Regeneration of *Coffea arabica* and Quality of Coffee Found in an *Eucalyptus grandis* Plantation

Shiferaw Alem [1], Tadesse Woldemariam [2]
[1] Mendel University, Faculty of Forestry and Wood Technology, Zemedelska 3/613 00, Brno, Czech Republic. E-mail: shife19@yahoo.com
[2] Environment and Coffee Forest Forum, P. O. Box 28513, Addis Ababa, Ethiopia,

Abstract

The paper focuses on the impact of *E. grandis Hill* ex Maiden on the natural regeneration of C. *arabica* L. and on its cup quality as compared with the adjacent natural forest coffee. The objectives were to assess the natural regeneration status of *C. arabica* under *E. grandis* plantation in comparison with its adjacent natural forest, and examine and compare the coffee quality (Green quality (Odour + defect) + Cup quality (Acidity + Body + Flavour)) of natural forest coffee and the *E. grandis* plantation coffee. For data collection, twenty plots, with an area of 20 m × 20 m for each, were established in both of *E. grandis* plantation and adjacent natural forest, independently. In each plot, all coffee plants diameter and height were recorded. Numbers of seedlings were counted in five sub-plots (4 m^2) established at the corners and the centre of each major plot. For the coffee quality test, beans were collected in both forest types independently and its quality assessed in the coffee and tea quality-liquoring laboratory following the standard procedure. The analysis result indicated that the density of coffee plants in the plantation was 1,022 stems/ha, while it was 1,042 stems/ha in the natural forest. The number of coffee seedlings in the *E. grandis* plantation was 3,350 seedlings/ha while in the natural forest it was 7,000 seedlings/ha. The quality test result indicated that the green quality of coffee beans found in the natural forest was 35%, while it was 33% in those collected in the plantation. The Cup quality was 45% in both the natural forest and the *E. grandis* plantation. There was no significant difference on the bean size of coffees collected from both the natural forest and the *E. grandis* plantation. Finally, coffee beans harvested from the natural forest and plantation was assigned in the category of grade two exportable standard coffees. To utilize *E. grandis* as a shade tree for coffee, further investigations with regard to moisture competition, root interaction, and allelopathic effects were recommended.

Keywords: *Coffea arabica*, *Eucalyptus grandis*, Natural forest, Quality, Regeneration

Introduction

Plantation forests adjacent to exposed remnants of indigenous forest can provide shelter, accommodate edge-specialist species and generalist forest species that would benefit from any forest type (Christian *et al*., 1998; Norton, 1998). It can also have catalytic effect on regeneration of some species and used as a management tool to reclaim degraded lands, (Lugo 1997; Yitebitu 1998;

Engelmark 2001; Eshetu 2002; Feyera et al. 2002; Mulugeta and Demel 2004; Mulugeta et al. 2004). However, some plantation species like Eucalyptus has attracted the most criticism (Evans 1992). Some of the critics associated with it are: the species depletes water resources and competes with agricultural crops; it has an allelopathic effect, so that it cannot be used for agro-forestry purposes (Jagger and Pender 2000).

Even if, people deem that the species would not serve for agro forestry purpose, under rain fed conditions, 6x1 m spacing, *Eucalyptus* as agro forestry tree has given the best results (Mathur et al. 1984). When sweet potato was inter-cropped in 208.7 ha of *Eucalyptus* plantations in China it gave good results, and brought an income of 1,286 RMB/ha (Zeng 1992). In India, Nepal, and Thailand, agricultural and horticultural crops growing with *Eucalyptus,* and no adverse effects were noted (White 1988). The use of some *Eucalyptus* trees in agro-forestry is also common in Nigeria and Thailand (Igboanugo et al. 1990). In Srilanka *E. grandis* forms an interesting agro-forestry combination with cardamom (Stocking 1993).

Moreover, under certain conditions tropical farmers use very fast growing and presumably competitive trees in tree crop associations. In some parts of Costa Rica, the use of *Eucalyptus deglipta* as coffee shade is common, and no evidence of negative effects of the trees on coffee growth, yield, and mineral nutrition was found despite the fast tree growth (Schaller et al. 2003). Generally, not all *Eucalyptus* species may have equal negative effects on different species growing with it. Their effect may vary within different geographical areas, rainfall regimes and within species. The overall objective of this study was to evaluate the effect of *E. grandis* over story tree in its underneath naturally regenerated *C. arabica* and on its quality. The hypotheses of the study were a) *Eucalyptus grandis* as an over story tree does not affect the natural regeneration of *C. arabica* as compared to its adjacent natural forest b) *Eucalyptus grandis* as a shade tree has a negative effect on the cup quality and green quality of coffee.

Materials and Methods

Site description

The study was conducted in Belete state forest (7^0 31' N, 36^0 33' E) in the south-western part of Ethiopia (Figure 1). The study area has an altitudinal range of 1978 - 2113 m above sea level. The physical feature is characterized by a rugged topography, dominated by gentle slopes and a localized steep slopes ranging from 4 – 45%. The *E. grandis* plantation was established in 1975 for the purpose of provenance trial and planted in 2.5 m x 2.5 m spacing. The mean height and mean diameter at breast height (DBH) of *E. grandis*, in the year 2006, were 19.5 m and 30.9 cm, respectively.

The study area has a uni-modal type of rainfall pattern with the highest rain occurring between January and April. The mean annual rain fall for the years 1968-2004 was 1547 $\pm$ 324.5 mm year $^{-1}$, with large inter annual variability. The mean annual temperature for the years 1980 - 2004 was 19.3 ^{0}C, with a mean minimum of 13.3 ^{0}C to mean maximum of 23.3 ^{0}C. The hottest months occur from September to November (maximum 27.8 ^{0}C). While coldness, occur from June to August (minimum 12.8 ^{0}C). The rocks in the study area consist of Precambrian rocks, and it has a Drystic Nitosols soil type, that has good potential for agriculture, good physical properties, stable structure, deep rooting volume, and high moisture storage volume (EMA 1988).

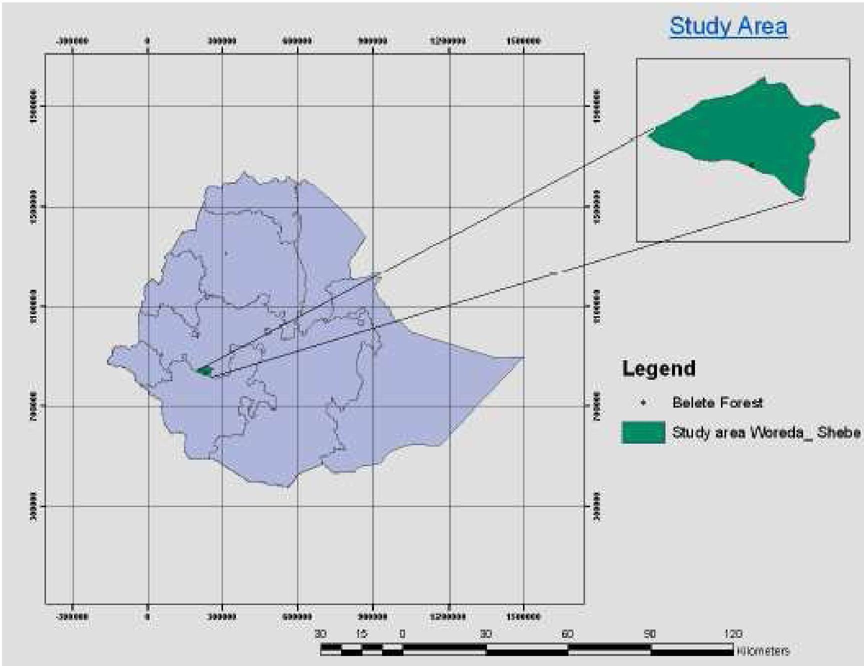

Figure 1. Study area (Belete State Forest)

Sampling and data collection

A systematic sampling design was used to collect data on coffee vegetation and environmental variables. A nested quadrant plot design was used to collect data. The plots were laid out along line transects. The distance between consecutive plots with in transect was 100 m, and the spacing between two adjacent transect lines was also 100 m. Inside each major plot (20 x 20 m), five subplots (2 x 2 m) established. Among these subplots, four of them were laid at the corners of the major plots, and the other at the centre. A total of 40 major sample plots, each having an area of 400 m^2 was laid out. Among these plots, 20 of them were in the natural forest and the remaining was in the *E. grandis* plantation. Hence, 100 subplots, each were placed in the plantation and natural forest. Within the major plot, the diameters of *C. arabica* individuals were taken at 30 cm above the ground. The total heights of individual stems of *C. arabica* were measured using a marked rod. Each subplot was used to collect data on numbers of coffee seedling (height < 25 cm).

Ripe coffee berries from both forest categories (Natural forest and *E. grandis* plantation) were collected in November 2005, and kept separately. Unripe, overripe, damaged berries, dirt, soil, and twig were sorted and removed from the harvested berries manually. Drying method, were used to prepare the coffee beans. Finally, the coffee beans were thoroughly mixed, and 1 kg sample from each forest category was taken. Coffee green quality, cup quality, and grading were done in the Laboratory of Coffee and Tea Quality Control and Liquoring Center of Ethiopia.

Data analysis

Density and structure of Coffee

Coffee data collected from each major plot and in each forest category were used for structural analysis. One-way ANOVA and Least Significant Difference (LSD) test was used to compare the mean diameter and total height of coffee plants (Mean diameter and total height values of each plot of the plantation and the natural forest were considered as a replication). Paired t-test was used to compare the density of coffee stems per plot that were enumerated in the natural forest and *E. grandis* plantation (Mean values of individual plots of the plantation and natural forest considered as a replication). The statistical test at 5% level of probability was analyzed using statistical SAS (9.1) software program (SAS 2003). The seedling data of coffee was also analyzed in a hectare base. Density and basal area of coffee in the two forest categories were calculated (Kent and Coker, 1994).

Coffee quality analysis

Coffee quality analysis were done and graded based on the Ethiopian Coffee Classification Standard. The samples were assessed, characterized and graded by appearance (bean size, uniformity, colour); number of defective beans per sample; cup quality, which includes acidity, flavour and body. Hundred point cupping system was used to score coffee characteristics. The overall coffee quality is analyzed as a sum of raw quality (Defect + Odour) and Cup quality (Acidity + Body + Flavour). Grading of coffee beans collected from the two forest categories were made after determining the overall quality [Cup quality (60 %) + raw quality (40 %)]. A coffee sample, which scored an overall quality of 81-100, 63-80, 50-62, 31-49, and 15-30 were classified as exportable standard coffee of grade 1, 2, 3, 4 and 5, respectively.

For the cup quality analysis, the coffee beans were roasted and the silver skins were removed before the coffee was crushed. Six standard sized cups (200 ml) were filled with 11 grams of grounded coffee. Boiled water was poured into the cups to half-full. The cups were then, stirred thoroughly. This procedure was repeated after 5 minutes. The floating silver skin and other waste substances were removed. Cup testing was performed after 20 minutes, when the cup reached the right temperature by three qualified and experienced cup testers, independently. The moisture percent of the coffee beans measured using Dickey-Jones Devices. Defect point was determined by taking 300-gram coffee beans from the sample.

Then, sorting out poor quality beans from good quality beans, percentages were noted. Bean size was determined using standardized screeners.

Results

Density of coffee and its growth

The density of coffee in the *E. grandis* plantation was 1022 stems/ha while it was 1042 stems/ha in the natural forest. The t- test statistics ($t_{0.025(38)} = 2.025$, t cal =0.0398) result revealed, no significant difference in the number of individuals of coffee in the natural forest and the Eucalypt plantation. The number of coffee seedlings in the Eucalypt plantation was 3,350 seedlings/ha, while it was 7000 seedlings/ha in the natural forest. On the other hand, the one-way ANOVA result (Table 1) revealed significance difference ($p < 0.05$) between the mean total height and diameter of coffee plants found in the plantation and the adjacent natural forest.

Table 1. Results of one-way ANOVA for mean diameter and total height of coffee grown in the natural forest and *E. grandis* plantation

Forest categories	Diameter (cm)	Total height (m)
Natural forest coffee	4.11A	3.89A
Eucalypt plantation coffee	3.29B	2.84B
P in ANOVA	0.0096	<0.0001

Means with the same letters are not significantly different at P=0.05

Coffee population structure

The diameter class distribution indicated that 81.9 % of coffee plants found in the Eucalypt plantation and 64.11% of coffee plants in the natural forest had a diameter of less than 4 cm (Fig. 2). The total height class distribution showed that 69.25 % of natural forest coffee and 72.3 % of Eucalypt plantation coffee fall in the height classes of 3, 4 and 5 (Figure 3). Coffee found in the plantation had a basal area of 18.76 % and 4.92 in the natural forest.

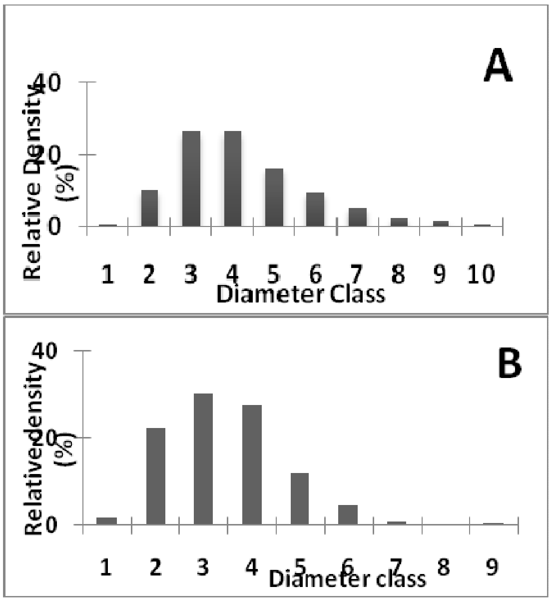

Figure 2. Diameter class distribution versus relative density of Coffee plants found in the natural forest (A) and *E. grandis* plantation (B).

1=0.1-1 cm., 2 = 1.1-2 cm, 3 = 2.1-3 cm, 4 = 3.1-4 cm, 5 = 4.1-5 cm, 6 = 5.1-6 cm, 7 = 6.1-7 cm, 8 =7.1-8 cm, 9 = 8.1-9 cm, 10 = ≥9.1cm

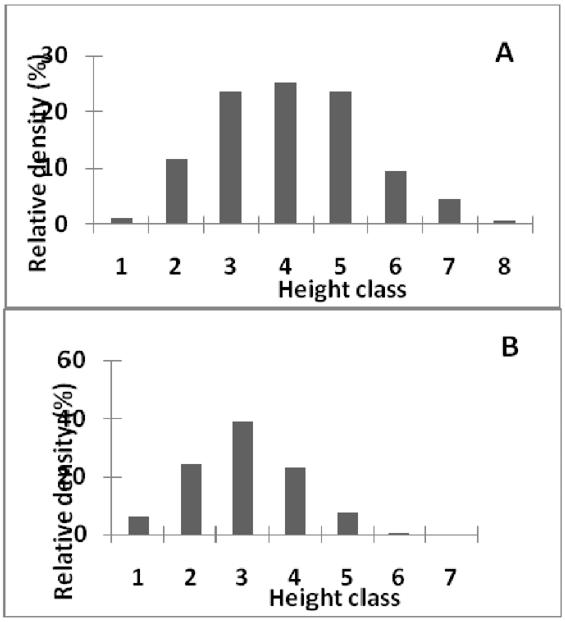

Figure 3. Total height class distribution versus relative density of Coffee plants in the natural forest (A) and *E. grandis* plantation (B)

1 = 0.1-1 m, 2 = 1.1-2 m, 3 = 2.1-3 m, 4 = 3.1-4 m, 5 = 4.1-5 m, 6 = 5.1-6 m, 7 = 6.1-7 m, 8 = 7.1-8 m

Coffee quality

The coffee quality (Green quality + Cup quality) inspection result indicated that 97 % of coffee beans collected in the Eucalypt plantation and natural forest were above screen 14 (Table 2). The total amount of defects of natural forest coffee was 79, while it was 90 in the plantation (Table 2). The cup quality (Acidity + Body + flavour) of coffee from natural forest and *E. grandis* plantation was the same (Table 2). Finally, the plantation coffee (green quality (33%, table 2) + cup quality (45%, table 3) =78 %) and the natural forest (green quality (35%, table 2) + cup quality (45%, table 3) =80 %) coffee has a grade two exportable standard Ethiopian coffee.

Table 2. Green quality analysis results of coffee beans collected in the natural forest and *E. grandis* plantation

Forest type	Moisture content (%)	Quantity above screen 14 (%)	Defect point (%)	Total score (%)
Natural forest	10	97	79	35
Eucalyptus grandis	9.8	97	90	33

Table 3. Cup quality analysis of coffee beans collected in the natural forest and *E. grandis* plantation

Forest type	Acidity	Body	Flavour	Total score (%)
Natural forest	15	15	15	45
Eucalyptus grandis	15	15	15	45

Discussion

Population structure, density, and growth

The ANOVA result revealed that, Coffee plants found in the natural forest were more vigorous than the plantation coffee. Though information on the history of the natural forest coffee is not available, this difference might be attributed to the age of coffee plants. The coffee plants in the plantation forest might be younger than natural forest.

The density of coffee plants decreased as the diameter class increased in both natural forest and the plantation. On the other hand, *C. arabica* had higher basal area in the plantation than the natural forest, suggesting that it is more abundant in the plantation than the natural forest. These results may indicate that *E. grandis* is one of the appropriate species, among others, where shade tree for *C. arabica* is desirable. Schaller et al. (2003) reported that the root system of coffee plants is competitive, and in areas where there is high availability of soil resources, coffee is compatible with very fast growing shade trees like *E.degelipta*. Density of coffee seedlings in the natural forest is much higher than that of the plantation. This may be associated due to collection of coffee beans by humans, since the coffee of Eucalypt plantation is more accessible than natural forest coffee. Therefore, few seeds were left in the ground to germinate in the plantation than the natural forest. Moreover, some farmers stated that seedlings under the *E. grandis* plantation uprooted and transplanted in the coffee farms by local communities. Studies made on the natural regeneration status of some species on exotic plantations in Ethiopia (*Grevillea robusta*), result revealed that in 55 % of the plots *C. arabica* were found naturally regenerating (Eshetu 2002). All this results can show that, some fast growing trees like *E. grandis* and *G. robusta* can catalyze the natural regeneration of *C. arabica*. Generally, these results may suggest that *E. grandis* favours the recruitment and growth of *C. arabica* and might not have a negative effect on coffee plants if used as shade tree.

Coffee quality

The quality of the coffee product is arguably the most important aspect of any production system and must be included in any discussion of shade. The result revealed that when *E. grandis* is used as shade tree, it has similar effect on the cup quality of coffee to the natural forest. Some studies showed that coffee bean size might increase or decrease slightly with shade (Andrea and Nair 2004). From, this study *E. grandis* as coffee shade tree does not have a different impact on the bean size of coffee from that of the natural forest. The total amount of defects was less under the natural forest than plantation coffee. This result may be attributed to insect attack of coffee beans during fruiting period in the Eucalypt plantation. Since, coffees in the plantation have open crowns, much more heat reaches and create favourable condition to insect breeding and attack than the natural forest coffee, which had dense crowns. Finally, as an over story tree *E. grandis* had no effect on the coffee quality. Natural forest and plantation coffee bean were assigned in grade two exportable standard coffees.

Acknowledgements

Canadian International Development Agency (CIDA) is acknowledged for the provision of funds to the study as part of thesis research work to the first Author.

References

Andrea A, PK Nair. 2004. Farmer perspectives on the role of shade trees in coffee production systems: An assessment from the Nicoya peninsula, Costa Rica. Journal of Human Ecology 32, 443 – 463

Christian DP, W Hoffman, JM Hanowski, GJ Niemi, J Beyea.1998. Bird and Mammal diversity on woody biomass plantations in North America. Biomass and Bioenergy14, 395-402.

Ethiopian Mapping Authority (EMA). 1998. National atlas of Ethiopia. Addis Ababa, Ethiopia. Pp. 76

Engelmark O. 2001. Ecological effects and management aspects of an exotic tree species: the case of lodge pole pine in Sweden. Ecology and Managment 141, 3-13.

Eshetu Y. 2002. Restoration of the native woody species diversity using plantation species as foster trees in the degraded highlands of Ethiopia. Dissertation, University of Helsinki. Pp. 61.

Evans J. 1992. Plantation forestry in the tropics: 2nd Edition. Oxford University Press, New York. Pp 403.

Feyera S, T Demel, N Bertake. 2002. Native woody species regeneration in exotic tree plantations at Munessa-Shashemene forest, Southern Ethiopia. New Forests 24, 131-145.

Igboanugo AB, JE Omijeh, JO Adegebehin. 1990. Pasture floristic composition in different *Eucalyptus* species plantations in some parts of the Northern Guinea savanna zone of Nigeria. Agroforestry system 12, 257-68.

Jagger P, J Pender. 2000. The role of trees for sustainable management of less favored lands: the case of *Eucalyptus* in Ethiopia, discussion paper No. 65. International Food Research Institute, Washington. Pp. 81

Kent M, P Coker. 1994. Vegetation description and analysis: a practical approach. John Wiley and Sons, England. Pp. 363

Lugo AE, 1997. The apparent paradox of reestablishing species richness on degraded lands with tree monocultures. Forest Ecology and Managment 99, 9-19.

Mathur RS, KK Sharma, MY Ansari. 1984. Economics of Eucalypts plantations under agro forestry. Indian Forester 5, 10-17.

Mulugeta L, T Demel T, 2004. Restoration of native forest flora in the degraded high lands of Ethiopia: constraints and opportunities. Ethiopian Journal of Science 27, 75-90.

Mulugeta L, G Taye, T Demel. 2004. Effects of canopy cover and understory environment of tree plantations on species richness, density and sizes of colonizing woody species in Southern Ethiopia. Forest Ecology and Managment 194, 1-10.

Norton DA. 1998. Indigenous biodiversity conservation and plantation forestry: options for the future. New Zealand Journal of Forestry 43, 34-39.

Schaller M, G Schroth, J Beer, F Jimenez. 2003. Species and site characteristics that permit the association of fast growing trees with crops: the case of *Eucalyptus deglipta* as coffee shade in Costa Rica. Forest Ecology and Managment 175, 205-215

White KJ. 1988. Tree farming practices in the Bhabar Terai of central Nepal, Sagarnath: Manual No 2. Ministry of Forestry, Kathmandu

Yitebitu M. 1998. The role of exotic plantation forests in fostering regeneration of native trees in an afromontane forest area in Ethiopia. Thesis, Wageningen Agricultural University. Pp. 52

Zeng Q. 1992. An effective measure for controlling soil degradation in Eucalypts plantation. Chinese Scientific and Technical Publishing House, Beijing.