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Evaluation of growth performance of common bean (*Phaseolus vulgaris* L.) genotypes during two phenological phases

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ABSTRACT

Genotypic differences in biomass yield of many crops are mainly associated with variations in leaf area. Physiological growth analysis is the important in prediction of the performance of genotypes during plant growth. Therefore, the field experiment was conducted to study growth characteristics of common bean genotypes at Hawassa university agriculture research site. Three genotypes including Red Wolayita, Hawassa Deme and Ibado were evaluated in randomized complete block design with four replications during 2017 using irrigation. Growth analysis was done using primary data from two successive samplings in 20 days interval during linear vegetative growth stage and flowering stage. Growth parameters, specific leaf area (SLA), leaf area ratio (LAR), leaf area ratio (LAI), net assimilation rate (NAR), crop growth rate (CGR), relative growth rate (RGR) and biomass yield and their correlation were determined. The study result revealed that, Red Wollita had the highest specific leaf area (241.975 $cm^2 g^{-1}$) and leaf area ratio (161.36 $cm^2 g^{-1}$), Hawassa Deme had the highest net assimilation rate (27.5 mg dm^{-2} Day^{-1}), leaf area index (1.35), relative growth rate (48.02 $gg^{-1} day^{-1}$), average growth rate (0.1g day^{-1}), crop growth rate (0.03g m^{-2} day^{-1}) and biomass yield (2989.6 kg/ha). The ANOVA result indicated that, there was highly significant difference ($p < 0.01$) among genotypes for biomass yield. Correlation of major growth parameters with biomass yield was investigated. Biomass yield had positively highly correlated with net assimilation rate, absolute growth rate, relative growth rate and crop growth rate with correlation coefficient of ($r = 0.39$, 0.33, 0.42 and 0.56), respectively.

***Keywords*:** Biomass yield, Correlation and Growth parameters, *Phaseolus vulgaris*

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1. INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is an important legume crop in the World. It is one of five cultivated species from the genus *Phaseolus* and it is a major grain legume produced in tropical region, third in importance after soybean and peanut, but first in direct human consumption (Broughton *et al*. 2003; Porch *et al*. 2013).

It is grown on an estimated 290202.43 hectares with the production of 4839226.5 quintals with an average productivity of 16.5 qt ha^{-1} (CSA, 2017).

Increased grain yield per land area achieved across the 20th century was mainly associated to extended photosynthesis per unit land area, obtained by increasing the duration of crop period and the amount of light intercepted by the canopy, rather than by enhanced photosynthesis per unit leaf area (Richards, 2000). Indeed, the yield of a common bean cultivar is more closely related to the leaf area duration, which integrates the leaf area over time, than with instantaneous leaf area (Lima *et al.* 2005).

Growth refers to the irreversible changes in the size of a cell, organ or whole plant. It involves both the cell division and enlargement. The plant growth can be visualized in terms of increase in length or plant height, stem diameter, volume of tissue, increase in cell numbers, increase in fresh weight and dry weight, increase in leaf area, leaf weight etc. At plant constituents level also increase in total proteins and total DNA is directly associated with the plant growth (Taiz and Zeiger, 2002). Growth is of paramount ecological importance for plants, as their survival, reproduction and competitive interactions depend on individual size.

The concept of growth analysis was first introduced by Blackman (1919), who recognized that the increase in plant biomass over a given period of time was proportional to the biomass present at the beginning of this period. In recent years growth analysis had much attention for ecosystem functioning and a possible link with species composition. Combinations of crops are determined partially by the length of the growing season and the adaptation of crops to particular environments (Addo-Quaye *et al*., 2011). Plants vary widely in relative growth rate (RGR), absolute growth rate (AGR) and crop growth rate (CGR) both within and among habitats (Paine *et al*. 2015). Physiological growth analysis is the important in prediction of yield. Growth analysis is a way to assess what events occurs during plant growth. Growth analysis is a suitable method for plant response to different environmental conditions during plant life (Taiz and Zeiger, 2002).

Correlation is a measure of the degree of association between traits. It is therefore, important for a breeder to understand that whenever two traits correlate positively, it indicates that selection for one trait can also mean selecting for the other trait (Çalar *et al*. 2010; Acquaah, 2012).

This association may be on the basis of genetics or may be non-genetic. Correlation analysis is a technique which helps to explain the degree of relationship among quantitative traits of a given genotype. It play vital role for genotype selection (Malik *et al*. 2005).

It is important to understand the correlation between the growth parameters and their contribution to the yield at different gorwth phases in common bean. So, plant growth analysis is considered as crucial in the development of productive lines and genotypes. Therefore, this experiment was conducted to evaluate the variability of biomass accumulation, plant growth rate at different growth stages and to correlate different growth parameters with the biomass yield of three common bean genotypes and correlation of growth parameter.

2. MATERIAL AND METHODS

2. 1. Study area

The experiment was conducted at Hawassa University College of Agriculture research site during 2017 off season using irrigation. Hawassa is located in Southern Nation Nationality Reagion of Ethiopia. It is located 275 km south of Addis Ababa. The site is located 6º 42' N and 38º 29'E of latitude at an altitude of 1650 m.a.s.l with mean annual rainfall of 900 mm, mean annual temperature minimum and maximum were 13 ºC and 27 ºC respectively.

2. 2. Experimental material and management

Three released common bean varieties including Red Wolayita, Hawassa Deme and Ibado (Table 1) were evaluated for growth analysis in 2017 off seasons using irrigation. The experiment was laid-out in a randomized complete block design with three replications. Each entry was planted in 6 m^2 plot area having 2m width and 3 m long with 40 × 10 cm spacing between rows and within row, respectively. 50 kg DAP per hectare recommendation rate at the time of sowing were applied. Irrigation was applied as per the recommendation of the crop water requirement to the area.

Table 1. List of genotypes used for the study.

Number	Variety name	Year of release	Growth habit	Source of genotypes
1	Red Wolayita	1974	determinate	HU
2	Hawassa Deme	2008	determinate	HU
3	Ibado	2003	determinate	HU

HU = Hawassa University Source; MOANR (2016)

2. 3. Sampling Method and data collected

For growth analysis, ten plants were randomly selected from each plot and uprooted for collecting the following necessary data. Primary data such as, plant height, Days to emergence, leaf area, leaf dry weight and dry biomass were collected from three sample plants in each plot in two successive sampling in 20 days interval; first sampling were taken at 30 days after emergence (linear vegetative growth stage) and second sampling were taken at 50 days after emergence (flowering stage).

Aboveground dry biomass yield was determined from the aboveground part of the plants that were cut at the ground level from the net plot area at flowering stage (50 days from sowing) after 48 hr oven drying at 70 ºC temperature. Leaf area, was measured using a leaf area meter and leaf dry weight, total dry weight, measured by sensitive balance from ten randomly selected plants from rows left for destructive sampling in two successive stages (linear vegetative growth stage and flowering stage).

Fig. 1. Field performance during early vegetative stage [12-19].

Fig. 2. Leaf area meter

2. 4. Data analysis

The dry mass was measure after 48 hr oven drying at 70 ºC temperature. Specific leaf area (SLA), Leaf area index (LAI), Leaf area ratio (LAR), Leaf weight ratio (LWR), Net assimilation rate (NAR), absolute growth rate (AGR), Crop growth rate (CGR) and Relative growth rate (RGR) were determined using the following formulas (Taiz and Zeiger, 2002; Rakesh *et al*. 2017).

$$SLA = \frac{(\textbf{leaf area})}{(\textbf{leaf dry weight})} \ \text{cm}^2\ \text{g}^{-1}$$

$$LAI = \frac{(A2-A1)}{2} \times \frac{1}{GA} \ \text{g day}^{-1}$$

$$LAR = \frac{(\textbf{leaf area})}{(\textbf{total dry weight})} \ \text{cm}^2\ \text{g}^{-1}$$

$$NAR = \frac{(\mathbf{W2-W1}) \times (\mathbf{lnA2 - ln\,A1})}{(\mathbf{T2-T1}) \times (\mathbf{A2 - A1})} \ \text{mg dm}^{-2}\ \text{day}^{-1}$$

$$AGR = \frac{(W2-W1)}{(T2-T1)} \ \text{g day}^{-1}$$

$$CGR = \frac{(W2-W1)}{(T2-T1)} \times \frac{1}{GA} \ \text{g m}^{-2}\ \text{day}^{-1}$$

$$RGR = \frac{(Ln\,W2 - Ln\,W1)}{(T2-T1)} \ \text{mg g}^{-1}\ \text{day}^{-1}$$

where:

W1 = Dry weight of the plant at time 'T1'
W2 = Dry weight of the plant at time 'T2'
T1 and T2 = Time interval in days
Ln = Natural logarithm
GA = ground area

The Biomass yield data was analyzed using GLM procedure of SAS version (9.3), and means are compared using least significant difference at 5% level of significance. Pearson correlation coefficients were computed by using SAS (2011) versions 9.3 software for evaluated growth parameters.

3. RESULT AND DISCUSSION

3. 1. Specific leaf area (SLA)

Statistical analysis results revealed that (Table 2), Red Wollita genotype had the highest mean specific leaf area during linear vegetative growth stage, but Hawassa Deme perform best during flowering stage after 20 days interval. So that, Red Wollita develop smaller and more leaves during early vegetative stage. This finding was in line with (Milla *et al*. 2008) who stated that larger leaves of a given species tend to have lower specific leaf area due to a relatively high investment in support and transport tissues.

Table 2. Mean values of Specific leaf area (SLA), Leaf area index (LAI), Leaf area ratio (LAR) and Net assimilation rate (NAR).

No	Genotypes	SLA (cm^2 g^{-1})			LAI	LAR (cm^2 g^{-1})			NAR (mg dm^{-2} day^{-1})
		LG	FS	Mean		LG	FS	Mean	
1	Ibado	229.72	251.79	240.76	1.31	163.45	149.89	156.67	26.59
2	Red wollita	242	241.95	241.98	1.26	169.69	153.03	161.36	27.5
3	Hawassa deme	222.46	253.94	238.2	1.35	159.07	156.81	157.94	30.37

LG = linear vegetative growth stage, FS = flowering stage, SLA = Specific leaf area, LAI = Leaf area index, LAR = Leaf area ratio and NAR = Net assimilation rate

3. 2. Leaf area index (LAI)

Statistical result revealed that (Table 2), Hawassa Deme had the highest leaf area index with the value of (1.35). So, it had good canopy that cover the ground. Red Wolayta had the lowest leaf area index (1.26).

3. 3. Leaf area ratio (LAR)

Results indicated that (Table 2), all genotypes did not show any increase in leaf area ratio between linear vegetative growth stage and flowering stage intervals. In the first sample during linear vegetative growth stage Red Wollita had the highest mean leaf area ratio, but in second sampling during flowering stage Hawassa Deme has the highest.

This result is conformity with the findings of Lima *et al*. (2005) who compared six field-grown common bean cultivars and evaluating them for leaf area ratio and he concluded that maximal leaf area was observed at early vegetative stage. A high leaf area ratio has been considered a desirable characteristic because it indicated the plant had a high photosynthetic potential in relation to its respiratory load (Taiz and Zeiger, 2002).

3. 4. Net assimilation rate (NAR)

Analysis result indicated that (Table 2), Hawassa Deme had the highest net assimilation rate (30.37 mg dm^{-2} day^{-1}). Being net assimilation rate (NAR) is measure of the photosynthetic efficiency of plants. So that, genotytpe Hawasa Deme had the highest photosynthetic efficiency.

3. 5. Relative growth rate (RGR)

About the relative growth rate (RGR) the response of three common bean cultivars was different in relative growth rate (Table 4). The result revealed that Hawassa Deme had the highest relative growth rate (48.02 $gg^{-1}day^{-1}$), but Ibado had the lowest in relative growth rate (41.45 gg^{-1} day^{-1}). These results are in conformity with the findings of Hokmalipour and Darbandi (2011) who reported that relative growth rate (RGR) was significantly different among the maize cultivars and observed a declining trend of relative growth rate as the crop proceeds towards maturity.

3. 6. Average growth rate (AGR)

Result revealed that (Table 3), Hawassa deme had the highest average growth rate (0.1 g day^{-1}), but Ibado had the lowest (0.08 g day^{-1}). Therefore, Hawassa Deme has grown fastest than other genotypes.

3. 7. Crop growth rate (CGR)

Result presented in Table 3 indicated that, Hawasa Deme had the highest crop growth rate (0.03 g m^{-2} day^{-1}), but Ibado had the lowest (0.02g m^{-2} day^{-1}). Genotype Hawassa Deme has produced the highest dry matter production per unit ground area capacity.

Table 3. Mean values of Relative growth rate (RGR), Average growth rate (AGR) and crop growth rate (CGR).

No	Genotypes	RGR ($gg^{-1}day^{-1}$)	**AGR** (g day^{-1})	**CGR** **(g m^{-2} day^{-1})**
1	Ibado	41.45	0.08	0.02
2	Red wollita	44.28	0.082	0.023
3	Hawassa deme	48.02	0.1	0.03

3. 8. Aboveground Dry Biomass

The ANOVA result revealed that there was significant difference ($P < 0.05$) among tested genotypes (Table 4). Genotype Hawassa Deme had the highest biomass yield (2989.6 kg/ha). On the other hand, the minimum biomass was produced by genotype Red Wolaita (2154.8 kg/ha).

Table 4. ANOVA output of Aboveground Dry Biomass

Source	df	Type III SS	Mean Square	F Value	Pr > F
Genotype	2	1393787.5	696894*	9.43	0.014

Replications	3	15369.5	5123.2	0.07	
Error	6	443360.8	73893.5		
Total	11	1852517.9			

* = significant difference, df = degree of freedom

Table 5. Mean separation values on biomass yield based on *least significant difference*

Genotypes	Mean of biomass yield (kg/ha)
Ibado	2154.8b
Red wollita	2573.6b
Hawassa deme	2989.6a
LSD	470.33
CV	10.6
R^2	90.3

where, LSD = Least significant difference. Means followed by the same letter are not significantly different at 5% level of significance.

3. 9. Correlation among growth parameters

Pearson correlation coefficients result revealed that (Table 5), there were found positive correlations in most growth parameters. Net assimilation rate had weak negative correlations with leaf area ratio (r = –0.0042). This finding was similar with Milla *et al*. (2008) who stated that it is hard to establish the correlations between net assimilation rate and leaf traits. And also similar with the findings of Çalar *et al.* (2010) who found negative correlation between Net assimilation rate and leaf area ratio at linear vegetative growth stage and flowering stage.Net assimilation rate had positive and strongly highly correlated with absolute growth rate and relative growth rate (r = 0.63 and r = 0.88), respectively and highly correlated with crop growth rate and specific leaf area (r = 0.5 and r = 0.44), respectively.

Average growth rate strongly highly positively correlated with leaf area index, crop growth rate, relative growth rate and specific leaf area with correlation coefficient of (r = 0.93, r = 0.93, r = 0.64 and r = 0.87), respectively. Crop growth rate had positive strong correlation with relative growth rate, specific leaf area and leaf area index with correlation coefficient of (r = 0.6, r = 0.77 and r = 0.92). These outcomes are supported by the finding of Lopez-Bellido *et al*. (2008).

Biomass yield had positively highly correlated with net assimilation rate, average growth rate, relative growth rate and crop growth rate with correlation coefficient of (r=0.39, 0.33, 0.42 and 0.56), respectively. This finding was similar with Çalar *et al.* (2010) who found strong correlation between biomass yield and growth parameters (net assimilation rate, relative growth rate and crop growth rate) on chickpea genotypes. And also elaborated by Amini and Fateh (2011) who observed relative growth rate had correlation with competitiveness of red kidney bean against weed due to having high biomass yield and

Table 6. Correlation matrix among growth parameters of common bean genotypes

	Biomass	NAR	AGR	CGR	RGR	SLA	LAR	LAI
Biomass	1							
NAR	0.45426*	1						
AGR	0.35227*	0.63717*	1					
CGR	0.20514 ^{NS}	0.50629*	0.92724**	1				
RGR	0.42286*	0.87639**	0.64268**	0.60266*	1			
SLA	0.28489*	0.44086*	0.8659**	0.77007*	0.43282 ^{NS}	1		
LAR	0.24021 ^{NS}	-0.0042 ^{NS}	0.38125 ^{NS}	0.48448 ^{NS}	0.17215 ^{NS}	0.65949*	1	
LAI	0.17158 ^{NS}	0.33515*	0.93551**	0.91638 ^{NS}	0.38276	0.88086**	0.49751*	1

AGR = average growth rate, CGR =crop growth rate, LAR = leaf area ratio, LAI = leaf area ratio, NAR = net assimilation rate, R GR = relative growth rate, SLA = specific leaf area
* = significant difference and **highly significant difference, NS = non-significant

4. CONCLUSION AND RECOMMENDATION

This study has shown genotypic performance evaluation is not only confined to the yield performance evaluation but also physiological performance needs to be determined. Growth and yield are functions of a large number of metabolic processes, which are affected by environmental and genetic factors. Studies of growth pattern and its understanding not only tell us how plant accumulates dry matter, but also reveals the events which can make a plant more or less productive singly or in population. Growth analysis is a way to assess what events occur during plant growth and it gives information for genotype selection.

The most important traits in plant growth analysis such as, Specific leaf area (SLA), Leaf area ratio (LAR), Leaf area index (LAI), Net assimilation rate (NAR), Relative growth rate (RGR), crop growth rate (CGR), average growth rate (AGR) and Biomass yield were determined during linear vegetative growth stage and flowering stage.

The result revealed that, genotype Hawassa Deme performed best among other varieties in most of growth parameters evaluated. Correlation result revealed that, among the growth parameters there were found positive correlations. Biomass yield had positively highly correlated with net assimilation rate, absolute growth rate, relative growth rate and crop growth rate with correlation coefficient of (r = 0.39, 0.33, 0.42 and 0.56), respectively.

Repetition of this experiment over year and location and also growth analysis needs to be examined at four growth stages (i.e. Slow vegetative growth stage (SG), linear vegetative growth stage (LG), flowering stage (FS) and grain filling stage (GF)) for better information on physiological growth parameters and variety selection based on their growth performance.

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