Shade Trees in Cocoa Agroforestry Systems in Ghana: Influence on Water and Light Availability in Dry Seasons

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Introduction

Cocoa (*Theobroma cacao L.*) is an understorey tree and it explains why the crop is traditionally cultivated under the shade of selectively thinned forests in Ghana. The forest shade trees remaining in cocoa systems contribute to carbon sequestration, nutrient recycling, accumulation of soil organic matter, and the conservation of biodiversity (Schroth *et al.*, 2004). Evapotranspiration which leads to moisture stress are reduced by shade trees during the drier seasons. This is crucial for the establishment and survival of cocoa seedlings in seasonally wet and dry environments (Beer, 1987). Thus, especially in circumstances of low-input agriculture, shade trees confer sustainability (microclimatic stability) to cocoa production (Schroth *et al.*, 2001). Usually, multiple species in cocoa agroforestry systems contribute functions not found in monocultures, such as the partitioning of resources, synchrony of resource use, and the capability of each species to capture and cycle nutrients (Schroth *et al.*, 2001).

Even though the favourable effects of trees in cocoa systems are widely stated (Beer, 1987), information on the magnitude of these effects and how they ultimately translate into effects on yield is scarce and often controversial. More precisely, it is not yet evident to what magnitude trees influence different microclimatic factors in cocoa systems and whether the magnitude of effects depends on the type of shade tree, thus which specific tree traits favour or hamper cocoa growth and yields, and to what extent (Somarriba and Beer, 2011). Benefits might differ between tree species and not all benefits might be equally important for cocoa growth and production.

Species-specific studies support the importance of shade trees in cocoa systems for improved microclimate (Isaac *et al.*, 2007) but comparisons of more species are required to give adequate tree trait based recommendations. The study therefore seeks to evaluate the effects of tree species in cocoa agroforestry systems on the availability of soil moisture and light for cocoa in the dry seasons and how these environmental factors influence potential cocoa pod yields.

Methods

The research was conducted in the moist semi-deciduous forest zone of Ghana. The area lies roughly between Latitude 6º 32' N and 6º 75' N and between Longitude 1º 45' W and 2º 00' W. Seven different shade trees that are commonly found in cocoa systems were selected (Table 1). Soil moisture measurements were done using hand held Time Domain Reflectometry (TDR) sensors. The Photosynthetic Active Radiation (PAR) photon flux sensors were used to determine the amount of light available to the cocoa in the sub canopy as well as in the open sun. Potential yields were asessed based on the number of mature, healthy cocoa pods (above 10cm long) and immature pods (below 10cm long) (Koko *et al.*, 2013) in each paired plot using the Hand Tally Counter.

An effect ratio comparing the sub-canopy effects to the open area (control) effects was used to test for differences between the individual tree species. The tree effect ratio is expressed as; (Sub-Open)/ (Sub+ Open), where a positive output means the tree sub-canopy effects are bigger, a negative output means the open area effects are bigger and a zero output means there are no effects.

The averages of the individual tree sub-canopy and open area readings were calculated to represent their respective replicate values. Data were analysed as one-way ANOVA using the R Statistical Package. For each variable, normal distribution was tested using the Shapiro-Wilk normality test for homogeneity of variances. Significant ANOVAs were subsequently assessed using Tukey's Honestly Significant Difference (HSD) test and probability was set at 0.05 for the statistical tests.

Table 1: Selected shade trees and their particulars

Tree name	Average Age (years)	Average Canopy Diameter (Meters)
Citrus sinensis	55	6.6
Entandrophragma angolense	38	3.3
Ficus capensis	30	11.5
Mangifera indica	36	14.8
Morinda lucida	32	9.1
Spathodea campanulata	55	12.1
Terminalia superba	66	8.5

Results

EFFECT OF TREE SPECIES ON SOIL MOISTURE CONTENT IN COCOA AGROFORESTRY SYSTEM

Soil moisture effect was highest in the sub-canopies of *M. lucida* (0.19), *S. campanulata* (0.16) and *F. capensis* (0.13) with the least being *C. sinensis* (-0.28) (Table 2).

Table 2: Effect of trees on soil moisture content in cocoa agroforestry system

Tree species	% Soil Moisture Content		Moisture effect
	Sub-canopy	Open area	
M. lucida	8.06 ± 2.25	5.33 ± 1.23	0.19 ± 0.08[a]
S. campanulata	9.80 ± 2.38	7.56 ± 2.12	0.16 ± 0.08[a]
F. capensis	12.69 ± 2.29	9.24 ± 1.22	0.13 ± 0.06[a]
T. superba	10.79 ± 0.61	10.24 ± 0.95	0.03 ± 0.03[ab]
M. indica	6.43 ± 0.65	6.06 ± 0.30	0.02 ± 0.07[ab]
E. angolense	12.64 ± 2.47	13.47 ± 2.77	-0.03 ± 0.02[ab]
C. sinensis	4.75 ± 1.67	7.31 ± 1.77	-0.28 ± 0.12[b]

Values with superscripts followed by the same letters are not significantly different at P≤ 0.05 level using Tukey's HSD range Test.

EFFECT OF TREE SPECIES ON PERCENTAGE PAR/ LIGHT TRANSMITTED TO UNDERSTOREY COCOA

E. angolense and *T. superba* had the highest PAR of 69% and 67% respectively, transmitted to the understorey cocoa and the lowest being *M. indica* (3%) (Figure 1).

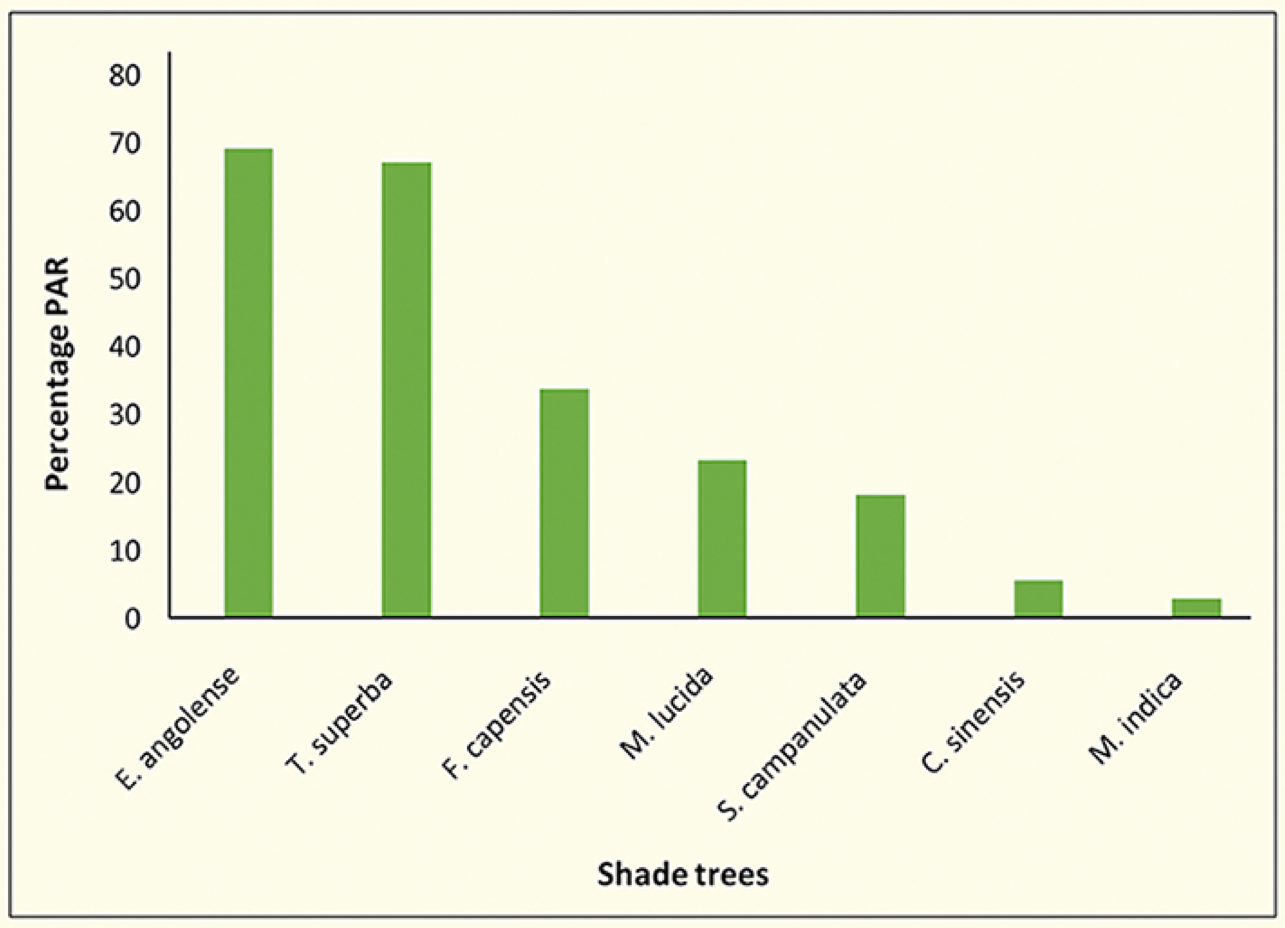

Figure 1: Effect of tree species on percentage PAR transmitted to understorey cocoa

EFFECT OF TREE SPECIES ON POTENTIAL POD YIELDS IN COCOA AGROFORESTRY SYSTEM

The yield effect of cocoa was highest under *M. lucida* (0.40), *T. superba* (0.40) and *E. angolense* (0.34), but lowest under *M. indica* (-0.55) and *C. sinensis* (-0.26) (Table 3).

Table 3: Effect of tree species on potential cocoa pod yields

Tree species	Number of pod yields		Pod yield effect
	Sub-canopy	Open area	
M. lucida	10.90 ± 1.80	4.50 ± 1.18	0.40 ± 0.17[a]
T. superba	8.23 ± 0.80	3.83 ± 1.42	0.40 ± 0.14[a]
E. angolense	15.05 ± 3.85	7.42 ± 3.42	0.34 ± 0.11[a]
S. campanulata	15.87 ± 1.47	11.67 ± 1.42	0.15 ± 0.10[ab]
F. capensis	5.60 ± 0.60	7.42 ± 3.42	-0.03 ± 0.22[ab]
C. sinensis	6.93 ± 3.70	11.25 ± 5.64	-0.26 ± 0.02[ab]
M. indica	3.58 ± 1.68	10.04 ± 1.63	-0.55 ± 0.15[b]

Values with superscripts followed by the same letters are not significantly different at P≤ 0.05 level using Tukey's HSD range Test.

Conclusion

Soil moisture content was higher under the sub-canopies of *M. lucida, S. campanulata* and *F. capensis*, but significantly lower in the sub-canopies of *C. sinensis* which could be due to below-ground competition with cocoa for soil moisture in dry seasons. *E. angolense* and *T. superba* transmitted higher light to the sub-canopy cocoa in the dry season. Potential yields of cocoa were higher in the sub-canopies of *M. lucida, T. superba* and *E. angolense* but lower in the sub-canopies of *C. sinensis* and *M. indica.*

M. lucida, T. superba, E. angolense and *S. campanulata* in cocoa agroforestry systems potentially ensure favourable microclimate in the sub-canopy, especially during dry seasons, which could translate into higher cocoa pod yields. Because *M. indica* and *C. sinensis* are fruit trees and farmers may include such trees in cocoa systems, further research should be directed at determining appropriate planting distance between the cocoa and the fruit trees to ensure positive microclimatic interactions leading to improved yields of cocoa.

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