

# Measuring fertility of soils by the bio-test method

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## Abstract

The experiment was conducted at An Giang University, Viet Nam. Eight kinds of soil were taken from different places around An Giang University to measure fertility of soils by using the bio-test with maize (*Zea mays*) and rice (*Oryza sativa*) as indicators, according to a 8x2 factorial arrangement with three replications. The soils were sand (negative control), clay soil, loam mixed with compost 1:1, loam with leaves and compost from the shade under the trees, sandy loam, sub-soil under loam, sub-soil under sandy loam (sub-soil taken at more than 20 cm. depth) and compost (positive control). The soil samples were put into 2 liters capacity plastic bags and 3 seeds of either maize or rice was planted in each bag (3 bags per soil/indicator plant). Date to germination, plant height at every 5 days intervals and final weight of biomass after 28 days were measured.

There were significant differences between soils in the growth in height and the amount of biomass of both the maize and rice after 28 days, and a significant interaction for soil \* plant for both measurements. For maize, there was a positive curvilinear response of biomass weight to level of organic matter and percentage of N in the soils ( $R^2 = 0.67$  and  $0.92$ ), but no response in rice ( $R^2 = 0.03$  and  $0.015$ ). The proportion of roots in the total biomass decreased as soil N and organic matter increased.

It is suggested that measuring fertility of soils by the bio-test method is a simple, practical and low cost procedure in integrated farming systems. The maize bio-test indicator was better suited to measuring fertility of soil than rice.

**Key words:** Bio-test method, maize, organic matter, pH, rice, soil fertility

## Introduction

Knowing the fertility of soils is important in agriculture particularly in making decisions on planting of crops. The measurement of the fertility of soils is usually done by chemical analysis for plant nutrients such as nitrogen (N), potassium (K), phosphorus (P) and trace elements, as well as physical measurements of soil structure. Such analyses require access to a laboratory and this is not feasible for most farmers, especially those with limited resources. Planting some indicator plants in the soil and measuring their growth and production is one way to measure fertility of soils in an indirect way (Nguyen Phuc Tien et al 2003).

In this experiment, maize and rice were chosen as bio-test indicator plants for measuring fertility of a range of soils.

## Materials and Methods

### Treatments

There were two sets of treatments (types of soil and indicator plants), arranged as a 8\*2 factorial with 3 replications in a Randomized Complete block design (RCB) (Table 1).

**Table 1:** Experiment layout

|           |      |      |      |      |      |      |      |
|-----------|------|------|------|------|------|------|------|
| BlockSIM1 | LoM1 | PcM1 | SmR1 | SsM1 | NcM1 | PcR1 | LoR1 |
| 1         | LIR1 | NcR1 | CIM1 | SmM1 | SsR1 | LIM1 | CIR1 |
| BlockSIM2 | SIR2 | SmM2 | SsM2 | SmR2 | CIR2 | NcR2 | LIM2 |

|       |      |      |      |      |      |      |      |      |
|-------|------|------|------|------|------|------|------|------|
| 2     | LIR2 | SsR2 | CIM2 | LoR2 | NcM2 | LoM2 | PcM2 | PcR2 |
| Block | LIR3 | LoR3 | SmM3 | SsR3 | SmR3 | NcM3 | PcR3 | PcM3 |
| 3     | SIM3 | CIR3 | LIM3 | SsM3 | NcR3 | CIM3 | LoM3 | SIR3 |

**Table 2** : 8 types of soil

| Types of soil          | Detail                                                                                             |
|------------------------|----------------------------------------------------------------------------------------------------|
| Sand (Nc)              | Used as a negative control                                                                         |
| Clay soil (Cl)         | Took from behind animal experiment unit place, 0-20 cm. depth.                                     |
| Loam with compost (Lo) | Loam took from the rear of animal experiment unit place, 0-20 cm. depth and mixed with compost 1:1 |
| Sub soil loam (Sm)     | Sub soil under loam, more than 20 cm. depth                                                        |
| Loam with leaf (Ll)    | Loam with leaf compost Took from shade area under trees, 0-20 cm. depth.                           |
| Sandy loam (Sl)        | Took from the rear of guest house, 0-20 cm. depth.                                                 |
| Sub soil sandy (Ss)    | Sub soil under sandy loam, more than 20 cm. depth                                                  |
| Compost (Pc)           | Used as a positive control                                                                         |

The two indicator plants were:

- M = Maize
- R = Rice

## Procedure

The 8 types of soil (Table 2) were taken from different places around An Giang University and put into plastic bags (2 liters capacity). 3 seeds of maize or rice were planted in each bag according to the experimental layout in Table 1. A hole was put in the bottom of each bag so the excess water could drain away. Water was applied uniformly to all bags every morning and evening and observations made of germination and growth of the plants. When the seeds had germinated 1 or 2 plants were removed to leave only one seedling in each bag (Photo 1).



**Photo 1:** The maize and the rice plants growing in the different soils

## Measurements

The dry matter (DM), organic matter, N and pH of soils were measured at the beginning. The height of the plants was measured every 5 days over a total period of 28 days. After 28 days, the plants and roots were removed from the bags, washed free of soil, and weighed 30 minutes later, the green parts (leaves and stems) and the roots separately.

## Laboratory analyses

The chemical analyses were done following standard procedures according to the Association of Official Analytical Chemists procedures (AOAC 1990), except for DM which was determined by micro-wave radiation (Undersander et al 1993).

## Statistical analyzes

The linear regression of height on days was calculated to determine growth rate in height. The ANOVA GLM option of the Minitab (2003) software was used to analyze the data. The sources of variables in the model were: soils, blocks and error. The Tukey test in the Minitab software was used to separate mean values that differed when the F-test was significant at  $P < 0.05$ .

## Results and discussion

### Chemical composition of soils

The DM content was highest in the negative control of sand (Nc) and lowest in the positive control of compost Pc (Table 3). The soils with high organic matter content were also high in nitrogen. Organic matter was highest in the positive control of compost (Pc) and lowest in Nc. Most of the soils were alkaline ( $pH > 7$ ) except L1 that had a pH of 5.8. Nitrogen content was highest in Pc (1.82 %) and lowest in Nc (0.05 %).

**Table 3:** Chemical composition of soils

| Types of soil                  | Dry matter, (%) | Organic matter, (% in DM) | pH  | Nitrogen, (% in DM) |
|--------------------------------|-----------------|---------------------------|-----|---------------------|
| Sand (Nc, negative control)    | 96.6            | 4.0                       | 7.6 | 0.05                |
| Sub soil sandy (Ss)            | 74.1            | 28.5                      | 7.8 | 0.11                |
| Sandy loam (Sl)                | 72.7            | 29.5                      | 7.6 | 0.11                |
| Clay soil (Cl)                 | 71.9            | 32.0                      | 7.4 | 0.11                |
| Sub soil loam (Sm)             | 71.7            | 33.0                      | 7.5 | 0.26                |
| Loam with compost (Lo)         | 64.0            | 42.0                      | 7.4 | 1.32                |
| Loam with leaf (Ll)            | 61.8            | 52.0                      | 5.8 | 0.63                |
| Compost (Pc, positive control) | 29.2            | 85.1                      | 7.2 | 1.82                |

### Germination

Maize germinated faster than rice ( $P < 0.001$ ) but there were no differences due to type of soil ( $P = 0.21$ ) (Table 4).

**Table 4 :** Days to germinate

| Types of soil                  | Maize        | Rice | Average |
|--------------------------------|--------------|------|---------|
| Sub soil sandy (Ss)            | 4.7          | 5.3  | 5       |
| Sandy loam (Sl)                | 3.7          | 4.7  | 4.2     |
| Sand (Nc, negative control)    | 4            | 6.7  | 5.3     |
| Clay soil (Cl)                 | 2.7          | 5.7  | 4.2     |
| Sub soil loam (Sm)             | 3.3          | 4.7  | 4       |
| Loam with leaf (Ll)            | 3.7          | 5    | 4.3     |
| Loam with compost (Lo)         | 3.7          | 5.3  | 4.5     |
| Compost (Pc, positive control) | 3.3          | 5.3  | 4.3     |
| Mean                           | 3.63         | 5.33 |         |
| SEM / P between plants         | 0.19 / 0.001 |      |         |
| SEM / P between soils          | 0.533 / 0.21 |      |         |

SEM = Standard error of mean, P = Probability level.

### Biomass production

There were differences in the responses of the two indicator plants (Table 4; Figures 1 and 2; Photo 2).



Photo 2. Biomass production of maize and rice after planting 28 days

Highest biomass yield with maize was in the positive control of compost. In contrast, highest yield of rice was in the loam with leaf compost taken from under the trees (LI). The lowest yield of maize was in the sub-soil taken from under the sandy loam (Ss); while the lowest yield of rice was in the negative control (Nc). (Table 5.)

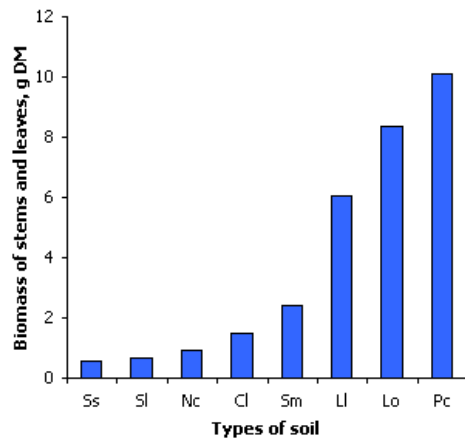
Table 5 : Biomass of plants DM (g)

| Types of soils                 | Leaves             |      | Stems             |      | Roots             |                   | Total              |                    |
|--------------------------------|--------------------|------|-------------------|------|-------------------|-------------------|--------------------|--------------------|
|                                | Maize              | Rice | Maize             | Rice | Maize             | Rice              | Maize              | Rice               |
| Sub soil sandy (Ss)            | 0.38 <sup>a</sup>  | 0.09 | 0.19 <sup>a</sup> | -    | 0.52 <sup>a</sup> | 0.04 <sup>a</sup> | 1.09 <sup>a</sup>  | 0.13 <sup>a</sup>  |
| Sandy loam (SI)                | 0.42 <sup>a</sup>  | 0.14 | 0.24 <sup>a</sup> | -    | 0.50 <sup>a</sup> | 0.06 <sup>a</sup> | 1.16 <sup>a</sup>  | 0.20 <sup>a</sup>  |
| Sand (Nc, negative control)    | 0.68 <sup>a</sup>  | 0.03 | 0.25 <sup>a</sup> | -    | 0.60 <sup>a</sup> | 0.03 <sup>a</sup> | 1.53 <sup>a</sup>  | 0.06 <sup>a</sup>  |
| Clay soil (CI)                 | 0.93 <sup>a</sup>  | 0.26 | 0.57 <sup>a</sup> | -    | 0.63 <sup>a</sup> | 0.08 <sup>a</sup> | 2.13 <sup>a</sup>  | 0.34 <sup>ab</sup> |
| Sub soil loam (Sm)             | 1.58 <sup>a</sup>  | 0.31 | 0.84 <sup>a</sup> | -    | 0.98 <sup>a</sup> | 0.14 <sup>a</sup> | 3.40 <sup>a</sup>  | 0.45 <sup>ab</sup> |
| Loam with leaf (LI)            | 3.95 <sup>b</sup>  | 0.76 | 2.08 <sup>b</sup> | -    | 2.46 <sup>b</sup> | 0.36 <sup>a</sup> | 8.49 <sup>b</sup>  | 1.12 <sup>b</sup>  |
| Loam with compost (Lo)         | 5.16 <sup>bc</sup> | 0.34 | 3.20 <sup>c</sup> | -    | 2.20 <sup>b</sup> | 0.10 <sup>a</sup> | 10.56 <sup>b</sup> | 0.44 <sup>ab</sup> |
| Compost (Pc, positive control) | 6.13 <sup>c</sup>  | 0.15 | 3.97 <sup>d</sup> | -    | 1.99 <sup>b</sup> | 0.03 <sup>a</sup> | 12.09 <sup>b</sup> | 0.18 <sup>a</sup>  |
| SEM / P between soils          | 0.196 / 0.001      |      | 0.101 / 0.001     |      | 0.123 / 0.001     |                   | 0.379 / 0.001      |                    |
| SEM / P between plants         | 0.098 / 0.001      |      | 0.051 / 0.001     |      | 0.062 / 0.001     |                   | 0.190 / 0.001      |                    |
| SEM / P between soil* plants   | 0.278 / 0.001      |      | 0.143 / 0.001     |      | 0.175 / 0.001     |                   | 0.536 / 0.001      |                    |

\* Rice stem included in leaf part.

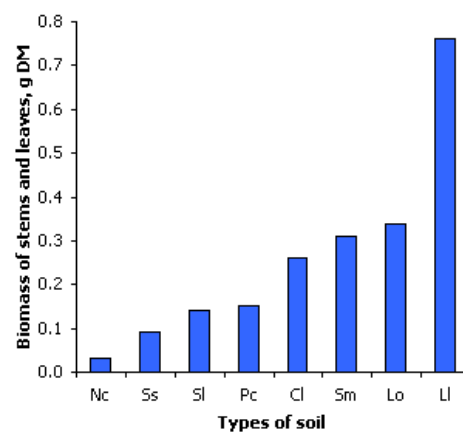
SEM = Standard error of mean, P = Probability level.

a,b,c,d = Value within the same column without superscript in common differ at P<0.05



Sub soil sandy (Ss), Sandy loam (SI), Sand (Nc, negative control), Clay soil (CI), Sub soil loam (Sm), Loam with leaf (LI), Loam with compost (Lo), Compost (Pc, positive control)

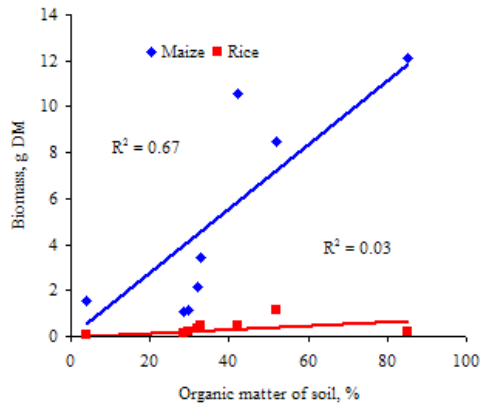
Figure 1: Green biomass yield of maize in different soils



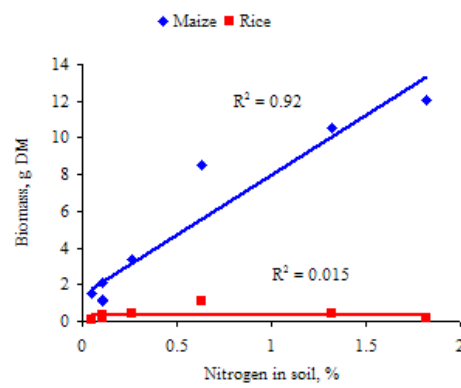
Sub soil sandy (Ss), Sandy loam (SI), Sand (Nc, negative control), Clay soil (CI), Sub soil loam (Sm), Loam with leaf (LI), Loam with compost (Lo), Compost (Pc, positive control)

Figure 2: Green biomass yield of rice in different soils

The soil samples which had a high organic matter content (compost, loam mixed with compost and loam with leaf compost from under the trees) supported high biomass production, which was to be expected as organic matter helps the soil hold water and supplies nutrients, which are crucial for crop production (Lickacz and Penny 2001). In the case of maize, biomass production was strongly related to soil organic matter ( $R^2 = 0.67$ ) and N ( $R^2 = 0.92$ ) (Figures 3 and 4). Similar relationships for maize were reported by Chamnanwit Promkot (2001). There was no relationship between biomass production and soil organic matter, or N, for rice.

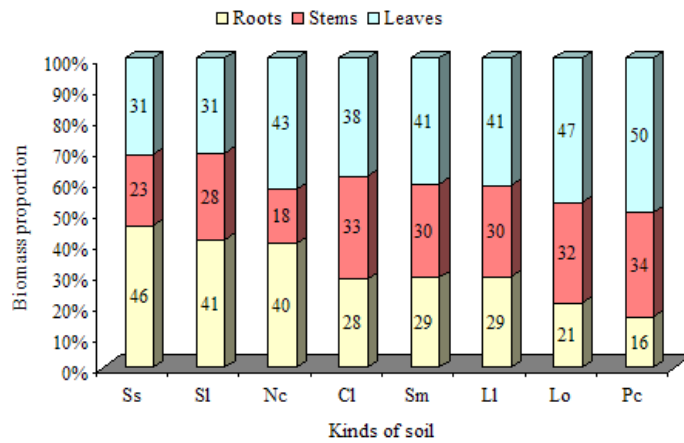


**Figure 3.** Relationship between organic matter of soils and biomass yield of maize and rice.



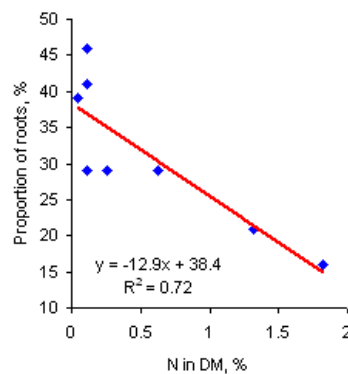
**Figure 4.** Relationship between N content of soil and biomass yield of maize and rice

The proportions of roots, stems and leaves in the fresh biomass of maize plants differed among the different soils (Figure 5). The proportion of the root component decreased as the organic matter and N content of the soils increased (Figures 6 and 7).

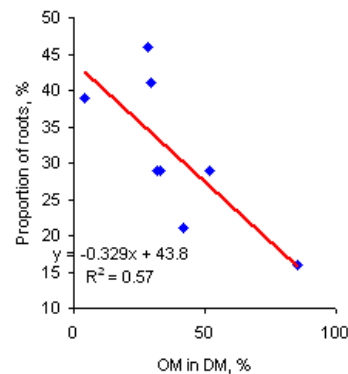


Sub soil sandy (Ss), Sandy loam (Sl), Sand (Nc, negative control), Clay soil (Cl), Sub soil loam (Sm), Loam with leaf (Ll), Loam with compost (Lo), Compost (Pc, positive control)

**Figure 5.** Proportion of roots, stems and leaves of maize plants grown in different kinds of soil



**Figure 6;** Relationship between N content of soil and the proportion of roots in the fresh biomass of maize plants



**Figure 7;** Relationship between organic matter content of soil and the proportion of roots in the fresh biomass of maize plants

### The height and grow rate of plants

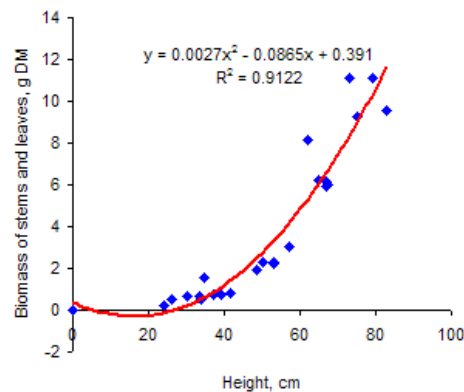
The height and growth rate of maize was highest in loam with compost (Lo), while for rice these measurements were highest in loam with leaf (Ll). The height and growth rate of both indicator plants were lowest in the negative control (Nc) (Table 6).

**Table 6 :** The height and growth rate of maize and rice

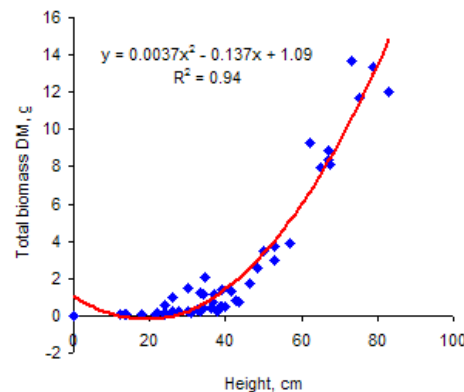
| Types of soils                 | Height at 25 days (cm) |                    | grow rate (cm/day) |                   |
|--------------------------------|------------------------|--------------------|--------------------|-------------------|
|                                | Maize                  | Rice               | Maize              | Rice              |
| Sand (Nc, negative control)    | 30.2 <sup>a</sup>      | 13.2 <sup>a</sup>  | 1.2 <sup>a</sup>   | 0.5 <sup>a</sup>  |
| Clay soil (Cl)                 | 34.3 <sup>a</sup>      | 36.3 <sup>ab</sup> | 1.4 <sup>a</sup>   | 1.5 <sup>b</sup>  |
| Sub soil sandy (Ss)            | 34.8 <sup>a</sup>      | 22.3 <sup>ab</sup> | 1.4 <sup>a</sup>   | 0.9 <sup>ab</sup> |
| Sandy loam (Sl)                | 34.8 <sup>a</sup>      | 26.7 <sup>ab</sup> | 1.4 <sup>a</sup>   | 1.1 <sup>ab</sup> |
| Sub soil loam (Sm)             | 52.8 <sup>ab</sup>     | 38.3 <sup>b</sup>  | 2.1 <sup>ab</sup>  | 1.5 <sup>b</sup>  |
| Loam with leaf (Ll)            | 67.2 <sup>b</sup>      | 44.2 <sup>b</sup>  | 2.7 <sup>b</sup>   | 1.8 <sup>b</sup>  |
| Loam with compost (Lo)         | 74.3 <sup>b</sup>      | 33.8 <sup>ab</sup> | 3.0 <sup>b</sup>   | 1.4 <sup>ab</sup> |
| Compost (Pc, positive control) | 71.3 <sup>b</sup>      | 26.5 <sup>ab</sup> | 2.9 <sup>b</sup>   | 1.1 <sup>ab</sup> |
| SEM / P between soils          | 3.247 / 0.001          |                    | 0.130 / 0.001      |                   |
| SEM / P between plants         | 1.418 / 0.001          |                    | 0.065 / 0.001      |                   |

SEM = Standard error of mean, P = Probability level

a,b = Value within the same column without superscript in common differ at  $P < 0.05$



**Figure 8:** Relationship between plant height and green biomass yield for maize



**Figure 9:** Relationship between plant height and total biomass yield for maize

There was a close relationship between plant height and yield of stems and leaves and of total biomass (green parts and roots) (Figures 8 and 9), indicating that plant height of maize after 25 days growth could be used as the indicator of soil fertility.

## Conclusions

- Maize was better than rice as an indicator plant to compare the fertility of different soils.
- For maize, growth in height was equally suitable as total biomass weight after 28 days as a means of comparing the different soils.
- Maize growth was closely correlated with organic matter and N content of the soils
- The proportion of roots in the total biomass decreased as soil N and organic matter increased

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