Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.5, No.17, 2015

Determining Suitable Shade Trees, Panting Pattern and Spacing for Arabica Coffee Production in South and Southwestern Ethiopia

Anteneh Netsere Taye Kufa
Jima Agricultural Research Center, P. O. Box 192, Jimma, Ethiopia

Abstract
In an attempt to determine suitable shade trees, planting pattern and optimum population density that promote productivity of Arabica coffee, two separate field experiments were carried out in south and south western coffee growing tracts of Ethiopia. In experiment one, seeds of thirteen shade trees were collected and established at Jimma Agricultural Research Center. Coffee berry disease resistant cultivar was stripe planted and intercropped with the shade trees in split-plot design with three replications, where shade trees and planting patterns assigned as main- and sub-plot, respectively. In experiment two, prominent shade trees were established at Gera Agricultural Research Sub-center and Metu and Wenago trial sites. The trial was laid out in split-plot design with three replicates, where shade trees and spacing between coffee trees assigned in the respective main and sub-plots. The results depicted that shade trees significantly ($P \leq 0.05$) affected coffee yield. The highest yield was noted for coffee trees planted under *Millettia ferruginea, Albizia maronguensis, Acacia abyssinica, Albizia tanganica, Erythrina abyssinica, Calpurnea subdecondra and Cordia africana.* The trees produced 1240 - 4512 kg ha^{-1} annum^{-1} litter fall and intercept 26 - 60% light intensity. Besides, the shade trees have mean canopy diameter ranged between 6 m * 6 m to 20 m * 20 m. Stripped plots significantly ($P \leq 0.05$) out yielded intercropped plots by 20.40%. In the overall year mean coffee population density of 5917, 3906 and 5102 trees ha^{-1} gave the highest yield at Gera, Metu and Wenago, respectively. It is, therefore, concluded that productivity of coffee trees can be improved by planting at its optimum population density in strip between the aforementioned prominent shade trees. However, investigation should continue to evaluate the effect of the shade trees on the row and liquor quality of coffee, smothering of weed growth, plant nutrient supply, soil moisture dynamics and physico-chemical properties of soil in major coffee growing areas of the country.
Keywords: Arabica coffee, intercropped, planting pattern, spacing, shade trees, stripped

Introduction

In Ethiopia, Arabica coffee is produced in four production systems, *viz*. forest, semi-forest, cottage and plantation, which account for 10, 35, 50 and 5%, respectively, under a variety of shade trees (Workafes and Kassu, 2000; Taye, 2006). In these production systems, the productivity of the crop is very low and hardly exceeds 0.71 t ha^{-1} clean coffee (Central Statistical Agency, CSA, 2012).. *Inter alias*, excessive or inadequate shading by overhead shade trees and irregular pattern of growing coffee trees with shade trees including high density planting in natural forest and low coffee population density under modern coffee plantation, are the major constraints which accounts for such low production and productivity of the crop in the country (Yacob *et al*., 1996; Tesfaye *et al*., 1998; Endale *et al*., 2008; Anteneh *et al*., 2015).

Coffee is a C_3 plant having high quantum utilization efficiency for photosynthesis. However, excessive shading/light interception by overhead shade trees would decrease growth and productivity of the crop as the plant spend much of its photosynthetic product for maintenance, which under normal conditions would have been utilized for the formation of plant parts and as substrate for respiration (Beer *et al*., 1998; Tesfaye, 1995; Yacob *et al*., 1996). On the other hand, if the light intensity is too high, there will be inadequate reaction centers in the leaves of coffee trees to accommodate all the incoming light energy and convert into biochemical energy. As a result, the plant photorespires and eventually most of the stored carbohydrates get depleted. This may lead to early dieback of entire coffee plantations and overbearing syndrome (Coste, 1992; Wrigley, 1988; Wintgens, 2004). Besides, excessive evapotransparation and sever water stress, death of actively growing shoots, seasonal crinkling of leaves and hail, frost and sun scorch damages and subsequent yield reduction are common problems observed in unshaded coffee orchards (Wintgens, 2004). Coffee plant rather requires moderate shade (30 - 70% of full light intensity) for optimum vegetative growth, biochemical synthesis and yield (Kumar, 1979; Yacob *et al*, 1996; Tesfaye, 1995; Anteneh *et al*., 2015). In line with this, the available research results revealed that canopies of selected shade tree species filter out such moderate light intensity when planted at normal spacing and thus promote productivity of the crop (Yacob *et al*, 1996; Tesfaye *et al.*, 1998; Endale *et al*., 2008).

In traditionally managed wild, semi-domesticated and garden plantations, coffee trees either sparsely or closely and irregularly spaced. In sparsely production system the limited available farmlands are less efficiently utilized and the productivity of the crop per unit area of and is very low. In contrast in densely populated orchards branches and canopies of coffee trees overlap and interlocked especially for open varieties in the latter years of production. This problem is further aggravated by excessive light interception by overhead shade trees above and competition among coffee trees for available moisture and nutrients below the ground. As a result the productivity of closed spaced coffee trees considerably reduced (Odeny and Kimemia, 1999; Wintgens, 2004). This study was, therefore, conducted with the objectives to identify suitable shade tree species and planting pattern of coffee with shade trees that promote yield of the crop and to determine optimum spacing (population density) to be used to plant (grow) Arabica coffee under the shade trees in south and southwestern coffee growing tracts of Ethiopia.

Materials and Methods

Two separate experiments were conducted in south and southwestern coffee growing areas of Ethiopia. In experiment one, seeds of thirteen commonly and widely used shade tree species for Arabica coffee production, *viz. Albizia maronguensis, Albizia tanganyka, Albizia schimperiana, Albizia gunifera, Millettia ferruginea, Erythrina indica, Erythrina abyssinica, Acacia abyssinica, Calpurnea subdecondra, Cordia africana, Leucaena lecosyphylla, Gravilea robusta and Tephrosia vogellii*, were collected and established at a spacing of 6 m * 6 m without considering their canopy spread at Jimma Agricultural Research Center. Coffee berry disease resistant coffee cultivar was striped planted between two shade trees and intercropped with individual shade trees at a spacing of 1.50 m * 2.00 m. A split-plot in randomized complete block design with three replications was employed, where shade trees and planting patterns were assigned as main- and sub-plot, respectively. Data on percent light interception, canopy diameter and seasonal fallen senescent leaves (litter fall) of some of the shade trees were collected. Mean percent of light interception by shade trees was estimated as the ratio of light measured at a given point above the coffee trees but under the canopy of the shade trees to that of an open air of clear sky using LI-1776 quantum light meter. Canopy diameter (lateral extension growth) of individual shade trees was measured in north-south and east-west directions and mean values were calculated for individual experimental shade trees planted in each experimental unit.

In experiment two seeds of prominent shade trees were collected and established at Gera Research Sub-center, and Metu and Wenago testing sites in split-plot design with three replications. Accordingly, shade trees assigned to main-plot and spacing between coffee tress to sub-plot. Except experimental variables, other routine management practices were timely and uniformly applied to experimental unit as per the recommendation until the completion of the study. The geographical description, long-term mean rainfall and temperatures and agro-ecological zones of the study sites are presented in Table 1.

In both experiment I and II red fresh cherries harvested from each experimental unit and weighted separately. The results were multiplied by the factor of 0.166 to convert into clean coffee and reported in quintal per hectare (Q ha^{-1}), where 1 Q = 100 kg. The collected data were statistically analyzed as per the design using SAS software (SAS version 9.1, 2008). Duncan's Multiple Range Test at P = 0.05 probability level were used to compare the difference between treatment means where significant differences were obtained by analysis of variance (Mandefro, 2005).

Table 1. Geographical description, mean rainfall and temperature, and agro-ecological zones of the study sites

Study sites	Latitude	Longitude	Altitude (m.a.s.l)	Temperature (^{0}C)		Rainfall (mm)	Agro-ecological zone
				Minimum	Maximum		
Jima	7^o 46'N	36^o 0'E	1753	11.3	26.2	1594.5	Sub-humid tepid to cool mountains
Gera	7^{0}7'N	36^{0}0'E	1900	10.4	24.0	1877.8	Tepid to cool sub humid low to high altitude
Metu	7^o 3'N	7^o 3'N	1550	12	27	1830	Sub-humid hot to warm low to mid highland mountain
Wenago	6^o 3'N	38^o 3'E	1850	10.6	27.7	1582.5	Tepid to cool humid mid high land altitude

Results and Discussion

Experiment I

Coffee yield was significantly ($P \leq 0.05$) affected by shade trees. Coffee trees planted under *Millettia ferruginea* gave the highest clean coffee yield of 18.09 Q ha^{-1} followed by *Albizia maronguensis* (15.80 Q ha^{-1}), *Acacia abyssinica* (15.34 Q ha^{-1}), *Albizia tanganyka* (15.21 Q ha^{-1}), *Erythrina abyssinica* (14.85 Q ha^{-1}), *Calpurnea subdecondra* (14.67 Q ha^{-1}), *Leucaena lecosyphylla* (12.16 Q ha^{-1}), *Cordia africana* (12.04 Q ha^{-1}) and *Tephrosia vogellii* (11.84 Q ha^{-1}). In contrast, lower coffee yield was recorded from trees planted under *Erythrina indica, Albizia schimperiana, Albizia gunifera* and *Gravilea robusta* (Table 2).

Significantly ($P \leq 0.05$) higher mean clean coffee yield were noticed in stripped than intercropped plots. Consequently, coffee trees striped between *Millettia* and *Albizia*, *Acacia* and *Leucaena,* and *Calpurnea* and

Acacia gave significantly higher clean coffee yield of 21.58, 18.96 and 16.93 Q ha^{-1}, respectively (Table 3). Coffee yields of striped plots were superior over intercroped by 20.40% (Table 2 and 3). Similarly, Yacob *et al.* (1996) documented the merits of strip cropping to avoid or reduce direct competition between the shade and the coffee trees for available natural resource, *viz*. light, moisture and nutrients. However, increase in coffee yield both in intercropped and striped plots as of this study could be attributed to higher rate of photosynthesis, as photosynthetic rate in C_3 crop like coffee is low when grown in open sun (without shade) or under deeply shaded environment, but it is enhanced under moderate light regimes (30 - 60%) (Tesfaye, 1995;Yacob *et al*., 1996; Tesfaye *et al*., 1998).

The lowest and highest light intensity of 19 and 60% has been intercepted by *Erythrina abyssinica* and *Erythrina indica*, respectively. However, most of the shade trees intercept moderate light regime ranging between 26 to 50% (Table 4). This confirm the earlier findings of Yacob *et al*. (1996) and Tesfaye *et al*. (1998), who indicated growth and productivity of coffee plant improved under moderate shades, but significantly reduced in open sun or under low light intensity/deep shade. Likewise, Tesfaye (1995) reported that moderate shade of 25 - 75% favored maximum growth and dry matter production by coffee seedlings and increased soil moisture status of the rooting media while deeper shade decreased the growth parameters of the crop in spite of increased level of plant and soil moisture content during the nursery period.

Mean canopy diameter of most of the shade trees ranged between 16 m * 16 m to 20 m * 20 m. However, *Calpurnea subdecondra* and *Millettia ferruginea* have the lowest canopy diameter of 6.0 m * 6.0 m and 8.0 m * 8.0 m, respectively (Table 4). The observed variation in canopy diameter among the shade trees revealed distinct inherent characteristic of the shade trees that require corresponding spacing based on their canopy spread. On the other hand, seasonal liter fall variation was observed among the shade trees. Accordingly, rate of litter fall (defoliation) were higher for *Albizia gunifera*, *Cordia Africana*, *Millettia ferruginea* and *Acacia abyssinica* with respective values of 4751.33, 4511.67, 4271.34, 2167.00 kg ha^{-1} annum^{-1} (Table 4). However, lower litter fall of 1549, 1293, 1240, 1022 and 452 kg ha^{-1} annum^{-1} was noticed for *Erythrina abyssinica*, *Erythrina indica*, *Albizia tanganyka, Albizia schimperiana* and *Calpurnea subdecondra,* respectively. In general, such seasonal litter fall from shade trees could serve as a source of organic matter to improve physico-chemical properties of the soil up on decomposition and thus promote organic coffee production in the country (Dechasa, 2004).

Experiment II

Gera

Shade trees not significantly affected coffee yield in all crop years, except in the 3rd crop year where the effect was significant ($p \leq 0.05$) (Table 5a). Though, the effect of shade trees on coffee yield was inconsistent over the different crop season, in most of the crop seasons higher yield was noticed for coffee trees planted under *Calpurina subdecondra.* In contrast, trees grow under *Cordia africana* gave the lowest yield in most of the crop seasons. Consequently, in the overall year the respective highest and lowest clean coffee yield of 27.70 and 19.33 Q ha^{-1} were noticed from coffee trees planted under the aforementioned shade trees. *Acacia* sp. and *Millettia ferruginea* also gave relatively higher yield with respective values of 22.72 and 21.67 Q ha^{-1} clean coffee (Table 5a). In general the present findings indicate that coffee tree planted under the study shade trees gave at least two times higher yield than the current low national average yield of coffee 0.71 t Q ha^{-1} clean coffee.

Population density (trees/ha) significantly affected coffee yield except in 5th, 6th and 8th cropping season when the effect was non-significant (Table 5a). Coffee yield increased with increasing tree density or closer spacing between coffee trees up to the third crop season. Thereafter, with an increased in coffee and shade trees canopy diameter and mutual/self shading in closely spaced coffee trees, yield tend to declined above population densities of 5917 trees ha^{-1} indicating the reduced efficiency of close spaced coffee tress at this production stage. Similarly, the overall mean coffee yield increased from 19.96 to 25.79 Q ha^{-1} clean coffee with increasing population density from 3460 to 5917 trees $^{-1}$. Thereafter, slight decrease in yield was observed (Table 5a). This suggests either to earn high profit for the first 3 - 4 consecutive crop years by planting coffee trees at closer spacing of 1.10 m x 1.10 m and then after thin out the coffee trees to population densities not exceeding 5917 trees $^{-1}$ at latter stage or high management inputs should be applied with the aim to mentain optimum vegetative and reproductive capacity and prolong the lifespan of coffee trees.

Metu

The effect of shade trees on coffee yield statistically at par for all crop years except in 6th crop season when the effect was significant ($P \leq 0.01$) (Table 5b). In most of the crop season coffee trees planted under *Acacia* sp. gave the highest clean coffee yield. Besides, yield of coffee trees planted under *Milletia ferruginea* linearly increased with the increased canopy diameter of the tree as production year progresses. In most of the crop season coffee trees planted under *Croton macrostachyus* and *Calpurina subdecondra* gave the lowest yield (Table 5b). However, in the over all year, maximum clean coffee yield of 18.54 and 18.34 Q ha^{-1} were recorded for coffee trees planted under *Acacia* sp. and *Millettia ferruginea,* respectively. Relatively higher yield also noted for *Albizia* sp., *Cordia africana* and *Erythrina abyssinica* with respective mean yield of 13.89, 12.21 and 12.10 Q ha^{-1} clean coffee. In contrast, coffee trees planted under *Calpurina subdecondra and Croton macrostachyus* gave the lowest clean coffee yield of 8.49 and 6.17 Q ha^{-1}, respectively.

Yield variations among population density (trees ha^{-1}) were non-significant for most of the crop season except in 2nd, 3rd and 6th crop seasons when the effect was significant ($P \leq 0.01$ or $P \leq 0.05$) (Table 5b). For the first three consecutive years coffee yield linearly increased with increasing population density from 2500 - 3906 trees ha^{-1}. However, in the latter crop years the effect of spacing on coffee yield was inconsistent. In the overall years yield sharply increased with increasing population density from 2500 to 3086 trees ha^{-1}. Thereafter, slight increase in yield was observed with closer spacing or increase in population density from 3086 to 3906 trees ha^{-1}.

Wenago

The different shade trees had no marked significant effect on coffee yield during the 1st and last crop seasons (Table 5c). In all crop years, coffee trees planted under *Albizia* sp. and *Acacia* sp. consistently gave the highest yield of 14.69 and 11.71 Q ha^{-1}, respectively. In contrast, *Cordia africana, Erythrina abyssinica* and *Croton macrostachyus* depressed coffee yield.

Yield variation due to spacing treatments was significant for all crop years except 3rd crop year when the effect was non-significant. In most of the crop seasons and in the over all year, yield linearly increased with increasing population density from 3086 to 5102 trees/ha (Table 5c). These seemed to be a good indicator for the existence of a room for increased coffee yield using a population density beyond 5102 trees ha^{-1}. Thus, quantification of the optimum population density through research and further fine-tuning is mandatory.

Conclusion and Recommendations

Millettia ferruginea, Albizia maronguensis, Acacia abyssinica, Albizia tanganica, Erythrina abyssinica and *Cordia africana* are suitable shade tree species for coffee production in areas where they can adapt well with coffee tress. These are the most commonly grown shade trees in coffee growing areas of Ethiopia with adequate canopy coverage and moderate light interception. However, the effect of these shade trees on raw and liquor quality of coffee is not investigated and thus requires a through investigation.

The productivity of coffee trees could be improved by strip planting or intercropping with the above mentioned shade trees. However, yield in strip plots was superior to those of intercropped plots. Thus, in the future shade trees, fruit or other complimentary crops should be strip planted with coffee tress.

Although the contribution of seasonal litter fall from the shade trees to coffee plant underneath is known, further study is required to quantify the effect of litter fall on soil water potential, nutrient supply, physico-chemical properties of soils and weed suppression.

Coffee population density of 5917, 3906 and 5102 trees ha^{-1} at Gera, Metu and Wenago, respectively, considerably gave higher yield over the lower population density. It is, therefore, concluded that productivity of coffee stands can be improved by growing coffee with optimum population density in strip between the aforementioned prominent shade tree species.

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Table 2. Mean coffee yield planted under shade trees in intercropping pattern

Shade tree species	Yield (clean coffee Q ha^{-1})[†]
Millettia ferruginea	18.09[a]
Albizia tanganyka	15.21[b]
Albizia schimperiana	9.16[ef]
Albizia gunifera	7.24[f]
Albizia maronguensis	15.80[b]
Erythrina indica	10.88[de]
Erythrina abyssinica	14.85[bc]
Acacia abyssinica	15.34[b]
Cordia africana	12.04[cd]
Leucaena lecosyphylla	12.16[cd]
Calpurnea subdecondra	14.67[bc]
Tephrosia vogellii	11.84[cd]
Gravilea robusta	3.95[g]
Mean	**12.40**

Means within a column followed by the same superscript letter(s) are not significantly different from each other at P = 0.05 probability level. [†]1 Q = 100 kg.

Table 3. Mean coffee yield planted in strip between two shade trees

Shade tree striped	Yield (clean coffee Q ha^{-1})
Millettia + Albizia	21.58[a]
Leucaena + Acacia	18.96[b]
Calpurnea + Acacia	16.93[c]
Gravillea + Millettia	13.43[d]
Albiziz + Acacia	12.55[de]
Tephrosia + Erythrina	11.36[def]
Tephrosia + Millettia	9.68[f]
Mean	**14.93**

Means within a column followed by the same superscript letter(s) are not significantly different from each other at P = 0.05 probability level.

Table 4. Percent light interception, mean canopy diameter and seasonal litter fall of prominent coffee shade trees

Shade tree species	Percent light interception	Mean canopy diameter (m)	Litter fall ($kg\ ha^{-1}\ annum^{-1}$)
Millettia ferruginea	40	8 * 8	4271.34
Albizia tanganyka	26	18 * 18	1240.00
Albizia schimperiana	29	20 * 20	1022.33
Albizia gunifera	32	18 * 18	4751.33
Acacia abyssinica	30	20 * 20	2167.00
Cordia africana	36	16 * 16	4511.67
Erythrina indica	60	18 * 18	1293.67
Erythrina abyssinica	19	16 * 16	1549.67
Calpurnea subdecondra	50	6 * 6	452.33

Table 5. Clean coffee yield ($Q\ ha^{-1}$) as affected by shade tree species and spacing between coffee plants

a) Gera

Treatment	Crop year									**Mean**
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	
Shade tree	Clean coffee yield ($Q\ ha^{-1}$)									
Calpurina subdecondra	1.49	16.32	42.84^{a}	15.04	43.74	11.05	42.96	14.52	61.32	**27.70^{a}**
Acacia abyssinica	1.52	12.46	25.28^{b}	23.73	33.34	15.89	31.33	11.52	49.37	**22.72^{b}**
Milletia ferruginea	1.58	12.01	20.77^{b}	20.81	27.78	15.96	31.06	16.45	48.59	**21.67^{b}**
Cordia africana	0.35	10.73	24.65^{b}	17.41	23.72	9.85	32.02	9.85	45.42	**19.33^{c}**
Significance level	**NS**	**NS**	*	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	
SE (±)	**0.41**	**2.65**	**3.60**	**4.52**	**4.46**	**3.12**	**3.77**	**4.58**	**7.04**	
CV (%)	**84.48**	**61.78**	**39.81**	**64.41**	**39.66**	**65.39**	**33.08**	**80.61**	**38.21**	
Spacing (m)/density (trees/ha)										
1.10 x 1.10/8264	1.58^{a}	15.23^{a}	33.41^{a}	20.60^{ab}	35.10	13.99	36.38^{a}	13.26	57.86^{a}	**25.39^{a}**
1.30 x 1.30/5917	1.20^{ab}	15.12^{a}	28.85^{a}	24.15^{a}	35.16	16.30	37.11^{a}	14.57	59.61^{a}	**25.79^{a}**
1.70 x 1.70/3460	0.76^{b}	8.21^{b}	19.15^{b}	18.47^{b}	30.81	12.70	28.06^{b}	13.15	48.36^{b}	**19.96^{b}**
Significance level	**	**	**	**	**NS**	**NS**	**	**NS**	*	
SE (±)	**0.14**	**1.01**	**1.30**	**1.15**	**1.93**	**1.20**	**2.00**	**1.55**	**2.99**	
CV (%)	**44.84**	**30.42**	**18.57**	**21.18**	**22.13**	**32.43**	**22.66**	**44.04**	**20.93**	

NS, * and ** = Non-significant and significant at P = 0.05 and 0.01 probability, respectively. Means within a column followed by the same superscript (s) are not significantly different at P = 0.05 probability level.

b) Metu

Treatment	Crop year								**Mean**
	1st	2nd	3rd	4th	5th	6th	7th	8th	
Shade tree	Clean coffee yield ($Q\ ha^{-1}$)								
Albizia sp.	3.65	10.41	7.84	11.58	12.69	25.77^{a}	20.32	18.89	**13.89**
Acacia sp.	7.33	15.81	12.51	13.24	18.71	23.15^{a}	36.60	21.59	**18.54**
Cordia africana	2.86	13.54	9.02	7.72	10.37	22.66^{a}	6.87	24.64	**12.21**
Croton macrostachyus	3.06	3.88	4.46	4.83	6.89	6.60^{b}	9.16	10.46	**6.17**
Calpurina subdecondra	2.64	9.05	5.98	7.08	9.21	16.98^{ab}	12.04	4.96	**8.49**
Erythrina abyssinica	3.53	11.50	8.02	-	14.35	23.49^{a}	18.95	16.92	**12.10**
Milletia ferruginea	3.69	14.13	-	-	-	18.35^{a}	25.88	29.63	**18.34**
Significance level	**NS**	**NS**	**NS**	**NS**	**NS**	**	**NS**	**NS**	
SE (±)	**15.74**	**15.70**	**20.01**	**10.05**	**22.69**	**21.51**	**43.70**	**24.53**	
CV (%)	**75.36**	**67.76**	**84.28**	**62.74**	**78.19**	**54.30**	**71.31**	**61.92**	
Spacing (m)/density (trees/ha)									
1.6 x 1.6/3906	4.45	13.52^{a}	13.50^{a}	21.46	14.46	28.65^{a}	20.57	19.06	**16.96a**
1.8 x 1.8/3086	3.66	11.98^{ab}	8.57^{b}	30.84	14.19	16.12^{b}	23.35	20.03	**16.09a**
2.0 x 2.0/2500	3.33	9.79^{b}	6.60^{b}	24.06	14.71	14.41^{b}	14.23	20.10	**13.40b**
Significance level	**NS**	**	*	**NS**	**NS**	*	**NS**	**NS**	
SE (±)	**2.67**	**5.17**	**7.16**	**7.19**	**6.76**	**13.79**	**26.31**	**15.06**	
CV (%)	**56.85**	**115.47**	**60.98**	**23.18**	**38.06**	**56.86**	**110.39**	**62.11**	

NS, * and ** = Non-significant and significant at P = 0.05 and 0.01 probability, respectively. Means within a column followed by the same superscript (s) are not significantly different at P = 0.05 probability level.

c) Wenago

Treatment	Crop year							**Mean**
	1st	2nd	3rd	4th	5th	7th	8th	
Shade tree	Clean coffee yield (Q ha^{-1})							
Albizia sp.	24.73	13.21^{a}	17.46^{a}	11.37^{abc}	9.91^{a}	12.63^{a}	13.53	**14.69^{a}**
Acacia sp.	15.51	10.78^{ab}	11.79^{b}	17.56^{a}	6.58^{b}	11.59^{a}	8.17	**11.71^{ab}**
Calpurina subdecondra	8.34	7.71^{bc}	5.45^{c}	15.88^{a}	5.86^{b}	11.34^{ab}	7.75	**8.90^{b}**
Cordia africana	4.45	$7.24b^{c}$	4.67^{cd}	11.63^{abc}	4.97^{bc}	7.00^{ab}	5.79	**6.54^{b}**
Croton macrostachyus	6.09	4.39^{c}	2.77^{cde}	7.54^{bcd}	2.96^{c}	7.79^{abc}	3.40	**4.99^{b}**
Erythrina abyssinica	4.76	4.66^{c}	0.77^{e}	5.24^{cd}	2.88^{c}	4.46^{bc}	2.29	**3.58^{b}**
Significance level	NS	*	*	**	**	**	NS	
SE (±)	**31.49**	**10.75**	**6.85**	**14.52**	**5.53**	**12.91**	**8.40**	
CV (%)	**70.00**	**75.00**	**56.06**	**69.38**	**48.81**	**86.36**	**64.97**	
Spacing (m)/density (trees/ha)								
1.4 x 1.4/5102	10.23^{a}	9.34^{a}	6.00	15.18^{a}	7.24^{a}	9.22^{a}	8.03^{a}	**9.32^{a}**
1.6 x 1.6/3906	10.57^{a}	6.57^{b}	6.52	8.56^{b}	5.19^{b}	6.88^{b}	6.11^{b}	**7.20^{ab}**
1.8 x 1.8/3086	6.88^{b}	5.49^{b}	5.75	7.53^{b}	4.67^{b}	6.23^{b}	5.19^{b}	**5.96^{b}**
Significance level	*	*	NS	**	*	*	*	
SE (±)	**4.76**	**3.43**	**3.69**	**4.39**	**1.81**	**4.30**	**2.48**	
CV (%)	**41.97**	**39.26**	**49.29**	**34.26**	**26.17**	**46.97**	**31.38**	

NS, * and ** = Non-significant and significant at P = 0.05 and 0.01 probability, respectively. Means within a column followed by the same superscript letter(s) are not significantly different at P = 0.05 probability level.