) who reported positive association in wheat and negative association in spring barley, respectively, between grain yield and harvest index. Grain yield was positively correlated with grain yield per plant (r = 0.23*) and negatively correlated with days to physiological maturity (r = -0.23*) (Table 7). The current finding revealed that grain yield had no association with number of seeds per pod (r = 0.06), pod length (r = 0.06), grain filling period (r = 0.12) and hundred seed weight (r = -0.10).

Similar results were reported by Kebere *et al.* (2006) who stated that there was no association among grain yields and number of seeds per pod, pod length and hundred seed weight. Several authors also observed no association between grain yield and hundred seed weight (Riggs *et al*., 1981; Waddington *et al*., 1987; White and Izquierdo, 1991; Tarekegne, 1994; Teklu, 1998). In contrast, positive correlations were recorded for grain yield with the number of seeds per pod and mean seed weight in soybean (Karmakar and Bhatnagar, 1996), with the number of grains per ear in wheat (Waddington *et al*., 1987; Perry and D'Antuono, 1989). According to this finding, plant height (r = 0.45**), number of pods per plant (r = 0.44**), number of seeds per plant (r = 0.38**), harvest index (r = 0.60**), biomass production rate in kilogram per hectare per day (r = 0.68**), biomass yield in kg per hectare (r = 0.64**), seed growth rate in kilogram per hectare per day (r = 0.98**) and grain yield per day in kilogram per hectare (r = 0.99**) were highly correlated with grain yield (kg ha^{-1}); so, plant breeders can possibly increase the final output by improving these characters, particularly the most interesting character, grain yield.

According to this study, bean anthracnose severity had no association with grain yield for large-seeded food type common bean varieties. But, characters like grain filling period (r = 0.29**), biomass production rate in kilogram per hectare per day (r = 0.39**), biomass yield in kilogram per hectare (r = 0.40**) was highly correlated; while harvest index (r = -0.25*) negatively correlated with anthracnose severity; for the rest studied characters, anthracnose severity had no association (Table 7).

Number of pods per plant and number of seeds plant (r = 0.91**), biomass yield in kilogram per hectare and biomass production rate in kilogram per hectare per day (r = 0.99**), seed growth rate in kilogram per hectare per day and grain yield in kilogram per day per hectare (r = 0.99**), grain yield in kilogram per day per hectare and grain yield in kilogram per hectare (r = 0.99**) and seed growth rate in kilogram per day per hectare and grain yield in kilogram per hectare (r = 0.98**) was strongly associated with each other in these large-seeded food type of common bean varieties during the study season.

Grain yield as a dependent variable, other unmentioned characters as independent variables and the stepwise regression analysis of the large-seeded food type of common bean varieties are tabulated hereunder (Table 8). Grain yield per day and days to physiological maturity were the most important characters that greatly contributed to the variation of grain yield of these common bean varieties (Table 8).

Grain yield per day contributed 82.5%, while days to maturity contributed 21.8% of the total variations in grain yield. On the contrary, seed size and anthracnose severity contributed 40.2 and 9.3%, respectively, for the reduction of grain yield.

Table 8. Summary of selection from stepwise regression analysis of mean grain yield of large-seeded food type common bean varieties as dependent variable on the other traits as independent variables

Independent variable	Grain yield Interception	Regression coefficients (b)	R^2	VIF
Grain yield day^{-1}		-0.643**	0.825	5.03
Days to maturity	-1834	0.177**	0.218	5.03
Seed weight		0.685**	-0.402	4.07
Anthracnose severity		0.395**	-0.093	1.04

Note: ** = Significant difference at $p \leq 0.01$, R^2 = Coefficient of determination and VIF = Variance Inflation Factor

4. Conclusion

The averages over locations grain yield ranged from 1050.2 kg ha^{-1} for GLP-2 variety to 2679.5 kg ha^{-1} for Ayenew. The tested common bean varieties were found to be genetically different. The tested common bean varieties exhibited significant differences for most of the studied characters, and locations also exerted considerable effects on common bean varieties. However, the common bean variety by location interactions on anthracnose severity (%) from large-seeded food made crossover type of interaction as well or the different varieties performed in different way at different locations. The older released varieties were more stable and better adapted than the recent ones; grain yields of large-seeded food type common bean varieties were reduced by 48.06 kg ha^{-1} (0.39%) annually and 720.9 kg ha^{-1} (5.85%) in the period of genetic improvement for the past fifteen years. This is because most of the recent large-seeded food type common bean varieties are released for their type to export than yield production. Relatively, better genetic progress was obtained from breeding large-seeded food type of common bean varieties in Ethiopia in seed size and biomass yield than in grain yield, harvest index and anthracnose resistance for the last 15 years of breeding period.

Therefore, to bring drastic changes in these characters, appropriate breeding strategies should be devised for future research consideration to come up with effective yield gains like crossing. When we consider the past improvement, genetic progress made for large-seeded food type of common bean varieties decreased due to the consistent performance of the first released variety, Gofta and the increase in seed size and anthracnose development as stepwise regression reflected. Therefore, from stepwise regression point of view, grain yield per day would be praised by plant breeders to generate attractive yield; days to maturity also would be considered as well. The homework for the next investigator should be further identification of the important character(s) that contribute more to the variation of grain yield of common bean varieties and including well practicing of crossing for this crop. Big seed size and anthracnose severity were considered as a reason for the reduction of the yield. Therefore, even if big seed size of common bean has a contribution on the market, it has the problem on the reduction of the yield and disease development; especially, anthracnose disease will be considered for the next researcher. Finally, among these evaluated large seeded food type common bean varieties, Ayenew (26.79.5 kg ha^{-1}), Gofta (2627.1 kg ha^{-1}) and Fedis (2180.6 kg ha^{-1}) will be recommended for the area.

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