

Introduction: Physicochemical properties of green coffee are correlated with environmental conditions (altitude, humidity, sunlight), shade cover, and intensive agricultural practices. However, fertilizers are expensive, the price is volatile and current approaches may lead to environmental pollution, degradation of soils, and health hazards.

The impact of less intensive field management methods such as organic fertilizers in combination with use of shade trees on the physicochemical properties of green coffee beans is less known.

This research aimed to investigate the relationships between agroforestry systems, (shade trees; fertilizers) on the physicochemical properties of green coffee and attempt to explain whether the organic agroforestry system could be more suitable for sustainable coffee production.

Methods: Twenty agroforestry coffee systems with different management practices (conventional and organic) and shade types were set up at Tropical Agricultural Research and Higher Education Center (CATIE), Turrialba, Costa Rica. Physical (density, bulk density, moisture content, and roasting loss) and chemical attributes (mineral, total lipid, fatty acids, caffeine, and carbohydrate contents) of harvested green coffee beans were tested, n=3, P<0.05.



Figure 1: Map of three blocks (n=3) in field

| Managements | K (g/Kg) | | | Mg (g/Kg) | | | P (g/Kg) | | | S (g/Kg) | | | Ca (g/Kg) | | |
|-------------|----------|------|---------|-----------|------|---------|----------|------|---------|----------|------|---------|-----------|------|---------|
| | Mean | Std. | p-value | Mean | Std. | p-value | Mean | Std. | p-value | Mean | Std. | p-value | Mean | Std. | p-value |
| IC vs MC | 20 | 1.4 | 0.292 | 2.0 | 0.2 | 0.651 | 1.8 | 0.69 | 0.251 | 1.9 | 0.13 | 0.088 | 1.4 | 0.10 | 0.059 |
| | 20 | | | 2.0 | | | 1.8 | | | 1.8 | | | 1.4 | | |
| MC vs IO | 19 | 0.7 | <0.001 | 2.1 | 0.2 | 0.013 | 1.8 | 0.08 | <0.001 | 1.8 | 0.16 | 0.578 | 1.4 | 0.13 | <0.001 |
| | 20 | | | 2.1 | | | 1.9 | | | 1.8 | | | 1.6 | | |
| IO vs LO | 20 | 1.0 | 0.676 | 2.1 | 0.1 | 0.699 | 1.9 | 0.06 | 0.98 | 1.8 | 0.09 | 0.26 | 1.6 | 0.07 | 0.003 |
| | 20 | | | 2.1 | | | 1.9 | | | 1.8 | | | 1.5 | | |
| IC vs IO | 20 | 1.2 | 0.579 | 2.0 | 0.1 | 0.145 | 1.8 | 0.08 | <0.001 | 1.8 | 0.11 | 0.151 | 1.4 | 0.09 | <0.001 |
| | 20 | | | 2.1 | | | 1.9 | | | 1.8 | | | 1.6 | | |
| Shade types | | | | | | | | | | | | | | | |
| FS vs TS | 20 | 2.5 | 0.323 | 2.1 | 0.3 | 0.205 | 1.8 | 0.15 | 0.054 | 1.9 | 0.23 | 0.283 | 1.5 | 0.08 | 0.002 |
| | 20 | | | 2.0 | | | 1.8 | | | 1.8 | | | 1.4 | | |
| Ev vs FS | 19 | 1.0 | 0.086 | 2.0 | 0.1 | 0.266 | 1.7 | 0.06 | 0.758 | 1.7 | 0.09 | 0.003 | 1.3 | 0.07 | <0.001 |
| | 20 | | | 2.1 | | | 1.8 | | | 1.9 | | | 1.5 | | |
| Scr vs Tim | 19 | 2.5 | 0.476 | 2.1 | 0.3 | 0.044 | 1.8 | 0.15 | 0.092 | 1.7 | 0.23 | 0.08 | 1.5 | 0.08 | 0.768 |
| | 20 | | | 2.1 | | | 1.8 | | | 1.8 | | | 1.5 | | |
| LT vs NLT | 20 | 1.0 | 0.658 | 2.1 | 0.1 | 0.551 | 1.8 | 0.06 | 0.247 | 1.8 | 0.09 | 0.054 | 1.4 | 0.07 | 0.052 |
| | 20 | | | 2.0 | | | 1.8 | | | 1.7 | | | 1.5 | | |

Figure 2: Exemplar Contrast results for major mineral contents (mg/g) dwb p<0.05 displayed in bold.

Results: Full sun and Erythrina shade trees significantly improved green coffee beans density and decreased moisture content and roasting loss. Intensive organic (IO) management practices significantly increased some mineral contents, (K, P, and Ca). Full sun also significantly increased Ca and Mn.

In terms of total lipid and fatty acids (FAs), compared with the moderate conventional (MC) management practices, IO was beneficial as it significantly increased the total green coffee lipid and FAs content, while the Erythrina shade tree system significantly increased the total green coffee lipid and FAs more efficiently than the other shade types.

Caffeine content was significantly higher under intensive conventional (IC) and IO than under the MC and higher under the full sun system than under the shaded system. The *Erythrina* shade tree system significantly improved green coffee carbohydrates.

Additional Results: Due to the complex nature of the field trial, please follow this QR code for links to the full results and additional results and discussion



| Shade types* | E | T | C | C+T | E+T | C+E | Full Sun |
|--------------|----|----|----|-----|-----|-----|----------|
| Management** | IC | IC | IC | IC | IC | IC | IC |
| | MC | MC | MC | MC | MC | MC | MC |
| | IO | IO | IO | IO | IO | IO | IO |
| | LO | LO | LO | LO | LO | LO | LO |

Shade tree species Phenology Canopy N-fixer Application
Erythrina poeppigiana (E) Evergreen Low compact Yes Service
Chloroleucon eurycyclum (C) Deciduous* High spreading Yes Timber
Terminalia amazonia (T) Deciduous* High compact No Timber

*E: Erythrina poeppigiana; T: Terminalia amazonia; C: Chloroleucon eurycyclum;
 **IC: Intensive conventional, MC: Moderate conventional, IO: Intensive organic, LO: Low organic; (n=3)

Conclusion: Intensive organic (IO) management practice improves the nutrition content of coffee beans, (minerals, lipids, and caffeine) and can be considered an excellent substitution (cf. MC) to standard management practices, especially when fertilizer prices are high. The shade tree *Erythrina* promotes the performance of green coffee beans due to the replenishment of organic matter in the soil by extremely strong pruning. As a result, the *Erythrina* system can be used as the main shade tree.