Evaluation of the Effects of Organic and Mineral Fertilizers with Mycorrhiza on the Dry Matter Yield and Nutrient Uptake of Theobroma Cacao in Ibadan, Nigeria

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Abstract:
A greenhouse trial was conducted at Cocoa Research Institute of Nigeria, Ibadan, to evaluate the effects of organic and mineral fertilizers with and without Mycorrhiza on the dry matter yield and nutrient uptake of CRIN Tc-1 and F3 Amazon cocoa seedling in Ibadan. The treatments consist of cocoa pod husk (CPH), Tithonia diversifolia leaves (TD), combination of CPH and TD (CPH+TD) and NPK fertilizer which were applied to F3 amazon and Tc1 hybrids of cocoa at two levels of mycorrhiza (with and without) inoculation, to supply 10Kg N/ha respectively and laid out in completely randomized design (CRD) in three replicates. All the fertilizer treatments with mycorrhiza were significantly (p<0.05) higher than the treatments without mycorrhiza for N uptake except for NPK and control. Application of sole CPH under mycorrhiza inoculation significantly (p<0.05) enhanced phosphorus uptake in Tc1 relative to the control. Potassium uptake was significantly(p<0.05) enhanced by CPH and CPH+TD without mycorrhiza. CPH with mycorrhiza gave the highest leaf and root dry matter yield (DMY) which were significantly higher than the control for Tc-1, while for F3Amazon, TD with mycorrhiza gave the highest root DMY relative to the control.

It can therefore be concluded that optimal and sustainable growth and dry matter yield of cocoa seedlings could be achieved by the use of organic fertilizer materials such as TD and CPH in combination with mycorrhiza.

Keywords: Theobroma cacao, cocoa pod husk, Tithonia diversifolia, NPK fertilizer, arbuscular mycorrhiza

1. Introduction
Cocoa (Theobroma cacao) is a tree crop of the humid lowland tropics and is cultivated in the forest belt of Nigeria. Tropical soils have an inherently low fertility status due to the low activity kaoliniltic clay type and soil organic matter (Obatolu and Agboola 1991). Soil organic matter is one of the most important indication of soil fertility hence the need to ensure a stable organic matter level. This can be achieved through the effective use of organic materials.

About 60% (Wet basis) of cocoa pod is made up of husk hence; cocoa farmers in Nigeria are handicapped on the best way of disposal of this large quantity of CPH on their farm. Cocoa pod husk (CPH) contains a sizeable amount of organic matter and inorganic nutrients as well (Akanbi et al 2013 and Ipinmoroti et al 2011). CPH has relatively high Potassium content (Sukha, 2004) hence the need for research into the use of CPH in combination with other organic materials in cocoa production. There is also the need to examine the importance of those organic resources with high nutrient concentrations that grows around our community. *Tithonia diversifolia* (Hemsley A. Grey) biomass is one of these organic materials with a great potential for use as soil amendment. *Tithonia diversifolia* (TD) commonly known as Mexican sunflower is an annual, aggressive weed growing to a height of about 2.5m. *Tithonia* accumulates high concentrations of nutrients in their leafy biomass and this mineralizes rapidly when incorporated into the soil (Jama et al., 2000).

The mycorrhizal fungi are fundamental for the efficient nutrition process and appropriate development and production for most of the plants. Hence, the objective of this study was to evaluate the potentials of mycorrhiza in combination with organic resources (cocoa pod husk and *Tithonia diversifolia*) on cocoa seedling.
2. Materials and Methods

The experiment was conducted in the greenhouse at the Cocoa Research Institute of Nigeria, Ibadan. Top soil (0-15cm) used for the study was collected from a cocoa plot, air-dried to pass through a 2mm sieve and 5kg soil was weighed into each pot. Representative soil sample was analyzed in the laboratory for routine physical and chemical properties. The pots were watered to field capacity and two cocoa beans sown directly into each pot. The experiment was factorial laid out in a completely randomized design and replicated three times. The three factors were mycorrhiza at two levels (with and without mycorrhiza), fertilizer types at five levels (CPH, CPH+TD, TD, NPK and the control) and cocoa varieties (F3 Amazon and Tc 1). There were 60 experimental units altogether. The fertilizer type used were Cocoa Pod Husk (CPH), Tithonia diversifolia leaves (TD), a combination of CPHand TD (CPH+TD) and NPK fertilizer. The organic materials were applied two weeks before sowing while NPK was applied two weeks after sowing. The seedlings were thinned to one per pot one week after emergence, watering was done three times a week. The experiment was terminated at six months after sowing. The plants were harvested and separated into leaves, stem and roots. The plant samples were oven dried at 70°C until a constant weight was obtained, weighed, milled and analyzed for the nutrient content. The nutrient uptake was then calculated using the formula: Nutrient Uptake = Yield (Kg) × Nutrient Content (%).

All data generated were subjected to statistical analysis using ANOVA and significant means were separated using Duncan Multiple Range Test.

3. Results and Discussion

The physical and chemical properties of soil used for the greenhouse experiment are shown in Table 1. The soil was slightly acidic (pH 6.0). The critical soil nutrient recommended for optimum production of cocoa in Nigeria are: Organic Carbon (OC) -18g/kg⁻¹, Total Nitrogen (N) -1.0gkg⁻¹ respectively (Egbe et al., 1989). Available Phosphorus - 5.5mgkg⁻¹, Exchangeable K - 1.2gkg⁻¹, Ca - 8.0cmolkg⁻¹ and Mg - 0.8cmolkg⁻¹. However, the test soil was low in OC, N, P, K, Ca and Mg and the values fall below the critical level for optimum production hence the need for nutrient amendment.

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| Soil Properties | Soil Nutrient Values | Soil Critical Values | CPH | TD |
|-----------------|----------------------|----------------------|-----|----|
| pH (1:1)        | 6.3                  |                      |     |    |
| Organic Carbon  | 14.6 (g/kg)          | 1.0 (g/kg)           | 242.6 (g/kg) | 140 (g/kg) |
| N (g/kg)        | 0.7 (g/kg)           | 5.5 (mg/kg)          | 2.9 (mg/kg) | 3 (mg/kg) |
| P (mg/kg)       | 3.67 (mg/kg)         | 1.2 (cmol/kg)        | 8.8 (cmol/kg) | 4.1 (cmol/kg) |
| K               | 0.17 (cmol/kg)       | 0.8 (cmol/kg)        | 2.0 (cmol/kg) | 9.8 (cmol/kg) |
| Ca (cmol/kg)    | 2.82 (cmol/kg)       | 0.3 (cmol/kg)        |     |    |
| Mg              | 0.69 (cmol/kg)       |                      |     |    |
| Na (cmol/kg)    | 0.21 (cmol/kg)       |                      |     |    |
| Exchangeable acidity (cmol/kg) | 0.25 (cmol/kg) |       |     |    |
| Zn (mg/kg)      | 11.57 (mg/kg)        |                      |     |    |
| Cu (mg/kg)      | 2.81 (mg/kg)         |                      |     |    |
| Mn (mg/kg)      | 104 (mg/kg)          |                      |     |    |
| Fe (mg/kg)      | 67.9 (mg/kg)         |                      |     |    |
| Sand            | 748 (g/kg)           |                      |     |    |
| Silt (g/kg)     | 110 (g/kg)           |                      |     |    |
| Clay (g/kg)     | 142 (g/kg)           |                      |     |    |
| Texture         | Sandy Loam           |                      |     |    |

Table 1: Properties of Soil and Organic Materials Used for the Experiment

The Tc1 cocoa hybrid treated with CPH fertilizer material under mycorrhiza inoculation gave the highest N uptake relative to the control (Table 2). Application of sole CPH with mycorrhiza inoculation significantly (P >0.5) improved P uptake in Tc1 irrespective of other fertilizer type, this was closely followed by CPH+TD under mycorrhiza inoculation and TD sole. Conversely, TD sole and TD +CPH both with mycorrhiza produced significantly (P >0.5) higher P uptake in F3 Amazon cocoa seedling.

The effect of CPH +TD and CPH both with mycorrhiza (+M) inoculation produced similar effect on the K uptake in Tc1 although CPH with mycorrhiza gave a higher K uptake. The two treatments were significantly higher than the control. Also TD +M, CPH+TD+M and TD without mycorrhiza (-M) recorded similar effects on K uptake in F3 Amazon cocoa seedlings (Table 2). Calcium uptake for CPH+TD, CPH, TD and control was significantly higher than that of NPK. Inoculation with mycorrhiza significantly affected the Ca uptake in Tc1 variety with CPH and CPH +TD and the control. Also, Mg uptake by Tc1 was the highest for CPH+TD fertilizer material under mycorrhizal inoculation and was significantly higher than NPK and control.
| Variety | Fertilizer | Mycorrhiza | N  | P  | K   | Ca   | Mg  | Fe  | Zn  |
|---------|------------|------------|----|----|-----|------|-----|-----|-----|
| Tc1     | CPH+TD     | M+         | 53.11abc | 53.11abc | 69.8ab | 4.67bc | 28.6def | 6.89ab | 1.47a |
| Tc1     | CPH+TD     | M-         | 28.6def | 30.19bcdef | 41.5de | 34.2bcdef | 28.6def | 54.3def | 2.12bcdef |
| Tc1     | CPH       | M+         | 48.8bc | 30.19bcdef | 41.5de | 34.2bcdef | 28.6def | 54.3def | 2.12bcdef |
| Tc1     | TD         | M+         | 61.03abc | 31.98cde | 20.34bcd | 21.01cde | 46.08bc | 24.44bdce | 0.77abc |
| Tc1     | TD         | M-         | 39.89cde | 30.19bcdef | 41.5de | 34.2bcdef | 28.6def | 54.3def | 2.12bcdef |
| Tc1     | NPK        | M+         | 48.8bc | 30.19bcdef | 41.5de | 34.2bcdef | 28.6def | 54.3def | 2.12bcdef |
| Tc1     | CTRL       | M+         | 48.8bc | 30.19bcdef | 41.5de | 34.2bcdef | 28.6def | 54.3def | 2.12bcdef |
| Tc1     | CTRL       | M-         | 39.89cde | 30.19bcdef | 41.5de | 34.2bcdef | 28.6def | 54.3def | 2.12bcdef |
| F3      | CPH+TD     | M+         | 32.2def | 19.72cde | 24.95bcd | 21.01cde | 46.08bc | 24.44bdce | 0.77abc |
| F3      | CPH+TD     | M-         | 26.94cdef | 19.72cde | 24.95bcd | 21.01cde | 46.08bc | 24.44bdce | 0.77abc |
| F3      | CPH+TD     | M+         | 32.2def | 19.72cde | 24.95bcd | 21.01cde | 46.08bc | 24.44bdce | 0.77abc |
| F3      | CPH+TD     | M-         | 26.94cdef | 19.72cde | 24.95bcd | 21.01cde | 46.08bc | 24.44bdce | 0.77abc |
### Table 2: Effects of CPH, TD, CPH+TD and NPK with Mycorrhiza on Nutrients Uptake (mg/plant) by Cocoa Seedlings

| Variety | Fertilizer | Mycorrhiza | N | P | K | Ca | Mg | Fe | Zn |
|---------|------------|------------|---|---|---|----|----|----|----|
| CTRL M+ | F1         | M-         | 20.96ef | 3.44c | 21.46cde | 1.04gh | 0.45ed | 1.18cdef | 0.42f |
| CTRL M- | F1         | M+         | 27.23def | 4.52bc | 26.72bcede | 1.29fgh | 0.56cde | 0.03f | 0.56bcdef |
| NPK M+  | F2         | M-         | 37.3cdef | 3.41c  | 21.49cde | 2.43defg | 0.67bcd | 3.54b  | 0.78abcd |
| NPK M-  | F2         | M+         | 53.01abc | 4.63bc | 21.87bcde | 2.69def | 0.74bcd | 2.67bcde | 0.85abc |
| TD M+   | F3         | M-         | 31.07def | 5.00bc | 23.53bcde | 1.33fgh | 0.80abcd | 3.93bcde | 0.64abcdef |
| TD M-   | F3         | M+         | 43.56bcd | 5.19bc | 28.11bcede | 0.35h  | 0.71bcd | 2.58bcde | 0.75abcde |
| CPH M+  | F4         | M-         | 28.54def | 2.87c  | 15.05de | 2.28defg | 0.51cdef | 1.17cdf | 0.51cdef |
| CPH M-  | F4         | M+         | 36.68cdef | 2.28defg | 22.52bcde | 0.41f | 1.17cdef | 0.41f | 0.41f |

The Dry Matter Yield (DMY) followed the order leaf> stem> root (Table 3). The shoot DMY was higher than the root DMY. CPH with mycorrhiza gave the highest shoot and root DMY which was significantly higher than the control for both Tc1 and F3 Amazon. TD with mycorrhiza gave the highest root DMY which was significantly higher than the control. CPH +TD, CPH in combination with mycorrhiza gave the highest TDMY which was significantly higher than the control for both Tc1 and F3 Amazon. This could be as a result of increased microbial activities that led to increased mineralization of organic matter and increased availability of nutrients in the soil leading to increased dry matter accumulation and the TDMY. These are consistent with those of Akanbi et al (2013) who reported an increase in cocoa seedling growth and dry matter yield using cocoa pod ash and palm bunch ash.
Variety | Fertilizer | Mycorrhiza | leaf DMY(g) | Stem DMY(g) | Root DMY(g) | TDMY(g)
--- | --- | --- | --- | --- | --- | ---
Tc1 | CPH+TD | M+ | 15.73ab | 6.07a | 3.73ab | 25.53a
Tc1 | CPH+TD | M- | 11.43abcd | 1.8c | 1.36e | 14.58bc
Tc1 | CPH | M+ | 16.10a | 4.02abc | 5.00a | 25.12a
Tc1 | CPH | M- | 8.61cde | 2.63bc | 1.37e | 12.64bc
Tc1 | TD | M+ | 10.39cd | 4.84abc | 2.21bcde | 17.44abc
Tc1 | TD | M- | 12.86abc | 4.7abc | 3.11bcde | 20.67ab
Tc1 | NPK | M+ | 16.10a | 4.02abc | 5.00a | 25.12a
Tc1 | NPK | M- | 8.61cde | 2.63bc | 1.37e | 12.64bc
Tc1 | NO | M+ | 7.46de | 2.67abc | 1.47de | 11.63bc
Tc1 | NO | M- | 8.15cde | 2.27abc | 1.90cde | 12.32bc
F3 | CPH+TD | M+ | 10.7cd | 3.93abc | 2.49bcde | 17.12abc
F3 | CPH+TD | M- | 7.9de | 2.57abc | 1.38e | 11.85bc
F3 | CPH | M+ | 7.9de | 3.02abc | 2.57bcde | 13.48bc
F3 | CPH | M- | 7.67de | 2.07abc | 2.11bcde | 11.94bc
F3 | TD | M+ | 11.01bcd | 3.53abc | 2.97bcde | 17.51abc
F3 | TD | M- | 10.92cd | 5.42ab | 2.19bcde | 18.53abc
F3 | NPK | M+ | 11.04bcd | 4.73abc | 2.77bcde | 18.54abc
F3 | NPK | M- | 11.20bcd | 2.63bc | 3.20bc | 17.03abc
F3 | CTRL | M+ | 8.20cde | 4.26abc | 1.60cde | 12.91bc
F3 | CTRL | M- | 4.87e | 3.10abc | 1.30e | 10.43c

Table 3: Effects of CPH, TD, CPH+TD and NPK with Mycorrhiza on Dry Matter Yield of Cocoa Seedlings

CPH=Cocoa Pod Husk; TD=Tithonia diversifolia; M+ with Mycorrhiza; M- without Mycorrhiza; CTRL = Control

4. Conclusion
The study shows that application of organic materials and mycorrhiza increased the nutrient uptake as well as the total dry matter yield of cocoa. Hence, CPH, CPH +TD could serve as an alternative for NPK which is expensive and not readily accessible to low income farmers.

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