

Growth Characteristics and Yield Evaluation of *Arabica* Coffee (*Coffea arabica* L.) Promising Selections Under Sidama and Gedeo Growing Condition, Southern Ethiopia

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Abstract

Ethiopia possesses a diverse genetic base for the *Arabica* coffee with considerable heterogeneity and is the center of origin for *Coffea arabica*. Even though Ethiopia produces a range of distinctive *Arabica* coffees and has considerable potential to sell a large number of specialty coffee, there is still a limited availability of yield competitive Variety; suitable for southern Ethiopian agro ecology. Therefore, this study was conducted in three location at Awada, Wonago and komato; highland and mid land representative agro ecology to evaluate sixteen south coffee promising selections from 1997 collection batch and two standard check varieties (Angafa and 744) in order to identify promising selection that exhibits stable performance across wide environments. The experiment was laid as in a Randomized Complete Block Design (RCBD) with three replications. Data were collected for Plant height (cm), Stem girth (cm), Canopy diameter (cm), Inter node length on the main stem (cm), Number of nodes on the longest primary (No.), Internodes length on the longest primary (cm), Number of primary branches (No.), Length of the longest primary branch (cm) and Number of main stem nodes (No.) as growth parameters and yield for five consecutive year's per hectare basis. The study indicated that significantly high yield per hectare was recorded for promising selection 9737 (14.9 Qh⁻¹) at Awada, 744 (8.92 Qh⁻¹) at Wonag and 9716 (7.88 Qh⁻¹) followed by 975 (7.7 Qh⁻¹) at Komato than the rest of the selection. Whereas it was lowest for 9715 (6.46 Qh⁻¹) at Awada, for 973 (1.25 Qh⁻¹) followed by 9719 (1.42 Qh⁻¹) at Wonago and 9753 (2.27 Qh⁻¹) at Komato. The lowest mean yield 9.27 Qh⁻¹ obtained from 973; 1.65 Qh⁻¹ from 973 and 2.63 Qh⁻¹ from 9738 at Awada, Wonago and komato respectively. In conclusion, this study result indicates that the existence of promising high yielder selection over standard check variety. Therefore, the promising selection has to be promoted to verification plot in order to test and release *Coffea arabica* improved selection varieties for southern coffee growers.

Keywords: Promising selection; Variety; Clean coffee yield; Growth parameter; South ethiopian coffee

Introduction

The tribe Coffeae (Rubiaceae) consists of 11 genera, including the closely related genera *Coffea* and *Psilanthus* [1]. *Coffea* is further divided into two subgenera, *Coffea* and *Mascarocoffea* [2,3]. All caffeine containing species of *Coffea* belong to the subgenus *Coffea* which comprises 103 species [4]. *C. arabica* is the only tetraploid species in the genus and is self-fertile, while other species are diploid and generally self-incompatible [5]. Commercial coffee production relies only on two species, *C. arabica* L. and *C. canephora* Pierre ex Froehner contributing 60% and 40%, respectively, of the global market [6-8].

Ethiopia is the primary center of origin and diversification for *Arabica* coffee [9,10]. It grows wild in some forest areas, from semi Savannah climate of the Gambella plain (500 m.a.s.l.) to the continuously wet mountain forest zones of the southwest, in gardens and back yards of southeast and northern regions up to 2600 m.a.s.l. [11-13]. The soil varies from sandy loam to heavy clay while the dominant soil types are acidic (pH 4.2-6.8) red, reddish brown lateric

loams or clay loams of volcanic origin and total annual rainfall varies from 750 to 2,400 mm [14].

Many researchers [15-17] have reported the existence of high genetic diversity among *Arabica* coffee germplasm collections in Ethiopia. The existence of such high genetic diversity of a self-pollinated *Arabica* coffee is believed to be attributed to the availability of extremely diverse agro-ecological variations under which coffee grows in Ethiopia, evolutionary tendencies or changes of the species or natural mutations occurring to the population of the crop [18]. According to World Coffee Research WCR, 2014 Annual Report [19], over 90% of the world's *Arabica* coffee genetic diversity thrives in Ethiopia and what has been collected and *Ex situ* conserved in different research centers and institutions around the world only represent less than 10% of the total genetic diversity available indicating the significance of Ethiopian coffee genetic resources to the future of the world coffee industry.

Even though Ethiopia has high genetic diversity, diverse and suitable agro-ecologies and suitable land mass, the national coffee yield per unit area is generally low (748 kg/ha) [20]. Of the major factors, lack of yield competitive improved cultivars for Ethiopia ecological zones is a key problem. Hence, development of varieties which are high yielder, disease resistant and insect pest tolerant as well as best quality brand through selection and hybridization are highly essential.

In Ethiopian institute of agricultural research under coffee commodity research program, Awada Agricultural Research Sub-center, which was established in 1999 G.C. with assistance of the Switzerland government; is mandated to run research activities mainly on Southern Ethiopia and Yirgachefe (flora flavored) coffee types. The sub-center together with Jima Agricultural Research Center have been actively engaged in the collection, characterization and evaluation of indigenous coffee type in the major coffee growing areas of southern Ethiopian regions. Through these efforts, four varieties has been released, many coffee accessions from the southern region (Sidama, Gedeo, Amaro, Gamo Gofa, Jinka etc.) has been collected and characterization and evaluation is currently underway.

Sidama and Gedeo zones are the best coffee quality brand growing areas and research works are on progress to develop coffee varieties that suits the growing area and known quality brand. To minimize adaptation problems and avoid blending effects of known quality Sidama and Gedeo coffee with coffee from another area(s), designing of breeding work in selection of Sidama and Gedeo local land races and crossing from the respective location is arguent task to develop yield competitive improved varieties.

Significant genotype-environmental interactions for yield of coffee have been reported by several researchers [21,22]. Therefore, variety may adapt and fulfill the commercial interest in one coffee growing region, but may not suitable to use in another due to the influences of environmental factors such as soil type and soil fertility level, temperature, humidity and rainfall [22-24]. Therefore, a variety must be adapted to or suited to a region. Hence, this study conducted with the following objective:

To identify and promote best promising Sidama and Gedeo landrace *Arabica* coffee selections for variety development.

Materials and Methods

Description of the study sites

The experiment was conducted in variety trial plots at Awada research sub-center, Wonago sub-station and Komato trial site. Awada research sub-center is located at 6°3'N latitude, and 38°3'E, longitudes and at an Altitude of 1740 masl. The mean annual rainfall of the sub-center is 1335 mm. The mean maximum temperature is 28°C while the mean minimum annual temperature is 11°C. Wonago sub-station is located at 6°3'N latitude, and 38°3'E, longitudes and at an altitude of 1850 masl and also Komato trial site is located 1600 m.a.s.l.

The two experimental sites are classified in mid-altitude (Awada and Komato) and the rest experimental site (Wonago) is classified in the high land of the coffee growing agro-ecology of the country [25].

Treatment and design

Sixteen *Arabica* coffees promising selections and two checks cultivars (Angafa and 744) were used and their seedling raised in the nursery site of the respective research stations (Table 1). They were selected for their high potential for resistance to Coffee Berry Disease (CBD), yield and cup quality during a preliminary evaluation carried out at Awada. Primarily, they were collected from different farmers' field of southern region of the country along with quite large numbers of coffee accessions. The seeds (beans), which were used for preparing the seedlings, were prepared from representative bushes of each genotype. The experiment was laid out in a Randomized Complete

Block Design (RCBD) with three replication; consisting of 8 trees per plots. The spacing between treatments and replications were 2 m × 2 m and 4 m × 4 m, respectively.

No	Treatment Designation	Description
1	973	Promising Selection
2	975	Promising Selection
3	9713	Promising Selection
4	9714	Promising Selection
5	9715	Promising Selection
6	9716	Promising Selection
7	9719	Promising Selection
8	9727	Promising Selection
9	9736	Promising Selection
10	9737	Promising Selection
11	9738	Promising Selection
12	9745	Promising Selection
13	9747	Promising Selection
14	9749	Promising Selection
15	9753	Promising Selection
16	9756	Promising Selection
17	744	Cultivar/Released variety
18	Angafa	Cultivar/Released variety

Table 1: Description of experimental materials.

Experimental procedures

Land preparation: The experimental fields clearing, whole digging refilling and relining were done as per the recommendation.

Planting: Normal and healthy seedling were planted in study plots in July, 2006 with a population of 8 trees per plot in a spacing of spacing of 2 m × 2 m.

Harvesting: Cherries were picked at red ripe stage and weighted per tree base at harvesting season.

Field management practices like weeding, input application, permanent shedding and others were applied as per recommendation.

Data collected

The data collected were: Stem girth (cm), Height up to first primary branch (cm), Plant height (cm), Number of nodes on the main stem (No.), Number of primary branches (No.), Number of secondary branches (No.), Length of longest primary (cm), of Nodes on the longest primary (No.), Internodes length on longest primary (cm), Inter node length on the main stem (cm), Canopy diameter (cm), and yield (Qh⁻¹) data were recorded.

The method of data collection for each character was as follows:

Plant height (cm): This measured using pocket meter from the base up to the tip of the tree in centimeters.

Height up to first primary branches (cm): Height of the tree from the ground level to the first primary branch of the main stem.

Stem girth (cm): this was measured above 5 centimeter at the ground level using caliper.

Canopy diameter (cm): Average length of tree canopy measure twice, east-west and north- south, from the widest portion of the tree canopy.

Average Inter node length on the main stem (cm): By computing per tree as (TH-HFPB)/TNN-1, where TH=total plant height, HFPB=height up to first primary branch, TNN=total number of main stem nodes.

Number of nodes on the longest primary (No): This character was recorded by counting the number of nodes.

Number of primary branches (No): This character was recorded by counting the number of primary branches.

Number of secondary branches (No): This character was recorded by counting the number of secondary branches

Length of the longest primary branch (cm): This was measured in centimeters using pocket meter.

Number of nodes on main stem (No): Are total numbers of nodes count per tree

Inter node length on longest primary branch (cm): Calculated as LLP/NNPB, where Length of longest primary branch, NNPB=height of longest primary branch.

Yield (Qh⁻¹): Fresh cherry weight that had already been recorded per tree bases was used and converted to clean coffee in quintals per hectare.

Data analyses

The data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) of the Statistical Analysis System (SAS)

of statistical package and the mean values were compared using the procedure of Least Significant Difference (LSD) test at 5% level of significance.

Results and Discussion

Growth characters

Statistically significant result was observed for main factors (location and promising coffee selections) but not for interaction effect; from recorded growth characters, steam girth, canopy diameter, number of primary branches, and length of longest primary branch. On the other side statistically non-significant result revealed for the rest of parameters collected during the study.

Statistically highest stem girth (7.14 cm) was observed for promising selection 975 and 9719 whereas the lowest (6.38 cm) recorded for 9714. The result revealed that the longest height (343.9 cm) observed for promising selection 9727 followed by 9716 (341.47) whereas the lowest (6.38 cm) observed for promising selection 9714. Significantly higher canopy diameter (209.89 cm) was recorded for selection 9727 followed by (202.29 cm) for selection 9713 whereas the lowest (299.73 cm) observed for check variety 744 (Table 2).

The highest number of primary branches (103.36) were recorded for selection 975 followed by (102.99) for selection 97347 whereas the lowest (70.66) recorded for check variety 744. Statistically highest length of longest primary (105.4 cm), recorded for promising selection 9719; whereas the lowest length of longest primary (395.1 cm) recorded selection 9737 (Table 3).

Considering growing environment the highest stem girth (7.11 cm), height up to first primary (26.19 cm), plant height (354.26 cm), number of node on main stem (72.2), inter node length on main stem (7.4 cm), canopy diameter (204.93 cm), length of longest primary (107.7 cm) and Inter node length on longest primary (7.07 cm) recorded at Awada growing condition. The highest number of secondary branch (146.14) and average internode length on main stem (3.92 cm) recorded at Komato Growing condition (Table 2).

Parameters												
Location	SG	HFP	H	NNMS	INLMS	CD	NPB	NSB	LLP	NNLP	INLLP	AIL
Awada	7.11	26.19	354.26	72.2	7.4	204.93	91.38	117.13	107.7	26.33	7.07	3.54
Wonago	6.89	25.13	312.9	70.47	5.97	188.57	94.59	112.78	100.48	26.65	4.86	3.08
Komato	6.67	22.86	319.86	61.49	6.4	184.46	96.39	146.14	95.63	26.02	4.89	3.92
P-value	**	**	*	**	***	***	Ns	**	**	ns	***	**
LSD	0.173	1.804	7.763	2.177	0.38	5.853	8.391	5.852	3.298	1.225	0.262	0.151
Treatment												
9719	7.14	25.33	338.52	70.43	6.74	199.33	98.99	137.44	105.4	27.8	5.98	3.52
9745	7.06	23.67	311.11	64.77	5.95	189.71	87.4	129.9	95.06	25.1	4.93	3.51
9737	6.77	25.33	315.18	65.57	6.36	182.95	80.87	119.8	96.06	26.36	5.48	3.47
9736	6.78	20.93	336.49	67.33	6.52	179.97	84.54	117.93	95.1	24.44	5.27	3.73

9713	6.8	25.88	339.46	69.08	7.02	202.29	101.77	129.64	100.28	26.84	5.86	3.56
9749	7.09	23.22	340.74	70.51	6.65	198.13	102.99	124.82	109.22	28.66	5.93	3.51
9747	7.13	23.97	343.7	71.14	6.86	194.62	98.95	127.03	97.8	25.03	5.77	3.51
9738	6.78	24.79	326.3	66	6.02	185.32	80.88	127.53	99.73	27.03	5.43	3.64
9756	6.76	25.43	315.38	67.73	5.99	193.38	94.89	116.99	102.7	27.22	5.23	3.32
9714	6.38	25.88	324.44	67.62	6.55	191.16	93.2	115.37	100.87	26.48	5.77	3.46
975	7.14	26.08	335.38	70.89	6.61	187.11	103.36	128.32	104.2	26.66	5.68	3.36
9716	6.88	26.79	341.47	72.12	7.27	191.6	121.21	129.51	98.55	24.8	5.91	3.36
9715	7.11	23.96	337.4	70.03	6.78	196.63	99.43	127.38	103.92	26.5	5.81	3.51
973	6.74	24.51	324.27	68.67	6.42	198.14	97.54	126.89	99.88	25.72	5.55	3.42
9727	7.1	24.61	343.9	67.56	6.93	209.89	102.39	128.54	113.21	27.21	5.83	3.77
9753	6.71	25.19	327.59	67.92	7.54	183.14	85.09	125.24	103.46	26.35	5.97	3.5
Angafa	6.86	23.88	321.1	65.14	6.62	194.34	90.03	124.06	96.02	25.73	5.49	3.63
744	6.81	25.67	299.73	62.44	5.83	190.08	70.66	119.86	101.46	26.02	5.01	3.49
CV	6.58	19.12	6.18	8.38	15.1135	7.96	23.366	12.23	8.536	12.189	12.235	11.268
Significance	*	ns	**	*	*	*	**	Ns	***	ns	ns	Ns
LSD	0.424	ns	19.016	5.333	0.38	14.336	8.391	Ns	3.298	ns	ns	Ns

Table 2: Growth parameters of promising coffee selection grown at Awada, Wonago and Komato. Whereas SG=Stem Girth; HFP=Height up to First Primary; H=Plant Height; NNMS=Number of Node on Main Stem; INLMS=Inter Node Length on Main Stem; CD=Canopy Diameter; LLP=Length of Longest Primary; NNLP=Number of Node on Longest Primary; INLLP=Inter Node Length on Longest Primary; NPB=Number of Primary Branch; NSB=Number of Secondary Branch and AIL=Average Internode Length on main stem.

Yield

The result indicated that existence of significant variation among selection for mean yield in three locations. The promising selections exhibited differential yielding ability at three locations. The highest five years mean yield 14.9 Qh⁻¹ (2500 tree/ha) obtained from 9737 at Awada; 8.92 Qh⁻¹ from 744 at Wonago and 7.88 Qh⁻¹ from 975 followed by 7.70 Qh⁻¹ from 975 at komato. The lowest five years mean yield 9.27 Qh⁻¹ obtained from 973; 1.65 Qh⁻¹ from 973 and 2.63 Qh⁻¹ from 9738 at Awada, Wonago and Komato respectively (Table 3).

The highest five years mean yield 12.21 Qh⁻¹ (2500 tree/ha) recorded at Awada followed by 5.342 Qh⁻¹ at Komato and the lowest 4.34 Qh⁻¹ recorded at Wonago growing condition. The over all yield at komato is very low as compared to Awada Growing Condition (this is may be due to soil type and soil fertility level at Komato-the soil is very degraded none fertile). The reason for lowest yield at wonago may be due to high severity of coffee berry disease (CBD). Because, Wonago is spot area for CBD resistant screening and many selection were severely attacked by CBD.

Clean coffee yield in Qh ⁻¹																		
Clean coffee yield in Qh ⁻¹																		
Selec- tion	Awada						Wonago						Komato					
	Cropping years						Cropping years						Cropping years					
	2010/ 11	2011/ 12	2012/ 13	2013/ 14	2014/ 15	Mea n	2010/ 1	2011/ 2	2012/ 3	2013/ 4	2014/ 5	Mea n	2010/ 1	2011/ 2	2012/ 3	2013/ 4	2014/ 5	Mea n
973	0.63	13.06	3.13	12.5	17.04	9.27	2.74	1.53	1.2	0.86	1.93	1.65	0.83	3.01	13.67	4.4	6.1	5.6
975	0.47	25.24	7.03	28.13	8.02	13.78	4.99	5.7	1.9	3.7	13.47	5.95	1.27	5.08	19.5	1.87	10.77	7.7

9713	1.43	11.73	2.69	15.37	6.63	7.57	6	3.33	1.3	1.3	4.27	3.24	0.83	3.96	20.4	1.47	4.93	6.32
9714	3.7	22.27	10.23	28.27	4.32	13.76	5.91	6.63	1.97	6.63	10.87	6.4	1.13	2.07	10.23	0.57	3.3	3.46
9715	1.07	13.3	5.43	11.2	7.99	7.8	4.38	2.1	0.4	2.76	1.97	2.32	1.13	4.3	12.93	4.27	4.4	5.41
9716	0.23	19.13	6.37	21.73	14.97	12.49	3.59	3.87	1.73	2.8	6.27	3.65	2.2	4.05	14.73	8.47	9.97	7.88
9719	1.03	11.27	7.8	20.47	11.13	10.34	3.67	1	0.87	0.43	3.4	1.87	2.2	5.09	14.7	4.43	7.77	6.84
9727	0.77	12.17	5.73	21	17.09	11.35	4.16	2.93	1.8	3.9	6.3	3.82	0.93	4.8	17.3	2.53	8.73	6.86
9736	2.03	19.03	13.47	26.03	7.96	13.7	8.13	3.63	1.6	1.5	5.63	4.1	0.77	1.31	10.27	1.6	3.17	3.42
9737	2.73	17.1	15.43	29.93	9.31	14.9	5.36	3.4	1.63	2.63	5.9	3.78	0.83	2.48	14.33	4.4	5.4	5.49
9738	4.17	20.03	14.13	21.7	12.07	14.42	4.56	7.43	2.27	4.33	7.73	5.26	0.3	1.52	6.67	2.67	2	2.63
9745	2.23	15.88	7.6	22	5.31	10.6	5.56	1.05	1.43	2.06	3.37	2.69	0.9	4.39	14.57	1.33	3.27	4.89
9747	1.23	22.71	11.55	24.36	4.39	12.85	3.65	4.23	2.63	3.56	9.03	4.62	0.52	2.47	7.7	3.13	5.03	3.77
9749	1.13	18.11	14	27.1	4.27	12.92	3.69	4.93	0.77	1.6	5.9	3.38	0.67	3.75	21.47	2.4	6.37	6.93
9753	3.17	16.8	5.87	23.57	13.6	12.6	6.14	2.7	1.87	4.46	6.9	4.41	0.93	1.73	7.43	0.97	2.73	2.76
9756	0.67	19.49	9.3	16.6	14.3	12.07	4.67	10.23	2.33	7.3	9.07	6.72	0.83	4.84	19.1	1.43	6.33	6.51
Angafa	3.17	20.4	16.73	26.79	5.78	14.57	5.66	3.1	3.07	4.6	9.93	5.27	0.97	3.48	15.7	4	6.5	6.13
744	2.43	23.89	7.3	26.91	13.37	14.78	4.54	11.4	5.17	7.2	16.27	8.92	1	1.8	10.37	0.77	4.07	3.6
Mean	1.79	17.87	9.1	22.43	9.86	12.21	4.86	4.4	1.89	3.42	7.12	4.34	1.01	3.34	13.9	2.82	5.6	5.34
CV	82.62	33.38	41.8	22.86	52.04		44.9	47.78	65.41	69.1	38.18		43.67	37.73	27.79	66.91	41.21	
P-value	*	ns	**	**	*		ns	**	*	*	**		**	**	**	**	**	
LSD(0.05)	2.51	ns	6.31	8.51	3.48		ns	3.49	2.05	3.95	4.51		0.74	2.09	6.43	3.13	3.83	

Table 3: Mean yield of promising coffee selection in three locations for seven consecutive years at Awada, Wonago and Komato.

Summary and Conclusion

The promising selection 9737 best performed over the existing improved check varieties at Awada while, the promising selections 9716 best performed over the existing improved check varieties at Komato. No yield competitive selection was observed at Wonago (check variety 744 best performed over selections). Awada growing environment is most suitable for coffee production as compared to Wonago and Komato.

Recommendation

Since, significant genotype and environmental interactions for yield was observed; *Arabica* coffee breeding program should give due attention in incorporating genetic and environmental factors. As the study result indicates that, the existence of promising high yielder

selection over standard check variety at Awada and Komato growing condition, the best performing promising selections has to be promoted to verification plot in order to test and release *Coffea arabica* improved selection varieties.

Hence, no yield competitive selection was observed at Wonago, further breeding work in selection of southern local land races as well as Crossing from the respective location has to be done to develop yield competitive southern coffee quality brand improved varieties.

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