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Adaptability and Performance Evaluation of Coffee (*coffea arabica* l.) Varieties on Growth, Yield and Assosiation of Traits at Mid Highland Area of Western Ethiopia

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Abstract: The bases of the idea to conduct this field experiment was the uses of the coffee and the suitable agro-ecology of mao-komo special distinct area, which have relatively the same ecology with potential coffee producing area of western wellega. To identifying adaptable coffee varieties that could exhibit higher yield to maximize coffee production and productivity to the environments of mao-komo special distinct, western Ethiopia, in order to diversify their production and to maximize the income of the farmers in the area. Based on this fact, a field experiment was conducted using six released coffee varieties, arranged with a randomized complete block design with three replicates to select varieties which could exhibit relatively better performance at the area. Those varieties were planted at a spacing of 2 m by 2 m between plants and rows, respectively and were evaluated for yield and yield components. They were grown with shade of Susbaniasusben. From the evaluated varieties it was noted that parameters as plant height, height up to primary branch, internodes length on main stem, canopy diameter, clean coffee yield had significant difference ($p<0.05$) among the varieties and the highest clean Coffee yield (1392.9, 1338.5 and 1100 Kg ha^{-1}) was scored by the 75227, 7440 and F59 varieties respectively. On the contrary 74110 exhibited least mean yields of 860.1 Kg of clean coffee per hectare. Based on the yield performance 75227 and 7440 varieties were recommended to producers of coffee at Mao-komo area and demonstration needs to be investigated.

Keywords: Arabica Coffee, Clean Coffee, Environments, Released Coffee Varieties, Yields

1. Introduction

Coffee belongs to the family Rubiaceae and genus Coffea L. comprised 104 species native to forests and scrublands of tropical Africa, Madagascar, and the Mascarene Islands in the Indian Ocean based on a pre-phylogenetic circumscription [1]. A number of coffee-producing countries in sub-Saharan Africa, including Uganda, Ethiopia, Rwanda and Burundi, depend on the export of this commodity for more than half of their foreign exchange earnings [2]. About 75% of the world's coffee comes from the tetraploid species coffee Arabica. It is native of the wet highland forests of Ethiopia where it grows wild.

In Ethiopia, coffee is produced organically as the bulk of the production comes from forest, semi-forest and home gardens where the use of inorganic fertilizers and chemicals is lacking. Economically, depending on prices on world market the share that comes from coffee still constitutes 25 to 40% of the national export [3, 4]. In addition, about 25 per cent of the population directly or indirectly depends on coffee industry through production, processing and marketing [5].

There is high genetic diversity among Arabica coffee germplasm collections in Ethiopia [6, 7]. This is due to 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 [8]. Even though Ethiopia has high genetic diversity, diverse and suitable agro-ecologies and suitable land mass, the national average coffee yield per unit area is generally low (about 750 kg/ha) [9], which is half of that achieved in Latin America and almost one third of Asia's productivity [10]. Such low yield is attributed to the lack of high yielding, disease resistant, lack of stable varieties that exhibit wide adaptation across wide ranges of environments of Arabica coffee in the country [11].

Different reports were shows significant genotype-environmental interactions for yield of coffee have been reported by several researchers [12]. A 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 environment; such as soil, temperatures, humidity and rainfall; thus a variety must be adapted to or suited to a region [13]. In the region especially mao-komo special area is potentially conducive for cultivation and extension of the coffee crop. Different varieties have different response to a given environments, Jimma agricultural research center released several coffee varieties for the country in general and also for particular area. It is critical to observe those varieties their adaptation and performance for western part of the country areas. So this paper was initiated based on the following objective.

To evaluate the improved coffee varieties for their adaptability and yield response to mao-komo special distinct.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was carried out at Mao- Komo sub center of Assosa Agricultural Research Center started in cropping seasons 2013/14. Mao-Komo Special district is bordered by Oromia Regional state in the East, Sudan in the West, Assosa Zone in the North and Gambela Region in the South. It is situated in Benishangul Gumuz region at 9° 23'.165''N latitude and 340 24 '.380'' E longitudes and the altitude of the district ranges from 950-1960 m.a.s.l. The study area is located south east of Assosa town and west of Addis Ababa about 125 km and 685 km distance respectively. Mao-Komo sub-center is also characterized by uni-modal rainfall which starts in April and extends to end of November with maximum rainfall received in June, July, August, September, and October [14]. The total annual average rainfall of Mao-komo is 1316.00 mm. The mean annual air temperature from 2009 to 2010 is 20°C varies from 13°C to 26°C. The major soil types found in the experiment area is Eutric Nitisols followed by Orthic Acrisols and Eutric Fluvisols [15].

2.2. Experimental Procedure

The six previously released CBD resistant coffee varieties which were collected from Jimma Agricultural Research Center where evaluated under mao-komo special distinct. The seedlings were raised at nursery which all nursery preparations and subsequent management practices were applied according to the established procedure or recommendation. Seeds (beans) were sown in polythene bags (10cm x 10cm) filled with one hand of forest soil, one hand of sandy soil and 2 hand of top soil and managed for 10 months. Site selection and preparation were carried out prior to field transplanting. Other pertinent agronomic and horticultural practices applicable to coffee were also followed in the field based on the recommendation.

2.3. Treatments and Experimental Design

Treatments consisted of six coffee varieties (7440, 75227, F59, 74158, 7454, 74110) were used. Accordingly, 40 cm X 40 cm (depth X width) planting holes size were dug. Seedlings from the nursery bed were field planted in June 2013 using randomized complete block design with three replications, 12 trees per plot and 2mx2m spacing between plants and rows. All field management practices were properly applied according to the recommendation. *Sesbania sesban* (temporary shade bush) and *Acacia spps* shade tree were planted before field transplanting of the coffee seedlings based on the recommended spacing to protect the coffee trees from direct sun light.

2.4. Data Collection

Data were collected for the following quantitative characters:

Height up to first primary (cm): The height from ground level up to first primary branch was measured in cm.

Plant height (cm): Measured in cm from the ground level to the tip of apical shoot using meter tape.

Number of primary branches: Total number of primary branches was counted for each tree.

Canopy diameter (cm): The diameter of the trees was measured in East-West and added to the South-North diameter and divided by two.

Internodes length (cm): Computed as (TH−HFPB)/(NN−1) where, TH=total height, HFPB=height up to first primary branch, NN=number of nodes on main stem.

Numbers of main stem nodes: this was recorded by counting the number of nodes on the main stem.

Length of the 1st primary branch (cm): Length of first longest primary branch measured from main stem to the tip of the branch.

Number of nodes on the longest primary branch: this character was recorded by counting the number of nodes.

Length of the longest primary branch: this was measured in centimeters using pocket meter.

Yield (kg/ha): Fresh cherries were harvested from all plants of the plot and converted to clean coffee bean yield in kg per hectare.

2.5. Statistical Data Analysis

All the data were analyzed using analysis of variance (ANOVA) as Proc GLM procedures of SAS version 9.2 statistical software. The difference between treatment means was computed using the Duncan's multiple range Test (DMRT) at 5% probability level. Pearson correlation was used to measure association of characters among themselves and clean coffee yield. Correlation analysis was made using proc corr procedures of SAS [16].

3. Result and Discussion

3.1. Growth Performance and Yield Components

The results of analysis of variance for all the parameters recorded were indicated in table 1 and discussed bellow.

Table 1. *Improved CBD resistance Arabica coffee varieties evaluated for growth and yield components at Mao-Komo sub center, Mao Komo Special district.*

Variety	Plant height (cm)	Height up to primary branch (cm)	Inter node length on the main stem (cm)	Number of main stem node
75227	221a	20.2ab	5.6667a	51.583
F59	170.5bc	19.93ab	4.8333c	48.25
74110	182.92bc	16.93b	4.75c	46.417
7440	234.5a	23.73a	5.25b	52.333
74158	191b	15.93b	4.75c	47.833
7454	163c	15.4b	4.6667c	49.167
P-value	**	*	**	Ns
LSD (0.05)	23.319	5.0582	0.3865	4.3065
CV%	6.61	14.87	4.261	4.805

Table 1. *Continued.*

Variety	steam girth (cm)	Length of Longest Primary (cm)	Number of primary branch	Canopy diameter (cm)	Clean cherry coffee yield (kg/ha)
75227	12.367	102.833a	54.5	208.083a	1392.9a
F59	12.9	84.25b	47.417	195.167ab	1100.5bc
74110	11.4	82.583b	46.25	169.25c	860.1c
7440	13.8	99.417a	50.833	211.083a	1338.5ab
74158	11.33	81.167b	48	177bc	1097.5bc
7454	12.467	82.083b	47.167	186.75bc	1078.6bc
P-value	Ns	**	NS	**	*
LSD (0.05)	1.8091	8.8414	6.0273	19.748	270.82
CV%	8.034	5.477	6.757	5.67648	13.00475

CV= Coefficient of variation, LSD= Least significant difference; Ns= none significant difference, Values with the same letter (s) are not significantly difference.

Plant Height

The mean of Plant height was highly significant difference (P≤0.05) among the tested varieties throughout the growth period. 7440 variety (234.5 cm) and 75227 (221cm) had significantly higher plant height than other varieties while 7454 variety had the lowest plant height (163 cm) and with over all mean of plant height ranged from 1.63-2.34 meter per plant for all varieties (Table 1). The difference among between the varieties could be attributed to the genetic variability among tested varieties; this is because maximum phenotypic differentiation for a trait is expressed in optimum environments and genetic composition of varieties.

Height up to primary branches

The mean values of height up to primary branches were statistically non-significant differences (P≤0.05) among the tested varieties. The varieties exhibited numerically the mean height up to primary branches ranges from 15.4-23.7 cm per plant.

Inter node length on the main stem

Inter node length on the main stem were significant difference (P≤0.05) among the tested varieties throughout the growth period. Variety 75227 (5.67 cm) had significantly higher inter node length on the main stem than other varieties, while 7454 variety had the lowest (4.67 cm) (Table 1).

Number of nodes on longest primary branch

There was statically non-significant variation (P≤0.05) among the tested coffee varieties in terms of number of nodes on longest primary branch. Almost all tested varieties showed higher number of nodes on longest primary branch without significant difference among themselves However, Variety 75227 was numerically the highest (52.33) and 74110 the lowest (46.4) values for this characteristic, respectively (table 1).

Number of main stem node

The varieties showed that there was a non- significant variation (P≤0.05) in number of main stem node. The highest average number of main stem node (52.33) was recorded by 7440 variety but statically par with pother varieties.

Steam girth

The mean values showed that there were statistically non-significant differences (P≤0.05) in steam diameter among the tested varieties. The variety exhibited the mean steam diameter ranges from 11.3-13.8 cm per plant.

Number of Primary Branch

The experimental varieties showed there was a non-significant variation (P≤0.05) in number of primary branch. The highest average number of primary branch (54.5) was recorded by 75227 variety, the average number of primary branch ranged from 46 to 54.5 while, variety 74110 had the least number of primary branch per plant (Table 1).

Canopy Diameter

The canopy diameter indicated that there was significant difference (P≤0.05) among the varieties of coffee. The highest canopy diameter ranges from 211.08 cm was scored by 75227 variety. While, the rest of testing material scored 169-211 cm average mean value of canopy diameter per plant

3.2. Yield Parameters

Clean Coffee bean Yield

The results showed that, significant differences (P≤0.05) among the varieties were observed for clean coffee bean yield per hectare. The highest mean clean yield was recorded for 75227 followed by F59, with values 1392.9 kg $ha^{-1}$and 1338.5 kg ha^{-1} respectively. The lowest mean clean yield on the other hand, was obtained from 74110 with value of 860.1 kg ha^{-1}. However, this value was statistically not different from values recorded for most of the released varieties except the 7440 top yielders (table 1).

Figure 1. *Yield performance of 7440 variety on the field.*

In general, all the evaluated varieties revealed variable performance with regard to clean coffee yields per hectare. Only one variety, namely, 7440 have showed highest yield variation with average yield performance of about 10 Qt ha^{-1} while statically significant variation from other varieties, the remaining six varieties did not statically exhibit better performance, but from those F59 were the second performed variety. Thus, this indicated that 7440 have better adaptive potential to the environment where this experiment is executed than the remaining ones. The yield difference could be attributed to the fact that genotypes usually exhibit different responses to the environment. These are a potential variable which induces genotype by environment interaction and only genotypes with wide adaptation across such environments butter yield stability this is in line with work of [17].

3.3. Correlation Coefficient Analysis

The relationship between yield and agronomic traits is important to the plant breeders to find out the traits correlated with yield and also how they are associated among themselves. Correlation analysis showed that plant height (r = 0.66**), Inter node length on the main stem, number of nodes on longest primary branch,

Highly and number of primary branches (r = 0.55*), canopy diameter (r = 0.53*) and stem girth (r = 0.42*) were significantly and positively correlated with clean coffee yield per hectare (table 2), this indicating that those characters have strong tie to improve productivity of coffee per tree basis. Pearson correlation (r) of plant height was highly significantly and positively correlated with stem diameter (r = 0.71), number of primary branch (r = 0.56) and canopy diameter (r = 0.33), while height up to primary branches (r = -0.07) was non significantly and negatively correlated. All the above positive and strong association of growth characters implies those components are most important for clean coffee yield improvement at mao-komo area.

Table 2. *Pearson's correlation (r) of clean coffee yield and its components of coffee varieties.*

Pearson Correlation Coefficients, N = 18									
Prob > |r| under H0: Rho=0									
	PH	**HPB**	**NMSM**	**ILMS**	**SG**	**CD**	**LLP**	**PB**	**YLD**
PH	1								
HPB	0.49474*	1							
NMSM	0.5186*	0.32105ns	1						
ILMS	0.69999**	0.62227**	0.50966*	1					
SG	0.33471^{ns}	0.33858ns	0.7817***	0.2003^{ns}	1				
CD	0.52155*	0.62256**	0.69541**	0.59294*	0.66057**	1			
LLP	0.69107**	0.3548^{ns}	0.75175***	0.75492***	0.53917*	0.58476*	1		
PB	0.62662**	0.08004^{ns}	0.70214**	0.56731**	0.55374*	0.64244**	0.73388***	1	
YLD	0.66206**	0.36295^{ns}	0.69194**	0.70856**	0.42244*	0.52655*	0.74537***	0.5492*	1

PH= plant height, HPB= height up to primary branch, ILMS=Inter node length on the main stem, NMSN= number of main stem node, SG= steam girth (cm), LLP= Length of Longest Primary (cm), NPB= number of primary branch, CD= canopy diameter (cm), CY= clean coffee yield.

4. Summary and Conclusion

The released varieties showed differential response to the tested environment. The result of almost all of the parameters as plant height, number of primary branch per plant, steam girth, canopy diameter and clean coffee yield recorded was statically significant difference among varieties, except height up to primary branch which is non-significant difference. From the present evaluation it was noted that the highest clean coffee yield (1011.5 and 806.3 Kg ha^{-1}) was scored by coffee genotypes 7440 and F59 variety respectively. On the contrary 7454, 75227, 74158 and 74110 exhibited least mean yields ranges from 603-775 Kg of clean coffee per hectare. The relationship of the growth characters were significantly and strongly correlated (P≤0.05) with clean coffee yield; this indicates the improvement of clean coffee yield was through most of growth parameters. From this study, it was concluded that variety 7440 and F59 produce better plant height, number of primary branches, canopy diameter and clean coffee yield to the environment indicates a good performance and adaptation. Therefore this variety was suggested to be produced by farmers at the study area and more research work on demonstration and popularization to producers needs to be investigated.

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