

# Effect of biochar and biodigester effluent on yield of Taro (*Colocasia esculenta*) foliage

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## Abstract

Two experiments were carried out to evaluate effects of soil amendment with biochar and biodigester effluent on biomass yield of Taro. In the first experiment, five levels of biochar (0, 0.5, 1, 1.5, 2 kg/m<sup>2</sup>) were applied to Taro grown in 3\*3m plots according to a completely randomized (CRD) design with 4 replicates. All plots were fertilized with biodigester effluent at the rate of 50 kg N/ha. There were linear increases in yield of Taro leaves and petioles, and in their content of crude protein, when biochar was applied to the soil at levels from 0 to 2 kg/m<sup>2</sup>. Soil fertility as measured by pH, water-holding capacity and nitrogen content was increased linearly according to the level of biochar.

In the second experiment, five levels of biodigester effluent (0, 25, 50, 75, and 100 kg N/ha) were applied to Taro grown in 1\*1m plots that had been amended with 2 kg/m<sup>2</sup> of biochar. Applying biodigester effluent at levels up to 100 kg N/ha resulted in linear increases in biomass yield and in crude protein content of leaves and petioles and to increased soil fertility as measured by pH, water-holding capacity and nitrogen content.

**Key words:** *nitrogen, organic carbon, organic matter, pH, soil N, water holding capacity*

## Introduction

The discovery in the Brazilian Amazon of the long-term effects of carbonized biomass on soil fertility (Glaser et al 2001, 2002) has given rise to worldwide interest in the potential role of carbonized biomass (biochar) application to soils as a means of improving soil fertility and sequestering atmospheric carbon (Lehmann 2007).

The integration of soil amendment with biochar and use of biodigester effluent as fertilizer is especially relevant in poor tropical countries such as Lao PDR.

## Hypothesis

- Applying biochar and biodigester effluent to the soil will improve soil fertility and increase the yield and nutritive value of Taro foliage.

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## Materials and methods

### Experimental design:

There were two experiments:

#### Experiment 1: Effect of level of biochar on yield of taro foliage and on soil fertility

##### Location and Duration

The experiment was conducted in the farm of the Centre for Developing Sustainable Agriculture, Nasae Village, Keoudom District, Vientiane Province, Lao PDR, from November 2015 to February 2016.

##### Experimental design

Five levels of biochar (0, 0.5, 1, 1.5, 2 kg/m<sup>2</sup>) were compared in a completely randomized (CRD) design with 4 replicates.

##### Procedure

There were 20 plots each measuring 3\*3m, with 2m between individual plots. Biochar produced from rice husk was added to the top 20 cm of the soil. Taro was planted from suckers approximately 20 cm in length including the roots. Thirty-six suckers were planted in each plot.

Effluent was taken from a biodigester charged with pig manure (Photo 1) and applied at 50 kg N/ha, divided equally in 3 occasions at 30, 60 and 90 days' All plots were irrigated twice weekly in amounts determined from measurements of soil moisture.

##### Measurements

###### Plant biomass

The taro (leaves and petioles) were harvested at 30, 60, 90 and 120 days. Fresh biomass of leaves and petioles was recored and samples taken for DM and crude protein estimation.

###### Soil analysis

Samples of soil were taken before planting and at 120 days after the taro was harvested. Determinations were made of pH, water-holding capacity, nitrogen, organic matter and organic carbon, using standard methods (AOAC 2000).

###### Statistical analysis

Data were analyzed by the General Linear Model in the ANOVA program of the Minitab (2016) software. Sources of variation in the model were: levels of biochar, replicates and error.

## Results

### Biomass yields

The yield of leaves, petioles and total foliage were increased with curvilinear trends as the level of biochar in the soil was increased (Table 1; Figure 1).

**Table 1.** Mean values for DM yield of leaves and petioles of Taro with increasing levels of biochar

|                | Level of biochar, kg/m <sup>2</sup> |     |     |     |     | SEM  |
|----------------|-------------------------------------|-----|-----|-----|-----|------|
|                | 0                                   | 0.5 | 1   | 1.5 | 2   |      |
| Leaf           | 204                                 | 389 | 432 | 460 | 499 | 2.95 |
| Petiole        | 111                                 | 176 | 190 | 197 | 203 | 0.87 |
| Leaf + petiole | 315                                 | 565 | 622 | 656 | 702 | 3.13 |

**Figure 1.** Effect of biochar on DM yield of leaf and petiole of the Taro

The percentages of crude protein in the DM of the leaves and petioles were increased with linear trends as the level of biochar added to the soil was increased (Table 2; Figure 2)

**Table 2.** Mean values for crude protein in DM in leaves and petioles of Taro with 5 levels of biochar

|         | Level of biochar, kg/m <sup>2</sup> |      |      |      |      | SEM   |
|---------|-------------------------------------|------|------|------|------|-------|
|         | 0                                   | 0.5  | 1    | 1.5  | 2    |       |
| Leaf    | 16.0                                | 16.4 | 17.0 | 17.6 | 18.6 | 0.051 |
| Petiole | 5.97                                | 6.92 | 7.50 | 8.27 | 9.80 | 0.045 |

**Figure 2.** Effect of biochar on crude protein percentage in the DM of leaf and petiole of the Taro

All criteria of soil fertility were improved by addition of biochar (Table 3; Figures 3 to 7)

**Table 3.** Mean values of pH, water-holding capacity (WHC), nitrogen, organic matter and organic carbon in soil that received increasing levels of biochar

|              | Level of biochar, kg/m <sup>2</sup> |       |       |       |       | SEM    |
|--------------|-------------------------------------|-------|-------|-------|-------|--------|
|              | 0                                   | 0.5   | 1     | 1.5   | 2     |        |
| pH           | 5.04                                | 5.39  | 5.47  | 5.52  | 5.67  | 0.0050 |
| WHC          | 40.8                                | 47.0  | 50.4  | 52.8  | 55.2  | 0.295  |
| N in soil, % | 0.093                               | 0.115 | 0.145 | 0.147 | 0.214 | 0.0011 |
| OM in soil,% | 1.92                                | 2.15  | 2.38  | 2.44  | 2.70  | 0.0088 |
| Organic C, % | 1.12                                | 1.25  | 1.38  | 1.42  | 1.57  | 0.0051 |

**Figure 3.** Effect of biochar on soil pH

**Figure 4.** Effect of biochar on water-holding capacity

**Figure 5.** Effect of biochar on nitrogen content of the soil

**Figure 6.** Effect of biochar on OM in soil

**Figure 7.** Effect of biochar on organic carbon in soil

**Discussion**

The positive effects of biochar on the yield and protein content of leaves and petioles of Taro are similar to those reported for responses to biochar in other vegetables such as Celery cabbage

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(*Brassica chinensis* var), Chinese cabbage (*Brassica pekinensis*), Mustard green ( *Brassica juncea*) and Water spinach (*Ipomoea aquatica*) (Chhay et al 2013).

The increase in soil nitrogen when biochar was added to the soils is corroborated by similar findings reported by [Insixiengmai](#) et al (2017) when biochar was added to soils growing sugar cane. These major increases in soil nitrogen could be due to increased fixation of atmospheric nitrogen by soil microbes, stimulated by the improved habitat afforded by biofilms supported by biochar. The other possibility is that the biochar reduced emissions of nitrous oxides from nitrogenous compounds in the soil as has been shown for effects of biochar in soils growing sugar cane (Quirk et 2012).

## **Experiment 2: Effect of level of effluent on yield of taro foliage**

### **Location**

The experiment was conducted in the same site as Experiment 1, from February to August 2016.

### **Experimental design**

The treatments, arranged in a CRD design with 4 replications, were levels of biodigester effluent of 0, 25, 50, 75, 100 kg N/ha applied over 120 days to plots growing Taro. All the plots received biochar at the rate of 2 kg/m<sup>2</sup>.

### **Procedure**

There were 20 plots each measuring 1\*1m, with 20m between individual plots. Biochar produced from rice husk was added to the top 20 cm of the soil. Taro was planted from suckers approximately 20 cm in length including the roots. Four suckers were planted in each plot.

Effluent was taken from a biodigester charged with pig manure (Photo 1) and applied at rates to give 0, 25, 50, 75, 100 kg N/ha, divided equally in 4 occasions at 25, 50, 75 and 100 days. All plots were irrigated twice weekly in amounts determined from measurements of soil moisture.

### **Measurements**

#### **Plant biomass**

The taro (leaves and petioles) were harvested at 30, 60, 90 and 120 days. Fresh biomass of leaves and petioles was weighed and samples taken for DM and crude protein estimation.

#### **Soil analysis**

Samples of soil were taken before planting and at 120 days after the taro was harvested. Determinations were made of pH, water-holding capacity, nitrogen, organic matter and organic carbon, using standard methods (AOAC 2000).

#### **Statistical analysis**

Data were analyzed by the General Linear Model in the ANOVA program of the Minitab (2016) software. Sources of variation in the model were: levels of effluent, replicates and error.

**Photo 1.** The tubular plastic plug-flow biodigester charged with pig manure

## Results

There were linear increases in yield of leaves and petioles and of total biomass as the level of effluent N was increased from zero to 100 kg N/ha (Table 4; Figure 8)

**Table 4.** Mean values for DM yield ( $\text{g/m}^2$ ) of leaves and petioles of Taro with 5 levels of effluent N

|                | Level of effluent N, kg/ha |     |     |     |      | SEM |
|----------------|----------------------------|-----|-----|-----|------|-----|
|                | 0                          | 25  | 50  | 75  | 100  |     |
| Leaf           | 219                        | 268 | 284 | 296 | 316  | 4.8 |
| Petiole        | 389                        | 519 | 583 | 663 | 710  | 4.1 |
| Leaf + petiole | 609                        | 788 | 867 | 960 | 1027 | 6.1 |

**Figure 8.** Effect of biodigester effluent on DM yield of Taro

The crude protein in the leaves and petioles of the taro increased linearly with increasing application of biodigester effluent over the range 0 to 100 kg N/ha (Table 5; Figure 9).

**Table 5.** Mean values for crude protein in DM of leaves and petioles of Taro with increasing levels of biodigester effluent N,

|      | Level of effluent N, kg/ha |      |      |      |      | SEM   |
|------|----------------------------|------|------|------|------|-------|
|      | 0                          | 25   | 50   | 75   | 100  |       |
| Leaf | 15.9                       | 16.3 | 16.9 | 17.6 | 18.5 | 0.044 |

|         |      |      |      |      |      |       |
|---------|------|------|------|------|------|-------|
| Petiole | 5.96 | 6.92 | 7.50 | 8.26 | 9.79 | 0.050 |
|---------|------|------|------|------|------|-------|

**Figure 9.** Effect of biodigester effluent on crude protein content of taro leaves and petioles

Soil fertility parameters were all improved by application of biodigester effluent (Table 6; Figures 10 to 13). Major increases were in pH (from 5.4 to 6.8) and N content of the soil (from 0.08 to 0.38%) as the effluent N was increased from 0 to 100 kg N/ha.

**Table 6.** Mean values for soil parameters with increasing levels of biodigester effluent N

|            | Level of effluent N, kg/ha |       |       |       |       | SEM    |
|------------|----------------------------|-------|-------|-------|-------|--------|
|            | 0                          | 25    | 50    | 75    | 100   |        |
| pH         | 5.40                       | 5.63  | 5.96  | 6.54  | 6.75  | 0.0128 |
| WHC        | 52.5                       | 54.0  | 52.3  | 54.4  | 61.1  | 0.650  |
| N% in Soil | 0.077                      | 0.125 | 0.186 | 0.210 | 0.379 | 0.0011 |
| Organic C% | 1.88                       | 1.89  | 1.89  | 1.90  | 1.92  | 0.0084 |

**Figure 10.** Effect of biodigester effluent on soil pH

**Figure 11.** Effect of biodigester effluent on WHC

**Figure 12.** Effect of biodigester effluent on nitrogen in soil

## Discussion

The linear improvements in yield and nutritional quality of the taro leaves and petioles resulting from application of biodigester effluent confirm the value in smallholder farming systems of recycling animal manure through biodigesters. Biochar was applied to all plots thus its role in the improvement brought about by fertilization with biodigester effluent cannot be evaluated.

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## Conclusions

- There were linear increases in yield of Taro leaves and petioles, and in their content of crude protein, when biochar was applied to the soil at levels from 0 to 2 kg/m<sup>2</sup>. Soil fertility parameters as measured by pH, water-holding capacity and nitrogen content were increased linearly according to the level of biochar.
- Applying biodigester effluent at levels up to 100 kg N/ha to taro grown in soils amended with biochar led to: linear increases in biomass yield and in crude protein content of leaves and petioles; and to increased soil fertility as measured by pH, water-holding capacity and nitrogen content.

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