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Full Length Research Paper

Evaluation of some robusta coffee (*Coffea canephora* pierre ex a. Froehner) clones for optimal density planting in Ghana

G. J. Anim-Kwapong*, E. Anim-Kwapong and F. K. Oppong

Cocoa Research Institute of Ghana, P.O. BOX 8, New Tafo-Akim, Ghana.

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Increasing productivity is a main objective in Robusta coffee improvement in Ghana. A field trial was established in 1998 to evaluate the potential of ten Robusta coffee clones for optimal density planting, at the experimental field of the Cocoa Research Institute of Ghana sub-station, Afosu. The clones were evaluated at three planting densities (1667, 2222 and 2667 trees ha^{-1}) in a split plot design with three replicates, for yield and five vegetative traits namely: stem diameter, crown diameter, orthotropic internodes length, plagiotropic internodes length and number of bearing nodes per plagiotropic branch. Highly significant (P < 0.00) interaction effects were observed for all parameters measured. The highest yields (averaging 1289.5 kg ha^{-1} year^{-1}) were obtained from the highest planting density with clones 197, A129, B191, 181, and A115. These clones also had a relatively compact growth habit (smaller stem diameter and shorter plagiotropic and orthotropic internode lengths) compared to the other five clones (E152, B96, E138, E139 and B36). The findings suggest that productivity increases in Robusta coffee could be achieved through the use of planting materials which combine compact growth habit and high harvest potential in close spacing planting scheme.

Keywords: High density planting, robusta coffee clones, vegetative vigour, yield potential.

INTRODUCTION

In Ghana, coffee yields are generally low ranging between 100 and 200 kg ha^{-1} clean coffee annually on smallholder farms. Low coffee yields have been identified as a major factor contributing to the low level of cultivation and production of the crop in the country (Anon, 1996). A critical management option with potential for improving crop performance is plant density and arrangement (Cooper and Hammer, 1996).

To increase productivity, crops must either capture more light, water and nutrients or use them more efficiently. When resources are not limiting, densely planted monocultures usually provide the most efficient capture systems (Ong et al., 1996). Since robusta coffee is strictly self-incompatible it is essential to cultivate a number of cross-compatible clones in the field to ensure cross pollination and good yields. However, it must be emphasized that since there are complex interactions between the spatial arrangement of plants, the nature of resources, the episodic availability of resources and the plants' physiological and morphological response to levels of resource supply (Park et al., 2003; Schwinning and Weiner, 1998), consideration must be given to planting materials (clones/genotypes) of similar potential vigour to reduce asymmetrical competition among plants which occurs when large individuals utilize a disproportionately large share of the available resources to the detriment of the growth of smaller neighbours. This brings in to question the practice of evaluating different clones/genotypes at a single planting density and hence the need to test new materials under a wide range of planting densities. The aim of this paper is therefore to identify Robusta coffee clones suitable for high density planting and ultimately, to match specific planting material type to specific planting density that can be considered as optimum. Planting coffee at the optimum spacing will give the greatest economic return of robusta coffee yield per unit area.

MATERIALS AND METHODS

The study was initiated in 1998 at the Cocoa Research Institute of

*Corresponding author. E-mail: gjanimkwapong@yahoo.com.

Table 1. Effect of clone and spacing (planting density) on five years cumulative clean coffee yield at Afosu.

	SPACING			
	Clean coffee yield (kg ha^{-1})			
CLONES	**3 x 3 m**	**3 x 2 m**	**3 x 1.5 m**	**CLONE MEAN**
197	4403	5515	6978	5632
A129	4494	5180	7975	5883
B191	4354	4998	6228	5193
181	4536	6114	6408	5686
A115	3277	4081	4649	4002
E152	6420	5487	5270	5726
B96	6031	5362	4613	5335
E139	7203	5504	5179	5962
E138	4042	3942	3092	3692
B36	4206	3856	2534	3532
SPACING MEAN	4897	5004	5292	

s.e.d = standard error of difference.
s.e.d for comparing two spacing means = 109.2 (4 d.f.).
s.e.d for comparing two clone means = 141.8 (54 d.f.).
s.e.d for comparing two clones at a single spacing = 245.7 (54 d.f.).
s.e.d for comparing two differences between two clones for two spacing levels = 347.4 (54 d.f.).
s.e.d for comparing two spacing levels, either for the same clone or for different clones = 257.4 (no exact d.f.).

Ghana (CRIG) substation, Afosu (06°N, 0059°W and 228 m above sea level). The average annual rainfall is 1360 mm. The rainfall pattern is bimodal with maxima in May-June and September-October. Variation in monthly temperature is slight with mean monthly minimum and maximum temperatures of 27°C and 32°C. The natural vegetation is moist semi-deciduous forest south east type of the Celtis-Triplochiton floristic association (Hall and Swaine, 1981). The mean monthly sunshine duration is 162 h. Soils are Ferric Lixisol (Paleustalf), brown to yellowish red, well drained soils developed in situ from weathered materials of horneblende granodiorite (Buringh, 1979; FAO/UNESCO, 1977). The texture of the topsoil (0 - 15 cm depth) is sandy clay loam. Prior to the study, the site was under fallow vegetation.

Ten robusta coffee clones (197, A129, B191, 181, A115, E152, B96, E138, E139 and B36) were evaluated at three planting densities for growth and yield over five years under shade of *Gliricidia sepium* planted at 9 m x 12 m. Inter-row spacing was 3m and the intra-row spacing levels were 1.5, 2 and 3m giving a planting density of 2222, 1667 and 1111 plants ha^{-1} respectively. The trial was planted in a split plot design with three replicates. The main plot was the planting density and the subplot was the clones which were planted in line plots of 12 plants per clone per line plot. The plants were initially cultivated on one to two stems and height controlled at 1.7 m.

Clean coffee yield, some yield components and vegetative traits namely: stem diameter (measured at 15 cm from the base of the stem; for trees with two stems, diameter was measured following Stewart and Salazar (1992), crown diameter (span), plagiotropic internodes length and number of bearing nodes per plagiotropic branch were recorded during the first cycle of growth. Trees were coppiced after six years of growth. Two years after coppicing (second cycle), orthotropic internodes length was determined on free growing trees with three stems. Data on five year cumulative clean coffee yield; stem diameter, crown diameter, plagiotropic internodes length and number of bearing nodes per plagiotropic branch at the fifth year of harvest and orthotropic internodes length were subjected to analysis of variance (ANOVA, General Linear Models) using the MINITAB release 12 statistical software. Treatment means were compared using the Standard Error of the Difference between Means (SED). Correlations among the measured parameters were also carried out. Clustering of coffee clones was done using mean values of all the measured parameters of the clones (Tables 1 - 6) with the complete linkage method measured in squared Euclidean distance using the MINITAB release 12 statistical software.

RESULTS AND DISCUSSIONS

Highly significant ($p < 0.001$) interactions between clone and spacing were observed for all the parameters measured (Tables 1 - 6). Clone A129 performed best at 3 x 1.5 m (2222 tree ha^{-1}). Generally, the yield of this clone increased with increasing plant density while increased planting density caused a reduction in stem diameter (Table 2). This trend is an indication of the yield efficiency of the clone with respect to planting density. Similar trends were observed for clones 197, B191, 181 and A115. In contrast, the yields of clones E152, B96, E139, E138 and B36 declined with increasing density. Though clones E152, B96, E139, E138 and B36 performed best at 3 x 3m the cumulative five year average yield of 5580 kg ha^{-1} at this spacing was relatively lower than that of clones 197, A129, B191, 181 and A115 at the close spacing of 3 x 1.5 m which was 6447.6 kg ha^{-1} (Table 1). Hierarchical cluster analysis using data presented in Tables 1 - 6, grouped the clones into two clusters (Figure 1). Clones in cluster 1 (197, A129, B191, 181 and A115) were relatively compact with mean stem diameter (4.5), crown diameter (158.7cm), length of plagiotropic internodes (4.7cm) and length of orthotropic internode (6.3cm) compared to 5.3, 185.4, 5.5 and 8.2 cm respectively for clones in cluster 2 (E152, B96, E139, E138 and B36). Among significant correlations, stem diameter showed positive correlations with crown diameter ($r = 0.96$; $p < 0.001$) and orthotropic internodes length ($r = 0.72$; $p < 0.001$). The correlation between crown diameter and

Table 2. Effect of clone and spacing on stem diameter of Robusta coffee at fifth year of harvest at Afosu.

	SPACING			
	Stem diameter (cm)			
CLONES	**3 x 3 m**	**3 x 2 m**	**3 x 1.5 m**	**CLONE MEAN**
197	4.7	4.7	4.5	4.6
A129	4.9	4.6	4.4	4.6
B191	4.8	4.4	4.1	4.4
181	5.0	4.9	4.4	4.8
A115	4.6	4.3	4.0	4.3
E152	5.6	5.4	5.4	5.5
B96	5.5	5.4	5.0	5.3
E139	5.8	5.5	5.2	5.5
E138	5.4	5.3	5.0	5.2
B36	5.4	5.2	4.9	5.2
SPACING MEAN	5.2	5.0	4.7	

s.e.d for comparing two spacing means = 0.04 (4 d.f.)
s.e.d for comparing two clone means = 0.08 (54 d.f.)
s.e.d for comparing two clones at a single spacing = 0.13 (54 d.f.)
s.e.d for comparing two differences between two clones for two spacing levels = 0.19 (54 d.f.)
s.e.d for comparing two spacing levels, either for the same clone or for different clones = 0.13 (no exact d.f.)

Table 3. Effect of clone and spacing on crown diameter (span) of Robusta coffee at fifth year of harvest at Afosu

	SPACING			
	Crown diameter (cm)			
CLONES	**3 x 3 m**	**3 x 2 m**	**3 x 1.5 m**	**CLONE MEAN**
197	166.3	164.3	162.5	164.4
A129	172.2	164.4	162.4	166.3
B191	169.5	156.7	139.7	155.3
181	172.7	166.4	149.1	162.7
A115	157.1	144.4	132.1	144.5
E152	212.2	188.7	179.2	193.4
B96	189.9	183.3	175.7	183.0
E139	213.3	190.3	178.9	194.2
E138	184.2	176.1	173.7	178.0
B36	185.2	176.1	173.7	178.3
SPACING MEAN	186.3	171.0	163.0	

s.e.d for comparing two spacing means = 0.9 (4 d.f.)
s.e.d for comparing two clone means = 2.7 (54 d.f.)
s.e.d for comparing two clones at a single spacing = 4.6 (54 d.f.)
s.e.d for comparing two differences between two clones for two spacing levels = 6.5 (54 d.f.)
s.e.d for comparing two spacing levels, either for the same clone or for different clones = 3.1 (no exact d.f.)

orthotropic internodes length was also positive and significant ($r = 0.63$; $p < 0.001$). These show that clones with bigger stems had a corresponding larger crown diameter (span) and longer orthotropic internodes length. Such clones were grouped in cluster 2 (Figure 1).

Montagnon et al. (2001) associated the magnitude of stem diameter and length of orthotropic (main stem) internodes with level of vigour and aggression in robusta coffee. They further indicated that vigorous clones were more aggressive than others and that aggressive clones would undergo their own aggressiveness when grown alone in plantations. This observation plausibly explains the results shown in Table 1 where on average, a yield reduction of 26% was observed for the clones grouped in

Table 4. Effect of clone and spacing on primary branch (plagiotropic) internode length of robusta coffee at fifth year of harvest at Afosu.

	SPACING			
	Primary branch internode length (cm)			
CLONES	**3 x 3 m**	**3 x 2 m**	**3 x 1.5 m**	**CLONE MEAN**
197	4.5	4.6	4.7	4.6
A129	4.4	4.8	4.4	4.5
B191	4.6	4.8	4.9	4.8
181	4.3	4.3	4.9	4.5
A115	4.7	4.8	4.9	4.8
E152	5.0	5.2	5.1	5.1
B96	5.1	5.3	5.8	5.4
E139	5.0	4.7	5.4	5.0
E138	5.3	5.8	6.4	5.8
B36	5.2	6.0	7.8	6.3
SPACING MEAN	4.8	5.0	5.4	

s.e.d for comparing two spacing means = 0.22 (4 d.f.)
s.e.d for comparing two clone means = 0.32 (54 d.f.)
s.e.d for comparing two clones at a single spacing = 0.54 (54 d.f.)
s.e.d for comparing two differences between two clones for two spacing levels = 0.76 (54 d.f.)
s.e.d for comparing two spacing levels, either for the same clone or for different clones = 0.56 (no exact d.f.)

Table 5. Effect of clone and spacing on number of bearing nodes per primary branch of Robusta coffee at fifth year of harvest at Afosu.

	SPACING			
	Number of bearing nodes per primary branch			
CLONES	**3 x 3 m**	**3 x 2 m**	**3 x 1.5 m**	**CLONE MEAN**
197	10	10	9	9
A129	10	9	9	9
B191	10	9	8	9
181	13	11	8	11
A115	9	8	8	8
E152	11	8	8	9
B96	9	8	6	8
E139	11	10	7	9
E138	9	7	6	7
B36	9	6	4	6
SPACING MEAN	10	9	7	

s.e.d for comparing two spacing means = 0.33 (4 d.f.)
s.e.d for comparing two clone means = 0.51 (54df)
s.e.d for comparing two clones at a single spacing = 0.89 (54 d.f.)
s.e.d for comparing two differences between two clones for two spacing levels = 1.58 (54 d.f.)
s.e.d for comparing two spacing levels, either for the same clone or for different clones = 0.92 (no exact d.f.)

Cluster 2 on moving from 3 x 3 to 3 x 1.5 m spacing. This indicates that the vigorous clones are better suited for wide spacing planting where competition effect could be less intense. The results of the present study agrees with observations in cacao reported by Efron et al. (2003) where in the absence of competition, bigger trees tend to produce higher yields than smaller trees, but their yield efficiency, measured as yield in relation to vigour, may be lower.

Conclusion

The results of the present study shows that optimal plant-

Table 6. Effect of clone and spacing on main stem (orthotropic) internode length of Robusta coffee at second year of second cycle at Afosu

	SPACING			
	Orthotropic internode length (cm)			
CLONES	**3 x 3 m**	**3 x 2 m**	**3 x 1.5 m**	**CLONE MEAN**
197	5.9	6.2	6.6	6.2
A129	6.2	6.4	6.6	6.4
B191	6.2	6.4	6.5	6.4
181	6.4	6.5	6.6	6.5
A115	5.6	5.8	5.9	5.8
E152	7.3	8.6	9.2	8.4
B96	7.1	7.9	8.4	7.8
E139	8.3	8.6	9.0	8.6
E138	7.4	8.2	8.3	8.0
B36	7.9	8.2	8.4	8.2
SPACING MEAN	6.8	7.3	7.6	

s.e.d for comparing two spacing means = 0.04 (4 d.f.)
s.e.d for comparing two clone means = 0.07 (54df)
s.e.d for comparing two clones at a single spacing = 0.12 (54 d.f.)
s.e.d for comparing two differences between two clones for two spacing levels = 0.17 (54 d.f.)
s.e.d for comparing two spacing levels, either for the same clone or for different clones = 0.12 (no exact d.f.)

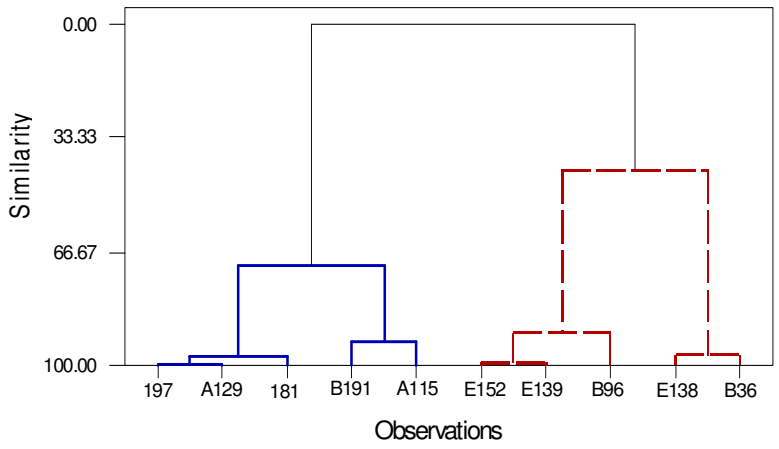

Figure 1. Dendrogram showing the hierarchical clustering of the ten clones used in the present study.

ing density for coffee clones could be related to the potential vigour of the trees. For planting in the field, it would be necessary to group clones based on similarity of morphological characters and yield to avoid or minimise asymmetrical competition. Generally, the larger clones in cluster 2 should be planted at 3 x 3 m and clones in cluster 1 planted together at 3 x 1.5 m for best results.

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