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Growth Response of Coffee (Coffea Arabica L.) Cultivars to Various Transplanting Methods at Bonga, South Western Ethiopia

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ABSTRACT
The use of an appropriate transplanting techniques and polythene bags (pot sizes) for cultivars vary from place to place due to lack of information based technology. Therefore, there is a need to determine area specific transplanting techniques for available cultivars. Accordingly, an experiment was conducted to evaluate the growth response of Coffee arabica cultivars to transplanting methods at Bonga South Western Ethiopia, in 2012/2013 cropping season. The first set of experiment encompasses two experiment factors that were two transplanting methods (bare rooted and ball rooted) and six (Coffea arabica L.) cultivars (75227, 741, 7440, Dessu, 74110 and 74112); their factorial combination was tested using randomized complete block design with three replications. Bare root transplanting methods significantly($p<0.05$) increase seedling vigor indices at first true leaf, leaf area index (LAI), internodes length, plant height and root volume (RV) and total biomass (TDW) at early growth stage of Arabica coffee seedlings, however it showed lower survival percentage (52.20%) after field transplanting. On the other hand, Seedling growth parameters; number of leaf, LAI, plant height, stem girth, root volume and TDW were significantly ($p<0.05$) influenced by arabica coffee genotypes. TDW increases from 2.65 g and 2.65 g/ seedling to 3.51 g and 3.50 g /seedling for 75227 and 741 open Arabica cultivars, respectively, however, open Arabica coffee cultivar (741) was revealed lower field survival percentage (48.83%) after field transplanting. Generally, coffee seedling grown under ball rooted transplanting methods were found under good growth performance (93.06%) after field transplanting. Therefore, among the studied Arabica coffee cultivars 7410, 74112, Dessue and 75227 could be recommended to be raised on ball rooted transplanting methods as an agronomical feasible choice for the study area.
Key words: coffee, transplanting, cultivar, relative growth rate, seedling, survival rate.

1. Introduction

Arabica coffee (*Coffea arabica L.*) is the most important agricultural commodity and beverage enjoyed throughout the world and generates income up to US $ 14 billion annually for producing countries, and more than 18 countries, including Ethiopia, cultivate coffee, which is exported as raw, roasted or soluble product to more than 165 countries worldwide providing a means of income for more than 100 million people around the world (ICO, 2011). For Ethiopia, coffee is a major and leading export item which accounts about 5% of the Gross National Product (GNP). In general, about 60-70% of the foreign exchange earning of the country comes from coffee. According to Central Statistical Authority report, the country earned more than 1.5 billion ETB from Arabica coffee export (CSA, 2010).

The area covered by Arebica coffee is about 620,000 hectares, with annual production ranges from 300,000-350,000 tons which is about 600 kg ha^{-1}. Out of this, more than 90 % of the coffee is produced by small-scale subsistent farmers, while the remaining comes from private and government owned large-scale farms (MoARD, 2010).

According to the reports of BoAD (2010), the South Nation Nationality and People Regional State (SNNPR) is one of the major coffee producing regions in Ethiopia, it has a great potential for coffee production due to its suitable agro-climatic conditions. Generally, Sidama, Gedio, Kafa, Bench-Majji, Sheka and Woliyita are the major coffee producing zones in the region. Totally, 336,455 ha of land is devoted to coffee production with the annual production of 164,517 tons to 171,018 tons which is about 489 kg ha^{-1} of which 95,968.25 to 122,155.72 tons are supplied to the central market. More than 92% of the coffee is produced by small scale farmers, the remaining produced by private investors and government state farms (BoAD, 2010).

Kafa zone has a major potential area for coffee production in SNNPR, it has suitable agro-climatic zonation and land forms for coffee production and it is also believed to be the center of diversity for *Coffea arabica*. Consequently, the regional government has given due attention to expansion of coffee production program in Kafa zone. However, about 95% of coffee production has been carried out by small scale farmers in conventional way of production which is characterized by poor yield (KZDOA, 2009). Currently, among the problems identified in the production of Arabica coffee at Kafa is low survival rate of coffee seedlings after field transplanting (Endale *et al*., 2008).

This was, due to lack of useful resent information and coffee technologies generated by the Jimma research centre, which still remain not adequately accessed around the study area where forest coffee production system with low crop productivity is predominantly practiced. Francis *et al* (2000) reported that comparing various methods of transplanting techniques research need for the expansion of improved coffee technologies in Kafa Zone.

According to FAO (2003) coffee cultivars originally brought from south west Ethiopia high land area had highest production potential under conventional system. However, these conventional methods of production were not studied and evaluated in research. KZDoA (2010) reported that farmers are using polythene bag having 11cm diameter by 23cm height, but they have failed to hold and transport large number of seedlings to their plantation field due to its larger pot sizes and soil volume. Optimization of pot size according to the Arabica coffee varieties helps to minimize cost of transplanting and increase area of plantation at the field level (Anteneh *et al.,* 1990). Furthermore, it enhances the survival rate of coffee seedling after transplanting (Godoy, 2001). As a result, farmers are forced to transplant few numbers of coffee seedlings to plantation field. In the study area, this was one of the major limiting factors that impaired coffee production and expansion program (Francis et al., 2000 and KZDoA, 2010).

Despite these facts, this study was attempted to examine the responses of various *Coffee arabica* genotypes to different transplanting methods were not studied. Therefore, this study was proposed to evaluate the response of arabica coffee cultivars to different transplanting methods.

2. Materials and Methods

2.1. Site description

The trial was conducted on experimental site of Bonga agricultural research center during 2011 to 2013 cropping season southwestern Ethiopia. The center is located "Kiakela" peasant association at Gimbo district of Kaffa zone, Southern Nations Nationalities and People's Region (SNNPR). It is found within the southwestern plateau of Ethiopia and 8 km, 450 km and 725 km far from zonal town Bonga, Federal city Addis Ababa and regional city Hawassa respectively. The area lies at $07^0$16'48''N Latitude and $036^0$14'25'' E Longitude at the altitude of 1860 masl. The area experiences one long rainy season, lasting from March or April to October. The mean annual rainfall ranges from 1710 mm to 2000 mm. Over 85 % of the total annual rainfall, with mean monthly values in the range of 125-250 mm occurs in the 8 months long rainy season. The mean temperature ranges from 18.1^0C to 21.4^0C. Environmentally the site is belongs to the sub-agro ecology tepid to midland and comprising of mixed arable farming and woodland, including much relict primary tropical forest. The soil of the study area is sandy clay loam at the top and sandy clay at sub soil characterized as "dystric nitosol" with ph of 5.4. The topography is characterized by slopping and rugged areas with very little plain land (WBISPP, 2001;Chernet, 2008; Tilahun and Kifle, 2015).

2.2. Treatments and Design

The treatments consisted of two transplanting methods (ball and bare rooted transplanting methods) and six Arabica coffee varieties (75227, 741, 7440, Dessu, 74110 and 74112). The experimental design was randomized complete block design in a factorial combination with three replications. Ripe red cherries were selectively handpicked from the already established coffee mother trees around the study area; simultaneously top soil was collected from the surface of cultivable lands at 2-5cm depth, crushed, sieved, and mixed with composed and uniformly used as described by Yakob *et al*. (1993). The numbers of seedlings per plot were 25 for each plot and a total of 900 coffee seedlings were used for the study.

The numbers of treatments were 12 with three replication 36 plots and total 900 seedlings were used for this study. Well prepared soil medium was spread over the seedbeds for the bare root transplanting up to the root zone of coffee seedlings at 23 cm depth. Simultaneously, conventional polythene bags were also prepared in (11cm diameter by 23 cm height) size.

Description of varieties

Six Arabica coffee varieties released by Inistitute of Agricultural Research were used for the study which have different canopy classes and recommended for different areas (IAR, 1996). The full description of the varieties and other information are described on Table 1.

2.3. Data collection

Seedling emergence

Emergency count was made from each experimental unit when just it was commenced (30 days after sowing) in seven days interval. This count was extended up to 90 days after sowing. Then, the number of seedlings that emerged above the soil surface and attained the soldier stage of growth were counted and recorded every 7 days till complete emergence. Then percentage of emerged seedlings (% E) was determined. Days required to 50%

emergence (MDE) and the rate of seedling emergence (ER) were calculated using the formulae described below (Eq 1 and 2).

$$Mean\ days\ to\ Emergence(MDE) = \frac{\sum(nt)}{\sum n} \quad \textit{(Eqn. 1)}$$

$$Emergence\ Rate(ER) = \sum\left(\frac{n}{t}\right) \quad \textit{(Eqn. 2)}$$

Where, n = number of newly germinated seeds at time t, t = days from sowing.

Table 1. Coffee (*Coffea arabica)* Varieties description

Varieties	Year of released	Yield (q/ha)		Canopy class	Recommended areas		
		On- Station	On-Farm		High altitude (1750-2100m)	Mid. altitude (1550-1750m)	Low altitude (1000-1550m)
741	1977/78	12.2	6-7	Open	S	S	S
75227	1980/81	17.9	8-9	Open	HS	S	S
7440	1979/80	16.2	8-9	Mid.Open	S	S	S
Dessue	1980	15.2	5-6	Mid.Open	S	HS	US
74110	1978/79	19.1	9-10	Compact	HS	S	US
74112	1978/80	18.1	9-10	Compact	HS	S	US

Key: *HS = highly suitable, S = suitable, US = Unsuitable*

Three parameters were recorded from the three random samples to evaluate the early growth potential of seedlings for the three varieties. These are a) girth diameter in mm. b) Stem height (cm). c) Tap root length (cm). using the value of these growth parameters, and the total percentage of the field emergence (% E), and/or the mean days required to attain the first true leaves growth stage (MDFTL), an attempt was made to establish some vigor indices for the young coffee plants at an early stage of growth following the techniques by IAR (1996). Then seedling vigor indices (SVI) of the young coffee plants were determined by the following linear model adopted by Wondyifraw (1994).

$$SVI-2 = GD\ x\ (SH + RL)\ x\ \%E/MDFTL) \quad \textit{(Eqn.3)}$$

$$SVI-4 = (GD\ x\ (SH + RL)\ x\ \%E \quad \textit{(Eqn.4)}$$

Where: SVI = seedling vigor index, GD= girth diameter (cm), SH = stem height (cm), RL = tap root length (cm), %E = percentage field emergence, and MDFTL = mean days to first true leaf growth stage.

Subsequent Growth Parameters

Non-destructive extension growth parameters were collected on the central three seedlings at an interval of one week, between October and July, 2011/2012, that was beginning from the start points of the experiments to 6 to 8 pairs of true leaves or up to the end of the experiment.

Non-destructive plant growth parameters such as emergence rate, emergence percentage, plant height per unit time (cm), girth diameter, number of true leaf, number of nodes, and internodes length (cm) and estimated leaf area (cm^2) were recorded at a month intervals, by using the procedure adapted by Yakob *et al.*, (1993) as follows:

Y = K x L x B

Where, Y is estimated leaf area; K is constant specific to cultivars and canopy classes; L is leaf length (cm) and B is maximum leaf breadth (cm).

From each experimental plot data was taken every seven days starting from 45^{th} days after sowing till all potentially capable seedlings in each plot developed their false leaves.

Shoot extension growth

Shoot growth parameters were measured from three seedlings taken randomly from the central rows and measurement of plant height (cm) and internode length were taken. Leaf area per leaf was calculated using the procedure adapted by (Yakob *et al*., 1993). Stem diameter (girth) was measured starting from first true leaf at the surface of the soil by using a caliper in order to develop some vigor indices.

These three seedlings also subjected to destructive sampling after removing above ground part at collar point by scissor, then shoot parts were separated to leaves and stems and fresh weight of each weighed using sensitive balance. The polythene bag containing the roots of the seedlings then, were immersed in running tap water and roots were separated carefully from the soil still being in water. The roots were subsequently washed with clean water, dried with water adsorbent cloth and fresh weight of roots (g), leaves (g), stems (g) and total fresh biomass yield (g) were measured by using sensitive balance. Square paper was put under clean glass to count the total number of squares covered by lateral roots and its length was calculated. Other growth parameters such as lateral root number and length (cm), tap root length (cm) and seedling vigor index were taken from the three randomly selected coffee seedlings from central row of a plot. Volume of fresh root was recorded by using water displacement methods in graduate cylinder at the field. After drying separately at 70-80^{0}C for 48 hr in paper bags in a hot air oven until a constant weight attained as described by Adjet-Twum and Solomon (1992).

The mean relative growth rate (RGR), specific leaf area (SLA= leaf area/leaf dry mass) and leaf area ratio (LAR = plant area/plant dry weight) of seedlings were the methods used to compare growth differences that arise from experimental treatments due to differing genotypes, growing media (Lambers and Poorter, 2008).

The mean relative growth rate (RGR) was calculated by taking plant growth at two points in time. The times were five months (T1) to nine month (T2) after sowing of Arabica coffee seeds at nursery. The equations used for calculating the RGR, SLA and LAR were written as:

$$RGR = \frac{lnW_2 - lnW_1}{T2 - T1} \quad \textbf{(Eqn. 5)}$$

$$SLA = \frac{LA}{LW} \quad \textbf{(Eqn.6)}$$

Where: W_1 and W_2 are the dry biomass at the beginning (T_1) and end (T_2) of the sampling period, and ln is the natural logarithm. SLA =Specific leaf area, LA= leaf area, LW= leaf dry mass, TDW = total plant dry weight.

In addition to these, linear measurements of girth diameter, shoot and root length at the first true leaf growth stage of the seedlings from each plot were also taken and used to develop vigor indices (Sited by Wondyifraw, 1994). Therefore, based on the records of viability test, the mean days to emergence and the rate of emergence of each treatment were computed following the procedure by Scott *et al*. (1994) as indicated in **Eqn.1** and **Eqn. 2**. Field survival rate was computed according to the measurement procedure of Wintegens (2004) within a month interval after field transplanting continuously for six months.

2.4. Statistical analysis

Finally, the data collected were subjected to analysis of variance using SAS software (SAS Institute, 2002). Comparisons among treatment means with significant differences for the measured and counted parameters were done based on the LSD test.

3. Result and Discussion

3.1. Emergence

Analysis of variance showed that seedling vigor at first true leaves (SVI-4) and mean days for first true leaves (MDFTL) were significantly ($p<0.01$) affected by the main effects of method of transplanting and variety (Table 2). However, emergence (%), mean days of emergence, rate of emergence and seedling vigor at emergence where affected only by the main effect of variety (Table 2). However, none of the interactions were significant in all the parameters (data not presented).

Bare rooted transplanting gave the highest vigor of 69. 63 followed by ball rooted transplanting method (62.93) (Table 2). However, in terms of mean days to first true leaves emergence (MDFTL), ball rooted transplanting gave higher (137.67) vigor than bare rooted transplanting (131.67) (Table 2). The high values of vigor in bare rooted transplanting might have been due to the presence of well aerated condition due to the space between plants at the early stage of growth which favored growth and development as compared to ball rooted planting which resulted in lower vigor. In line with this finding Endale *et al* (2008) also reported the effect of bare rooted transplanting on early growth.

Table.2. Main effects of transplanting methods and Varieties on seed emergence and vigor indices of coffee (*Coffea arabica)* seedlings at Bonga in 2013-14.

Treatments	MDE	E (%)	ER at 45th date	MDFTL	SVI-2	SVI-4
Methods of transplanting						
Bare root transplanting	52.78	87.33	2.46	131.61b	32.57	69.63^{a}
Ball root transplanting	52.61	86.67	2.44	137.67a	32.33	62.93^{b}
LSD (%)	NS	**Ns**	**Ns**	0.802	**Ns**	2.75
Varieties						
75227	45.00^{c}	98.67^{a}	3.13^{a}	131.50^{d}	43.57^{a}	85.32^{a}
741	44.66^{c}	98.00^{a}	3.23^{a}	130.50^{d}	43.01^{a}	83.77^{a}
7440	53.83^{b}	87.33^{b}	2.46^{b}	133.00^{c}	32.42^{c}	71.92^{b}
Dessue	52.33^{b}	88.67^{b}	2.39^{b}	133.67^{c}	35.42^{b}	64.81^{c}
74110	59.66^{a}	72.67^{c}	1.70^{c}	138.00^{b}	19.55^{d}	44.86d
74112	60.67^{a}	76.67^{c}	1.79^{c}	141.17^{a}	20.99^{d}	47.016^{d}
LSD (5%)	2.98	4.35	0.15	1.39	2.6	4.77
CV (%)	4.73	4.18	5.09	2.06	6.69	6.03

Means followed by the same letter within a column are not significantly different at P≤ 0.05; MDE= Mean days of emergence; E= Emergence percentage; ER = Emergence rate; MDFTL= Mean days of first true leaves; SVI-2= Vigor indices at Emergence, SVI-4 = Vigor indices at first true leaves.

The varieties were found to have difference in the different indices studied (Table 2). This agrees with the findings of Tesfaye and Ismail (2008), who reported the genotypic variation among *Coffea arabica* genotypes. Similarly, different authors also reported the variation among genotypes for emergence and vigor indices (Bayetta *et al*., 2008).

3.2. Extension Growth Parameters

Plant height was, internode length per plant, and leaf area index were significantly (p<0.01) affected by the main effects of method of planting and variety, while number of internodes, girth and number of leaves per plant were affected only by the main effect of variety; however, none of the parameters were affected by the interaction of method of transplanting and variety main effects (Table 3).

Bare root transplanting showed a significantly (p<0.01) higher plant height, internode length and leaf area index than ball root transplanting (Table 3). In agreement with this, Chane (1991) reported that the presence of adequate space creates vigorous growth of root system and this improves the physical status of the growing area including water holding capacity and aeration and availability of nutrients.

Varieties differed significantly (p<0.01) in plant height, number of internodes per plant, internode length, girth, leaf number per plant and leaf area indix (Table 3). This is due to genotypic difference among coffee cultivars which made different LAI values, the rate of photosynthesis also varies accordingly, the assimilate produced under open, intermediate and compacted verities are different, so they produces larger, medium and low root and shoot dry matter, respectively. These results agree with Lizaso et *al* (2003) and Taye and Jurgen (2008).

Table 3. Effects of Transplanting Methods and *Coffea Arabica* Cultivars o plant height, number of internodes per plant, internode length, girth, leaf number per plant and leaf area index at Bonga in 2013.

Treatments	Plant height (cm)	Number of internodes per plant	Internode length (cm)	Girth (mm)	Leaf Number per plant	Leaf Area Index
Methods of transplanting						
Bare root transplanting	24.83^{a}	8.59	2.89^{a}	3.01	12.91	1.91^{a}
Ball root transplanting	24.68^{b}	8.58	2.86^{b}	2.96	12.9	1.84^{b}
LSD (%)	**0.08**	**NS**	**0.013**	**NS**	**NS**	**0.03**
Varieties						
75227	27.52^{a}	9.13^{a}	3.01^{a}	3.53^{a}	14.02^{a}	2.02^{a}
741	27.50^{a}	9.14^{a}	3.01^{a}	3.49^{a}	13.85^{a}	2.01^{a}
7440	25.50^{b}	8.80^{c}	2.89^{b}	2.92^{c}	12.85^{b}	1.84^{b}
Dessue	25.49^{b}	8.88^{b}	2.87^{c}	3.09^{b}	12.85^{b}	1.83^{cb}
74110	21.25^{c}	7.78^{d}	2.73^{d}	2.51^{d}	12.00^{c}	1.78^{cb}
74112	21.25^{c}	7.77^{d}	2.74^{d}	2.41^{e}	12.01^{c}	1.78^{c}
LSD (5%)	**0.13**	**0.05**	**0.02**	**0.1**	**0.271**	**0.05**
CV (%)	**0.47**	**0.57**	**1.01**	**2.92**	**2.72**	**2.64**

Means followed by the same letter within a column are not significantly different at P≤ 0.05.

3.3. Shoot and root Growth

Dry weight of leaf, stem, root and total dry weight, and root volume were significantly (p<0.01) affected by the main effects of method of root transplanting and variety, however, the interaction effects were not significant (Table 4). Furthermore, shoot mass and root mass ratios were affected only by the main effect of variety. Tap root length, lateral root number, root to shoot ratio, relative growth rate, specific leaf area ratio and leaf area ratio were significantly (p<0.01) affected by the main effects of method of transplanting and variety (Table 5). However, lateral root length was affected only by the main effect of variety (Table 5). In all the parameters the interaction effect was not significant (Table 5).

Bare root transplanting was superior in leaf, stem and root dry weight, root volume and total dry weight (Table 4). In terms of root dry matter, ball root transplanting resulted in a significantly higher tap root length, root to shoot ratio, relative growth rate, specific leaf area ratio and leaf area ratio than bare root transplanting (Table 5). However, bare root transplanting gave higher lateral root number than ball root transplanting (Table 5). This might be due to the direct sowing coupled with suitable growing condition enabled the seedlings store adequate assimilates from source to sink (Anteneh *et al*, 2008). There was conspicuous difference among the coffea arabica genotypes in terms of all the parameters considered (Table 4 and 5). The current findings concur with Anteneh *et al* (1990) and Taye and Jurgen (2008), who reported that varieties exhibit differences in the different parameters considered.

Table 4. Dry matter Partitioning as affected by *Coffea arabica* cultivars and transplanting Methods at Bonga in 2013.

Treatments	Leaf Dry Weight (g)	Stem Dry Weight (g)	Root dry weight (g)	Root Volume (c^3)	Total Dry weight (g)	Shoot Mass Ratio	Root Mass Ratio
Methods of transplanting							
Bare root transplanting	0.87^{a}	1.13^{a}	1.102^{a}	6.27^{a}	3.10^{a}	0.53	0.46
Ball root transplanting	0.86^{b}	1.11^{b}	1.08^{b}	5.82^{b}	3.06^{b}	0.53	0.45
LSD (%)	**0.007**	**0.01**	**0.01**	**0.33**	**0.02**	**ns**	**Ns**
Varieties							
75227	1.07^{a}	1.32^{a}	1.13^{a}	6.99^{a}	3.51^{a}	0.64^{a}	0.37^{c}
741	1.07^{a}	1.32^{a}	1.12^{ba}	7.00^{a}	3.50^{a}	0.64^{a}	0.36^{c}
7440	0.87^{b}	1.11^{b}	1.09^{b}	5.84^{b}	3.08^{b}	0.55^{b}	0.43^{b}
Dessue	0.87^{b}	1.11^{b}	1.11^{ba}	6.01^{b}	3.09^{b}	0.55^{b}	0.44^{b}
74110	0.67^{c}	0.93^{c}	1.05^{c}	5.19^{c}	2.65^{c}	0.42^{c}	0.57^{a}
74112	0.67^{c}	0.93^{c}	1.05^{c}	5.25^{c}	2.65^{c}	0.41^{c}	0.56^{a}
LSD (5%)	0.01	0.02	0.03	0.58	0.03	0.01	0.02
CV (%)	**3.91**	**2.62**	**3.61**	**8.05**	**1.63**	**2.44**	**2.99**

Means followed by the same letter within a column are not significantly different at P≤ 0.05.

Table 5. Root dry matter of coffee seedlings as influenced by method of transplanting and varieties of coffea arabica at Bonga in 2013.

Treatments	Tap Root Length (cm)	Lateral Root Number	Lateral Root Length (cm)	Root to shoot ratio	Relative Growth rate (mg g^{-1} day^{-1})	Specific Leaf area ratio (m^2 kg^{-1})	Field Survival rate (%)
Methods of transplanting							
Bare root transplanting	19.71^{b}	49.81^{a}	167.34	0.95^{b}	64.00^{b}	0.22^{b}	52.20^{b}
Ball root transplanting	20.47^{a}	49.39^{b}	165.27	0.97^{a}	67.00^{a}	0.24^{a}	93.06^{a}
LSD (%)	0.206	0.378	Ns	0.01	2	0.007	2.46
Varieties							
75227	21.43^{a}	51.86^{a}	171.43^{a}	0.57^{c}	52.00^{d}	0.19^{c}	73.08^{b}
741	21.42^{a}	51.51^{a}	171.26^{a}	0.56^{c}	54.00^{cd}	0.19^{c}	48.83^{c}
7440	20.83^{b}	48.56^{b}	165.77^{cb}	0.79^{b}	64.00^{b}	0.22^{b}	78.19^{ab}
Dessue	20.83^{b}	48.52^{b}	166.09^{b}	0.80^{c}	59.00^{cd}	0.22^{b}	80.03^{a}
74110	19.46^{c}	46.63^{c}	161.65^{c}	1.32^{a}	82.00^{a}	0.28^{a}	77.92^{ab}
74112	19.61^{c}	46.54^{c}	161.65^{c}	1.31^{a}	81.00^{a}	0.28^{a}	77.75^{ab}
LSD (5%)	0.36	0.65	4.13	0.11	9	0.01	6.42
CV (%)	1.45	1.12	2.07	7.25	5.23	4.18	4.92

Means followed by the same letter within a column are not significantly different at P≤ 0.05; MDE= Mean days of emergence; E= Emergence percentage; ER = Emergence rate, MDBF= Mean days of better fly, SVI-2= Vigor indices at Emergence; SVI-4 = Vigor indices at first true leaves.

3.4. Relative Growth Rate and Field survival

Relative growth rate and specific leaf area (SLA)) were significantly (p<0.01) affected by the main effects of transplanting and Arabica coffee varieties, however, the interaction effect was not significant (p<0.01). Ball root method of transplanting resulted in a significantly (p<0.01) higher relative growth rate, specific leaf area and leaf area ratio than the bare root transplanting method (Table 5). The highest mean values of RGR and SLA were obtained under ball rooted transplanting methods with corresponding results of 67 mg g^{-1} day^{-1} and 0.24 m^2 kg^{-1}, respectively. In contrast, lowest mean value of RGR and SLA were observed for bare root transplanting methods with corresponding results of 64 mg g^{-1} day^{-1} and 0.22 m^2 kg^{-1}. This, result come up with luxurious growth condition that were created due to adequate intra-row spacing, aeration and favored growing condition, finally it had larger contribution for lesser relative growth rate of coffee seedling that had been grown under bare rooted transplanting methods. This result also associated with the findings of (Van, 2010).

Similarly the Arabica coffee cultivars having shorter growth habit had possessed thinner leaves, that helps to develop a high SLA (more area per unit dry weight) and the associated high protein concentrations would allow greater efficiency in acquiring light and in photosynthesis, leading to better competitive ability of the crops as the result it acquired larger RGR and SLA. This result directly related with the reports of Sobrado (2005) and Reich and Walters (2006).

Survival percentage at field transplanting was significantly (p<0.05) affected by transplanting methods and Arabica coffee cultivars. The highest and lowest field survival percentage 93.06% and 52.20 % mean value was recorded for ball and bare rooted transplanting methods, respectively. This result might be due to coffee seedling grown under ball rooted condition would not exposed for root disturbance and feeder root damage during transplanting in to the field, as a result this seedling management condition could increase field survival percentage of coffee seedlings. This directly associated with the work Wintegens(2004) who reports that coffee seedling grown under well management condition could have also better performance after transplanting to the field. The highest percentage mean value was observed on Dessue (80.03%), 7440(78.19%), 74110 (77.92 %), and 74112(77.75%), where as the lower mean value was obtained from 741(48.83% This is probably due to Arabica coffee cultivars having compacted growth habited could able to perform well at higher altitude than Arabica coffee cultivars having open growth habited. This is associated with the report of (Endale *et al.*,2008) who reported that compacted Arabica coffee cultivars have intended to show better morphological and physiological performance at south west high land of Ethiopia.

4. SUMMMARY AND CONCLUSION

The adequate space created well aerated condition for vigorous growth of the root and shoot components, this also improve the physical status of the growing media such as water holding capacity and increases available nutrient to plant growth. Consequently, the seedlings raised on bare root or conventional bed had significantly higher seedling vigor indices at first true leaf, the heaviest TDW, the larger leaf area index (LAI), longest plant height and the largest root volume (RV); however, post transplanting survival percentage of the seedlings was lower (52.20%) than ball root transplanted seedlings (93.06%). Ball rooted coffee seedlings had showed significantly lower seedling vigor indices at first true leaf (201.22), the lighter TDW (3.06 g), the smaller LAI (1.84), shorter plant height (24.68cm) and the smaller RV (5.82 cm^3). However, it has higher survival percentage (93.06%) after transplanting to the field. In general, ball rooted seedlings noted higher field survival rate than bare rooted seedlings for five Arabica coffee cultivars under taken to this study. Therefore, it is advisable to use ball rooted transplanting method as a means of propagation for *Coffea arabica* at Bonga southwestern Ethiopia.

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