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Research Article

Genetic Progress for Yield and Yield Components and Reaction to bean Anthracnose (*Colletotrichum lindemuthianum*) of Medium Sized Food Type Common Bean (*Phaseolus Vulgaries* L.) in West Shoa Zone, in Ethiopia

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Abstract

Eleven common bean (*Phaseolus Vulgaris* L.) varieties that were released in Ethiopia from 1998 to 2014 were evaluated as medium seeded food type common bean varieties. The objectives of this study were to: (1) estimate the genetic progress made in 16 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. & Magnus) Briosi & Cavara]. The study was conducted at two locations, Bako and Gute during the 2014/2015 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 a plant basis. Combined analysis of variance showed highly significant differences among the common bean varieties and between test environments for hundred seed weight. The variety by location (VXL) interaction showed highly significant differences in biomass yield, harvest index, days to flowering, grain filling period, and biomass production rate. Regression analysis of mean performance at both environments on year of varietal release showed positive relationship for Gran yield (r = 0.08), Seed weight (r = 0.08) and Harvest index (r = 0.4) but negative relationship for Biomass yield (r = 0.04) and anthracnose disease severity (r = 0.016). The highest mean grain yield was 3008.7 kg ha^{-1} for the Haramaya variety and the lowest was 1708.8 kg ha^{-1} for Ada, with an overall mean of 2271.1 kg ha^{-1}. The annual rate of genetic progress was 22.3 kg ha^{-1} (0.31% ha^{-1}), 0.56g 100 seeds^{-1} year^{-1}, 0.006%, 0.19%, and -60 kg ha^{-1} year^{-1} for grain yield, seed weight, harvest index, anthracnose disease severity, and biomass yield respectively. Generally, grain yield was slightly increased in the period of genetic improvement. Grain yield day^{-1} (90%) character explained more for the variation of grain yield but, anthracnose disease severity played the major role as grain yield did not respond significantly increment by (-33%) than seed weight (-0.01%) from stepwise regression results. The yield of medium seeded food type common bean varieties was increased due to grain yield day^{-1} for the past sixteen years (1998-2014) of breeding. The future crucial consideration will be managing the disease, like anthracnose disease for this common bean class and finally, Haramaya (3008.7 kg ha^{-1}), SER- 125 (2954.8 kg ha^{-1}), and SER-119 (2653.1 kg ha^{-1}) will be recommended for the study area.

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Introduction

There are a wide range of common bean (*Phaseolus vulgaris* L., 2n = 22) 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 [1]. 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 a major source of proteins in the lowlands where they are consumed as 'Nifro', 'Wasa', 'Shirowat', Soup, and 'Samosa'. According to a Ministry of Agriculture report, around 55 varieties were released in 2014 (e.g., SER 119, SER 125, Tatu, Waju, and Ramada were released in 2014) and are currently under production in Ethiopia [2]. The common bean was introduced to Ethiopia during the 16^{th} century [3] and it is an important commodity in the cropping systems of smallholder farmers. The area covered by common bean production in Ethiopia was 113,249.95 ha and 244,049.94 ha for white and red common beans respectively with a total area of 357,299.89 ha and total production of about 540,238.94 tons/ha and a national average yield was 1600 kg/ha [4]. Common bean is mainly grown in Eastern, Southern, South Western, and the Rift valley areas of Ethiopia [4]. 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 their 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 [5].

Common bean production is constrained by several environmental stresses. Biotic (field and post-harvest pests and diseases) and abiotic (drought, excessive rain/flooding, poor soil fertility, heat, and cold stress), each of which causes significant reductions in yield [3]. One of which is anthracnose, caused by the fungus *Colletotrichum lindemuthianum sacc and magnus* poses a major constraint on the production of dry beans in Ethiopia [6] 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 to the canopy and the stems and pods, resulting in the formation of brown to black sunken lesions [6]. In measuring progress in genetic yield potential, complications can arise as a result of the possibility of interactions between cultivars and growing conditions **[7]**.

Knowing the information on genetic progress achieved over time from a breeding program is absolutely essential to develop effective and efficient breeding strategies by assessing the efficiency of past improvement works and suggestions on future selection direction to facilitate further improvement [8,9]. The focus of this genetic progress work was on medium seeded food type common bean varieties with the objectives to A) estimate the genetic progress made in improving the yield potential of common bean varieties; B) assess changes in associated traits in the genetic improvement of common bean varieties released in Ethiopia, and C) assess common bean varieties reaction to anthracnose disease in Ethiopia.

Materials and methods

Description of the study areas

The experiments were carried out at two locations, *viz*, Bako and Gute. The locations are found in West Showa and East Wollega zones of Oromia Regional State located 250 and 316 km, respectively West of Addis Ababa. The weather (temperatures and relative humidity) and edaphic conditions of the test locations are summarized in Table 1.

Experimental materials

Eleven common bean varieties released between 1998 and 2014 from different Agricultural Research Centers in different regions of Ethiopia were used. Seeds of the test varieties were obtained from Bako, Melkasa, and Sirinka Agricultural Research Centers, and Haramaya University. The detailed descriptions of the varieties used in the experiment are summarized in Table 2.

Experimental design and field management

The experiments were conducted at Bako and Gute using a Randomize Complete Block Design (RCBD) with three replications during the main cropping season of 2014. A plot of $6.4m^2$ consisting of 4 rows of 4m length with 0.4m spacing between rows was used. A distance of 0.5m was maintained between plots and 1m between blocks. A seed rate of 80 kg ha^{-1}

Table 1: Description of the test locations for geographical position and physico-chemical properties of the soils

Parameter		Locations	
		Bako	Gute
Geographical position	Latitude	$09^{0}6'N$	$09^{0}5'30,N$
	Longitude	$37^{0}09'E$	$36^{0}42'0'E$
	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 temperature (^{0}C)	13.5	25.0
	Maximum temperature (^{0}C)	28.5	30.0
	Mean temperature (^{0}C)	21.0	27.5
	RH (%)	48.4	57.3
	Annual rainfall (mm)	1067.1	1350

Source: Meteorological Data of Bako Agricultural Research Center (2014) [2]

Table 2: Description of the food type medium seeded common bean varieties used in the study.

S.No.	Variety	Year of release	Grain yield (kg ha-1)	Crosses/ seed source
1	Beshbesh	1998	1778.7	Cross 5 MARC/EIAR
2	Goberasha	1999	2316.1	MARC/EIAR
3	Dimtu	2003	1880.1	MARC/EIAR
4	Dinknesh	2006	2219.7	MARC/EIAR
5	Haramaya	2006	3008.7	HU
6	Gabisa	2007	2180.2	BARC/OARI
7	Ada	2013	1708.8	MARC
8	Dandesu	2013	2122.7	MARC
9	Tatu	2014	2159.4	SRARI
10	SER-125	2014	2653.1	MARC
11	SER-119	2014	2954.8	MARC

Where MARC = Melkasa Agricultural Research Center, EIAR = Ethiopian Institute of Agricultural Research Center, HU = Haramaya University, BARC = Bako Agricultural Research Center, OARI = Oromia Agricultural Research Institute, and SARI = Sirinka Agricultural Research Institute.

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is used; 160 and 40 seeds were administered to each plot and each row, respectively. 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. The two middle rows were used for data collection.

Data collection

Collected data on a 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 flower.

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

Days to 90% 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 begin 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): The weight of 100 seeds was counted from each plot and weighed.**Grain yield per plot (GY):** Grain yield in a kilogram of plants from the two middle rows adjusted to 10 % moisture level and converted to kg ha^{-1}.

Harvest index (HI): Proportion of dry grain yield to the above ground biological yield (biomass yield).

$$\text{i.e. } HI=\frac{\text{Grain yield}}{\text{Biomass yield}}$$

$$\text{Biomass production rate }\left(kgha^{-1}day^{-1}\right)=\frac{\text{Above ground biomass yield}}{\text{Days to physiological maturity}}$$

$$\text{Seed growth rate }\left(kgha^{-1}day^{-1}\right)=\frac{\text{Grain yield(Kg/ha)}}{\text{Days to grain filling period}}$$

$$\text{Grain yield per day }\left(kgha^{-1}day^{-1}\right)=\frac{\text{Grain yield (Kg/ha)}}{\text{Days to physiological maturity}}$$

Bean Anthracnose: Anthracnose disease severity (1-9 scales) was pre-transformed into percentage values and then percentage values were Arcsine transformed for statistical analysis [10].

Collected data on a plant basis

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

The 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.

The number of seeds per pod: The 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.

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

Grain yield per plant: The average seed yield in grams was obtained from five randomly selected plants in each plot and adjusted with 10% moisture.

Statistical analysis

All the measured variables were subjected to analysis of variance following Gomez and Gomez [11]. 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 = $p_{ijk} = \mu + b_i + v_j + l_k + (vl)_{jk} + e_{ijk}$

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 within 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 = $Yij = \mu + Vi + Bj + eij$

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.

The least significant difference (LSD) was used to separate treatment means when analysis of variance showed significant differences ≤ 5% probability level.

The homogeneity of error mean squares between the two locations were tested by the F test on variance ratio and combined analyses of variances were performed for the traits whose error mean squares were homogenous (when the error mean square of one location was 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 were 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 a percentage.

$$\text{The annual rate of gain }(b):\frac{CovXY}{VarX}$$

Where X = the year of variety release, Y = the mean value

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of each character for each variety, Cov = covariance and Var = variance.

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

$$\text{The correlation coefficient between X and Y } \left(r_{xy}\right) : \frac{Cov(XY)}{\sqrt{Var(X)Var(Y)}}$$

Where 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 the dependent variable and the other characters (predictors) as the independent variable.

Results and discussions

Analysis of variance

The combined analysis of variance of medium-seeded food type common bean varieties showed that variety by location interaction had highly significant differences for biomass yield, harvest index, days to flowering, grain filling period, and biomass production rate (Table 3).

Performance of the varieties

The average performance of grain yield of medium seeded food type common bean varieties ranged from the lowest of 1708.8 kg ha^{-1} for the variety Ada to the highest of 3008.7 kg ha^{-1} for Haramaya, with the grand mean of 2271.8 kg ha^{-1} (Table 4). The mean harvest index produced ranged from the lowest percentage value of 0.15 % for the Beshbesh variety to the highest of 0.37 % for Haramaya, the grand mean being 0.3 % (Table 4). The mean average of biomass yield produced ranged from the lowest value of 5416.7 kg ha^{-1} for the Dandesu variety to the highest value of 10156.3 kg ha^{-1} for SER-119, the grand mean being 7490.6 kg ha^{-1} (Table 4). The mean average of anthracnose disease severity ranged from the lowest percentage value of 10.14% for seven varieties (Goberasha, Dimtu, Dinknesh, Haramya, Tatu, SER-125, and SER-119) to the highest value of 33.6 % for Ada respectively, the grand mean being 15 % (Table 4).

The variety by location interactions of harvest index of medium seeded food type of common bean varieties showed significant variation and there is slightly rank order changes among the varieties (i.e. it was a cross-over type of interaction) (Figure 1) and the locations favor and disfavor the tested varieties for this character. The difference between locations and varieties leads to the existence of the variety by location interactions. This indicated that the varieties differentially responded to changes in locations, the locations differentially discriminated against the varieties, or both.

Where environmental differences are great, it may be expected that the V×L interaction will also be great [12]. In such cases, it is not only the average performance of varieties that is important but also the magnitude of the V×L interaction and the consistency of performance across environments. Among the unique features of the Ethiopian environmental conditions is the variation experienced both from season to season and from place to place in the same season over relatively small areas [13].

Genetic progress from breeding of some characters

Grain yield: Past sixteen years, medium seeded food type common bean varieties' breeding efforts in Ethiopia have resulted in an average grain yield increment of 356.8 kg ha^{-1} (5 %) (Table 5) or an annual rate of genetic progress of 22.3 kg ha^{-1} (0.31 % ha^{-1} year^{-1}) (Figure 2a and Table 5) using the first released variety, Beshbesh as a reference (Table 6).

Table 3: Mean squares from combined analysis of variance of 11 medium seeded food types of common bean varieties evaluated over 2 locations during the 2014/2015 cropping season.

Characters	Source of Variations					Mean	CV (%)	R^2
	Location (L) (1)	Replications(Loc) (2)	Variety (V) (10)	VxL (10)	Error (20)			
Days to Flowering (DF)	**	Ns	**	**	1.5	37.6	3.3	0.96
Days to Maturity (DM)	**	*	**	NS	0.92	84.2	1.1	0.97
Plant Height (PH)	*	NS	**	NS	145.98	52.2	23.1	0.80
Number of Pods Per Plant (NPPP)	**	NS	NS	NS	7.24	11.4	23.7	0.54
Number of Seeds Per Pod (NSPP)	**	NS	**	NS	0.33	4.5	12.9	0.68
Number of Seeds Per Plant (NSPPT)	NS	NS	**	NS	240.54	52.4	29.6	0.55
Pod Length (PL)	**	NS	**	NS	0.39	9.1	6.9	0.83
Grain Filling Period (GFP)	*	*	**	**	1.86	47.5	2.9	0.90
Yield in Gram Per Plant (YGPT)	NS	**	NS	NS	22.11	16.3	28.8	0.55
Harvesting Index in Kg ha^{-1} (HI)	NS	*	**	**	0.00	0.3	12.9	0.79
Biomass Production Rate in kg ha^{-1} day^{-1} (BMPR)	**	NS	**	**	233.21	88.7	17.2	0.87
Biomass Yield in Kg ha^{-1} (BMY)	**	NS	**	**	1737802.1	7490.6	17.6	0.88
Seed Growth Rate in Kg ha^{-1} day^{-1} (SGR)	**	*	**	NS	81.18	47.3	19.0	0.83
Grain Yield Per Day in Kg ha^{-1} (GYD)	**	**	**	NS	25.96	27	18.9	0.85
Grain Yield in Kg ha^{-1} (GY)	**	**	**	NS	192441.22	2271.1	19.3	0.84
Anthracnose Disease Severity (ADSIV)	NS	NS	**	NS	0.9	15	64.2	0.56

CV = Coefficient of variation, NS = Nonsignificant, R2 = Coefficient of determination, VXL = Variety by location, and numbers in the parenthesis showed a degree of freedom

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Table 4: Mean Performances of the common bean varieties from combined analysis for some characters evaluated at Bako and Gute.

	Characters			
varieties	Grain Yield (kg ha^{-1})	Harvest index (%)	Biomass yield (kg ha^{-1})	Anthracnose disease Severity (%)
Beshbesh	1778.7	0.20	8020.8	30.20
Goberasha	2316.1	0.30	7864.6	10.14
Dimtu	1880.1	0.27	6979.2	10.14
Dinknesh	2219.7	0.27	8281.3	10.14
Haramaya	3008.7	0.35	8593.8	10.14
Gabisa	2180.2	0.27	7916.7	15.22
Ada	1708.8	0.34	4843.8	33.61
Dandesu	2122.7	0.38	5416.7	15.20
Tatu	2159.4	0.38	5520.8	10.14
SER-125	2653.1	0.30	8802.1	10.14
SER-119	2954.8	0.29	10156.3	10.14
Mean	2271.1	0.3	7490.6	15
LSD (5%)	217.9	0.02	654.9	11.2
CV (%)	19.3	12.6	17.6	59

Where: LSD = Least Significant different, CV = Coefficient of variation

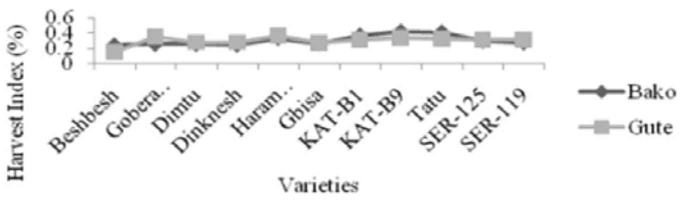

Figure 1: Performances of harvest index (a) for medium seeded food type of common bean varieties across two locations showing the existence of relative changes in ranks (cross-over) due to variety by locations (V×L) interaction.

This breeding gain is relatively lower as compared to an earlier report by Kebere, et al. (2006) who reported a gain of 3.24 % ha^{-1} $year^{-1}$. Another report also showed higher annual yield increases of 0.58 % ha^{-1} $year^{-1}$ from breeding soybean in Northeast China [14], 0.45 % ha^{-1} $year^{-1}$ from breeding soybean in Canada [15], and 1.34 % ha^{-1} $year^{-1}$ from decades of barley breeding in Ethiopia and 0.39 % ha^{-1} $year^{-1}$ from hundred years of barley breeding in England [16].

The average grain yield of Beshbesh, which is the first released variety, was 1778.7 kg ha^{-1}, while the average grain yield of Goberasha was 2316.1 kg ha^{-1}; Dinknesh 2219.7 kg ha^{-1}; Haramaya 3008.7 kg ha^{-1}; Gabisa 2180.2 kg ha^{-1}; SER-125, 2653.1 kg ha^{-1} and SER- 119 was 2954.8 kg ha^{-1} (Table 6). The recently (2014) released varieties exceeded the first released variety, Beshbesh by 380.7 and 21.4 for Tatu, 874.4 and 49.6 for SER 125, and 1176.1 and 66.1 for SER 119 in both kg ha^{-1} and %, respectively. The only recently released variety mean grain yield lower than the mean grain yield of the oldest released variety Beshbesh was Ada (1708.8) kg ha^{-1}, which is lower than the oldest released variety only by 69.9 kg ha^{-1} and 4% due to susceptibility of the variety for various disease, especially anthracnose disease.

Seed weight: The annual rate of genetic progress from breeding medium seeded food type of common bean varieties for seed weight in Ethiopia is estimated to be 0.56 g 100 $seeds^{-1}$ $year^{-1}$ (Figure 2b), which entails an increment of 1.24 % 100 $seeds^{-1}$ $year^{-1}$ or 8.96 g 100 $seeds^{-1}$ (19.79 %) for the past sixteen years of breeding period (Table 6). More genetic progress was made in seed weight (1.24%) than in grain yield (0.31%). This is similar to the report from chickpea breeding in Ethiopia which depicted more dramatic increments in seed weight than in grain yield [17]. Like grain yield, seed weight is also becoming one of the important traits in many food legumes because of the requirements of the export markets [18]. The inconsistent increment of seed weight from the oldest to recently released varieties of medium seeded food type of common bean varieties was recorded for the past sixteen years (Table 6). For instance, the mean seed weight of the first released variety, Beshbesh was 17.66 g and the mean seed weight of the recently released varieties, Goberasha, Haramaya, Ada, Dandesu and Tatu were 46.66 g, 32.83 g, 43.66 g, 44.33 g, and 41.83 g, respectively. The recently released varieties exceeded the oldest released variety, Beshbesh, by 85.9-164 % (Table 6).

Harvest index: Harvest Index is the ratio of seed yield to the above-ground biomass yield. The annual rate of harvest index changes from breeding common bean of medium seeded in Ethiopia was estimated to be 0.006 % (Figure 3a), which is not significantly different from zero. HI of 0.096 % for the last sixteen years of the breeding period was obtained (Table 6). Therefore, the present investigation revealed that there was insignificant genetic progress from the breeding of common bean in Ethiopia for harvest index for the last sixteen years (Figure 3a). Saxena, et al. [19] reported a higher harvest index value of 0.59 % for chickpeas. In another way, significant changes in the harvest index were occur with the release of modern varieties of wheat [20,21]. Teklu (1998) [22] and Bezawuletaw, et al. [23] observed that there was no change in the harvest index of tef and common bean for decades of genetic improvement. The mean harvest index of Beshbesh, the first released variety was 0.20 and the mean harvest index of the recently released varieties, Dimtu, Dinknesh, Gabisa, and SER-119 were 0.27 kg ha^{-1}, 0.27 kg ha^{-1}, 0.27 kg ha^{-1} and 0.29 kg ha^{-1}, respectively (Table 6). The increment of harvest index over the oldest variety ranged from 35-45 %. However, the mean harvest index of the other recently released varieties, namely Haramaya, Ada, Dandesu, and Tatu ranged from 0.34-0.38, whereas values for old varieties, ranged from 0.14 - 0.18 (%).

Biomass yield: Biomass yield of medium seeded food type of common bean varieties reduced by 961.6 kg ha^{-1} for the past sixteen years of the breeding period or the annual reduction of biomass yield was estimated to 60 kg ha^{-1} $year^{-1}$ or (Figure 3b and Table 6), which is equivalent to the reduction of -0.06 % $year^{-1}$ or 1.01 % biomass yield for the past sixteen years (Table 5). The mean biomass yield of the first released variety, Beshbesh, was 8020.8 kg ha^{-1} which significantly exceeded the mean biomass yields of the recently released varieties, namely Goberasha (7864.6 kg ha^{-1}), Dimtu (6979.2 kg ha^{-1}), Gabisa (7916.7 kg ha^{-1}), Ada (4843.8 kg ha^{-1}), Dndesu (5416.7

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Table 5: Annual relative genetic gain (ANRGG) and average relative genetic gain (ARGG) in % compared to the oldest variety Beshbesh of medium seeded food type of common bean varieties for some characters during the past 16 years.

Characters	Parameters				Gain in 16 years kg ha^{-1}	ANRGG year^{1} (%)	ARGG (%)
	Mean square of the regression	Regression coefficient (b)	P- value	Coefficient of determination (R^2)			
Grain yield (kg ha^{-1})	159044.1	22.3	0.39	0.08	356.8	0.31	5.0
Seed weight (g)	99.94	0.56	0.38	0.08	8.96	1.24	19.79
Harvest index (%)	0.013	0.006	0.029	0.4	0.096	2.51	40.27
Biomass yield (kg ha^{-1})	1153106	-60.1	0.52	0.04	-961.6	-0.06	-1.01
Anthracnose disease severity (%)	12.3	-0.19	0.69	0.016	3.04	0.04	0.68

Table 6: Mean performance and their percentage increments of some characters of medium seeded food type of common bean varieties released during the past 16 years compared to the first released variety Beshbesh

Varieties	Year of release	Characters												
		Grain yield (kg ha^{-1})			Seed weight (g)			Harvest index (%)		Biomass yield (kg ha^{-1})			Anthracnose severity (%)	
		Mean	Increment over Beshbesh variety		Mean	Increment over Beshbesh variety		Mean	Increment over Beshbesh variety	Mean	Increment over Beshbesh variety		Mean	Reduction of Beshbesh variety
			Kg ha^{-1}	%		g 100^{-1} seed	%		%		Kg ha^{-1}	%		%
Beshbesh	1998	1778.7	-	-	17.66	-	-	0.20	-	8020.8	-	-	30.20	-
Goberasha	1999	2316.1	537.4	30.2	46.66	29	164.2	0.30	50	7864.6	-156.2	-2	10.14	66.5
Dimtu	2003	1880.1	101.4	5.7	21.5	3.84	21.7	0.27	35	6979.2	-1041.6	-13	10.14	66.5
Dinknesh	2006	2219.7	441	24.8	24	6.34	35.9	0.27	35	8281.3	260.5	3.2	10.14	66.5
Haramaya	2006	3008.7	1230	69.2	32.83	15.17	85.9	0.35	75	8593.8	573	7.1	10.14	66.5
Gabisa	2007	2180.2	401.5	22.6	20.33	2.67	15.1	0.27	35	7916.7	-104.1	-1.3	15.2	49.7
Ada	2013	1708.8	-69.9	-4	43.66	26	147.2	0.34	70	4843.8	-3177	-39.6	33.6	-11.2
Dandesu	2013	2122.7	344	19.3	44.33	26.67	151	0.38	90	5416.7	-2604.1	-32.5	15.2	49.7
Tatu	2014	2159.4	380.7	21.4	41.83	24.17	136.9	0.38	90	5520.8	-2500	-31.2	10.14	66.5
SER-125	2014	2653.1	874.4	49.6	26.16	8.5	48.1	0.30	50	8802.1	781.3	9.7	10.14	66.5
SER-119	2014	2954.8	1176.1	66.1	27.16	9.5	53.8	0.29	45	10156.3	2135.5	26.6	10.14	66.5

kg ha^{-1}) and Tatu (5520.8 kg ha^{-1}) (Table 6). On the other hand, two varieties released in 2006 (Dinknesh and Haramaya) and the other two varieties (SER-125 and SER-119) released in 2014 were found to be superior to Beshbesh for biomass yield (Table 6). Harvest index steadily but smoothly increased with a breeding period (Figure 3a) while biomass yield was periodically decreased (Figure 3b). This indicated that the past breeding efforts enhanced reproductive traits at the expense of vegetative traits. A similar observation was made by other workers on wheat [24] but a contrasting observation of increasing biomass yield during the breeding period was made in soybean [25].

Anthracnose disease severity: The anthracnose disease severity of medium seeded food type of common bean varieties showed a reduction of only 3.04 % over the past 16 years or an annual rate of genetic reduction of 0.19 % (Table 5 and Figure 4). The current result supports the findings of Tolessa, et al. [26] who reported an annual rate of reduction in chocolate spot disease severity of 0.27 % in faba bean or a relative reduction of 21.5 %. The mean of anthracnose disease severity ranged from the lowest (10.14 %) to the highest (33.6 %) (Table 6). Except for Ada variety, which was severely attacked by anthracnose than Beshbesh by 11 %. Anthracnose disease severity of Gabisa and Dandesu was reduced by half, while the rest of the varieties showed reduced anthracnose disease severity by more than half for the past sixteen years (Table 6). Ada variety, which was found to be the most attacked by anthracnose, needs to be subjected to improvements to anthracnose disease resistance.

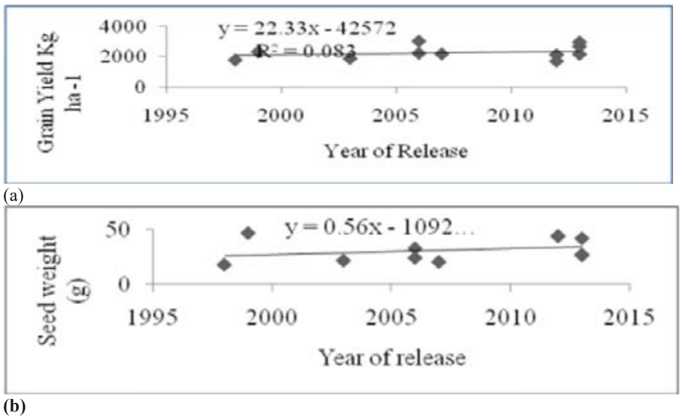

Figure 2: Bi plot of grain yield (a) and seed weight (b) of medium seeded food types of common bean varieties against years of varietal release.

Associations of Characters: The correlation coefficient is the measure of the 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 very important to make the desired selection of a combination of traits [27]. Therefore, correlated characters in medium seeded food type common bean varieties are indicated in Table 7.

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The correlation coefficients of characters in medium seeded food types of common bean varieties ranged from -0.74 to 0.99 (Table 7). Grain yield (kg ha^{-1}) had positive association with Plant height (0.36**), number of pods $plant^{-1}$ (0.50**), pod length (0.31**), grain filling period (0.47**), harvest index % (0.33**), biomass production rate kg ha^{-1} day^{-1} (0.87**), biomass yield kg ha^{-1} (0.85**), seed growth rate kg ha^{-1} day^{-1} (0.98**) and grain yield day^{-1} kg ha^{-1} (0.99**); but, negatively and highly correlated with days to flowering (-0.30**) (Table 7). This finding is in agreement with some other authors' reports, such as White and Izquierdo [28] and Teklu [22], and Waddington, et al. [8] who stated that the correlation between grain yield with grain yield day^{-1}, and grain yield day^{-1} and biomass production rate, respectively, were highly correlated. The same result was also obtained as grain yield was related positively (r = 0.965, P < 0.01) with biomass yield Kebere, et al. (2006) on haricot bean, Laing, et al. (1984) on haricot bean, Salado-Navaro, et al. [29] on soybean and Teklu (1998) on tef. In contrast to the present finding, these authors stated that grain yield showed no association with harvest index on their studied crop; on the other hand, other authors reported similarly, that grain yield has a positive association with both biomass yield and harvest index Riggs, et al., [16]; Waddington, et al. [8]; Perry and D'Antuono [20]. Tarekegne [21] stated that no relation between grain yield and biomass yield and positive association between grain yield and harvest index in bread wheat. The other similar idea to the present finding was that Seed growth rate, grain yield day^{-1}, and biomass production rate were positively associated with grain yield (kebere, et al. 2006) This finding also agreed with the work of [30-32].

Grain yield had slightly positive (0.25*) and (0.28*) and negative (-0.25*) correlation values with number of seeds $plant^{-1}$ and yield gram $plant^{-1}$ and number of seeds pod^{-1}, respectively (Table 7). Grain yield had no association with days

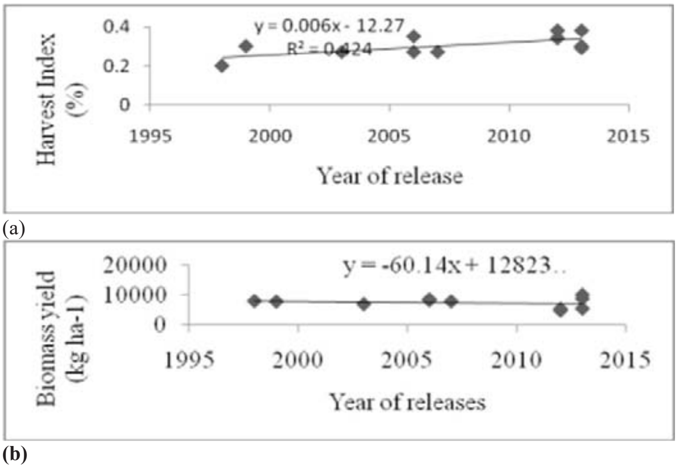

Figure 3: Bi plot of harvesting index (a) and biomass yield (b) of medium seeded food types of common bean varieties against years of varietal release.

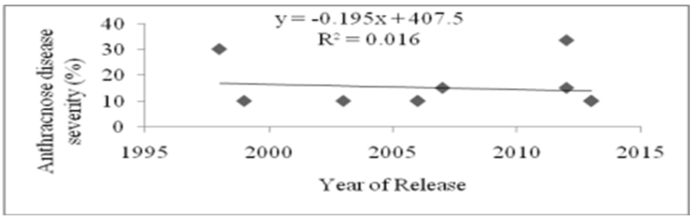

Figure 4: Bi plot of anthracnose disease severity of medium seeded food types of common bean varieties against years of varietal release.

Table 7: Correlation coefficients of yield and yield related traits of medium seeded food type of common bean varieties.

Characters	DF	DM	PH	NPPP	NSPP	NSPPT	PL	GFP	YGPT	SW	HI	BMPR	BMY	SGR	GYD	GY	ANSIV
DF	-	0.70**	0.37**	0.15	0.59**	0.44**	0.00	-0.48**	-0.28*	-0.74**	-0.61**	-0.08	-0.01	-0.25*	-0.38**	-0.30**	0.25
DM		-	0.67**	0.19	0.51**	0.42**	0.11	0.28*	-0.14	-0.70**	-0.45**	0.15	0.25*	-0.02	-0.08	0.05	-0.29**
PH			-	0.47**	0.36**	0.54**	0.28*	0.34**	-0.02	-0.60**	-0.18	0.39**	0.46**	0.32**	0.27*	0.36**	-0.28*
NPPP				-	0.12	0.83**	0.30**	0.02	0.50**	-0.22	0.01	0.53**	0.53**	0.55**	0.50**	0.50**	-0.31**
NSPP					-	0.60**	-0.04	-0.16	-0.02	-0.67**	-0.38**	-0.12	-0.06	-0.23*	-0.30**	-0.25*	-0.02
NSPPT						-	0.22	-0.07	0.40**	-0.52**	-0.20	0.34**	0.37**	0.29*	0.20	0.25*	-0.28**
PL							-	0.13	0.26*	0.08	-0.05	0.35**	0.35**	0.30**	0.29**	0.31**	-0.05
GFP								-	0.20	0.16	0.25*	0.29**	0.32**	0.31**	0.42**	0.47**	-0.43**
YGPT									-	0.39**	0.44**	0.09	0.07	0.28*	0.30**	0.28*	-0.28*
SW										-	0.59**	-0.13	-0.19	0.08	0.18	0.09	0.04
HI											-	-0.14	-0.18	0.33**	0.39**	0.33**	-0.09
BMPR												-	0.99**	0.87**	0.84**	0.87**	-0.21
BMY													-	0.85**	0.81**	0.85**	-0.23*
SGR														-	0.98**	0.98**	-0.21
GYD															-	0.99**	-0.22
GY																-	-0.27*
ANSIV																	-

** and *, highly significant at p ≤ 0.01 and significant at P ≤ 0.05 respectively; and Values with no asterisk are insignificant;
DF = Days to flowering, DM = Days to maturity, PH = Plant height, NPPP = Number of pods $plant^{-1}$, NSPP = Number of seeds pod^{-1}, NSPPT = Number of seeds $plant^{-1}$, PL = Pod length, GFP = Grain filling period, YGPT = Yield gram $plant^{-1}$, SW = Seed weight, HI = Harvest index kg ha^{-1}, 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}, ANSIV = Anthracnose severity

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to maturity and seed weight. Kebere, et al. (2006), stated that there was no association between grain yields and number of seeds pod^{-1}, pod length and hundred seed weight. Several authors also observed no association between grain yield and seed weight [8,16,28,21,22]. In contrast, positive correlations were recorded for grain yield with the mean seed weight in soybean [25], with the number of grains ear^{-1} in wheat [8] and Perry and D'Antuono (1989). Therefore, this finding showed that if Plant height, number of pods plant^{-1}, pod length, grain filling period, harvest index, biomass production rate, biomass yield, seed growth rate and grain yield day^{-1} are improved, significant grain yield response would be expected.

Strong associations were observed between number of seeds plant^{-1} and number of pods plant^{-1} (0.83**), biomass yield and biomass production rate (0.99**), seed growth rate and biomass production rate (0.87**), grain yield day^{-1} and biomass production rate (0.84**), grain yield and biomass production rate (0.87**), seed growth rate and biomass yield (0.85**), grain yield day^{-1} and biomass yield (0.81**), grain yield and biomass yield (0.85**), biomass production rate and seed growth rate (0.87**), grain yield day^{-1} and seed growth rate (0.98**), grain yield and seed growth rate (0.98**), biomass production rate and grain yield day^{-1} (0.84**), grain yield and grain yield day^{-1} (0.99**) (Table 7). Totally, biomass production rate (0.87**), biomass yield (0.85**), seed growth rate (0.98**) and grain yield day^{-1} (0.99**) had high contribution for grain yield increment of medium seeded food type of common bean varieties during the study season. Days to maturity (-0.29**), number of pods plant^{-1} (-0.31**), number of seeds plant^{-1} (-0.28**) and grain filling period (-0.43**) had negative correlation with anthracnose disease severity and grain yield of medium seeded food type of common bean varieties had a weak negative correlation with anthracnose disease severity (-0.27*) plant height (-0.28*), yield graham plant^{-1} (-0.28*) and biomass yield (-0.23*); but anthracnose disease severity had no association with days to flowering, number of seeds pod^{-1}, pod length, seed weight, harvest index, biomass production rate, seed growth rate and grain yield day^{-1} during the study season (Table 7).

Grain yield as a dependent variable and the other left characters as an independent variable, the step wise regression analysis indicated in (Table 8). Grain yield day^{-1} explained 90% alone for the variations in grain yield; unlikely, the reduction of grain yield was made by anthracnose disease severity, 33% and by seed weight, 1% separately.

Table 8: Summary of selection from stepwise regression analysis of mean grain yield as dependent variable on the other traits as independent variables.

Grain yield				
Independent variable	Interception	Regression coefficients (b)	R^2	VIF
Grain yield day^{-1}	2799	0.349**	0.90	1.05
Seed weight		0.547**	-0.01	2.02
Anthracnose disease severity		-0.156**	-0.33	3.12

** = Significant difference at p ≤ 0.01, R^2 = Coefficient of determination and VIF = Variance Inflation Factor

Conclusions

Generally, studying common bean crop by separating their purpose of utlization and seed size is not common before and very important to generate in formations for the users. As a result, the tested common bean varieties were genetically different. Varieties exhibited significant differences for most of the studied characters and location were also exerted significance differences on varieties. Harvest index made crossover type of interaction for some of the varieties and the different varieties performed in different ways in different locations. The mean grain yield and seed weight of medium seeded food type of common bean varieties across locations were different and increased from old to recent released varieties and better genetic progress was gained for these two characters. The recorded average over locations grain yield ranged from 1708.8 kg ha^{-1} for Ada variety to 3008.7 kg ha^{-1} for Haramaya. The yield of medium seeded food type common bean varieties were increased by 22.3kg ha^{-1} (0.31%) annually and 356.8 kg ha^{-1} 95%) in the period of genetic improvement for the past sixteen years. Harvest index also increased from oldest to recent released varieties but, not attractive; anthracnose disease severity reduced during genetic improvement period to some extent; while biomass production was reduced from oldest to recently released varieties during the study time. When we conclude the past improvement genetic progress made, the grain yield was increased in the period of genetic improvement; but, the increment was not significant; this was mainly because of anthracnose disease development. Therefore, from stepwise regression point of view, grain yield day^{-1} will be focused by breeder to generate attractive yield. The homework for the next investigator should be further identification of the important character (s) that contribute more for the variation of grain yield of common bean varieties and those character (s) that contribute for the reduction of grain yield of common bean varieties that to be improved will be suggested by this author. Finally, among these evaluated medium seeded food type of common bean varieties, Haramaya (3008.7 kgha^{-1}), SER-119 (2954.8 kg ha^{-1}) and SER-125 (2653.1 kg ha^{-1}) will be recommended for the area.

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