Application of organic and biofertilizers to increase soil biota diversity and vegetable production

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Abstract. The diversity of soil biota and vegetable production could be increased using organic fertilizer and biofertilizer. The objective was to determine the effect of organic fertilizer and biofertilizer on soil biota and vegetable production. The experiment was arranged in a randomized block design with 6 treatments, 4 replications. The treatments were T1: farmer practice (goat manure + chicken manure (CM) + banana stem dose of 20 t ha⁻¹), T2: (CM+ plant residue (PT)) dose 10 t ha⁻¹ + arbuscular mycorrhizal fungus, T3: (CM+PT) dose of 10 t ha⁻¹ + bio-fertilizer (BF), T4: (CM+PT) dose 10 t ha⁻¹ + Tithonia diversifolia 1 t ha⁻¹, T5: vermicompost of 12.5 t ha⁻¹ and T6: vermicompost 10 t ha⁻¹ + BF. The results showed that application of chicken manure + plant residue of 10 t ha⁻¹ and biofertilizer yielded 13.3 t ha⁻¹ of Chinese lettuce and chicken manure + plant residue of 10 t ha⁻¹ + Tithonia yielded 3.8 t ha⁻¹ of broccoli and the diversity of soil biota was significantly high. Vermicompost gave the lowest yield of Chinese lettuce and broccoli due to root disease causing by parasite nematode. Organic fertilizer and biofertilizer increase prospectively soil biota diversity and vegetable production.

1. Introduction

In general, organic farming system can be seen as an approach of an integrated farming system between the components of crop farming, horticulture or plantation, soil nutrient management, livestock, soil and water conservation, and also biological integrated pest management. This technology is an environmentally friendly that could be used to achieve a sustainable agricultural system to maintain soil fertility and biodiversity for a long-term [1-4]. Organic amendments used within the legal framework of organic farming may impact soil fertility and biodiversity indicators within seven years [5].

In Indonesia, total area of organic farming is up to 40,000 ha, including natural farmland such as mixed garden. For the Asian region, Indonesia has about 45,000 ha organic gardens representing considerable potential for the development of organic farming such as vegetables [6].

Organic farming maximizes reliance on farm-derived renewable resources for managing ecological and biological processes and integrations, to provide acceptable crop production and an appropriate return to the human and others resources employed [7]. Farmyard manure compost, green manure, cattle slurry, and crop residues are among the most common organic matters utilized in organic farming as nutrient sources [8]. A study showed that soil amendment with 25 t ha⁻¹ of manure compost gave the highest yield of Brassica chinensis L. of 0.75 t ha⁻¹ dry weight [9]. Another study found that various kinds of plant residues supplied significant amount of nutrients [10].

Soil organisms are an integral part of agricultural and forestry ecosystems; and these organisms play a critical role in maintaining soil health, ecosystem function and production [11]. Every organism has a
special role in the food chain in the soil. A study had classified soil biota based on ecosystem function [12].

The diversity of soil organisms creates a diversity of functions and processes in the soil. Each community of organisms performs different functions: as a nitrogen-fixing, phosphate solubilization, organic matter decomposer, ecosystem engineer (e.g. earthworms, termites, and ants). Soil biota such as Oligochaeta, Collembola and Acarina serve as the primary remodel of organic matter, nutrient distribution, soil mixing and the formation of soil aggregates [13]. In order to increase soil productivity, it is necessary to study the utilization of soil biota and its role in increasing soil fertility.

The purpose of the study was to determine the effect of organic fertilizer and biofertilizer on soil biota and vegetable production.

2. Materials and methods

This research was conducted in organic vegetable field at, Permata Hati Farm, Cisarua, Bogor, West Java Province, Indonesia (06°40’ 31.6” South latitude, 106°57’ 24.7” East longitude; 1004 m asl), from June to August (dry season) 2009. The experiment was set in randomized block design, 6 treatments and 4 replications. The treatments were T1: farmer practice (goat manure + chicken manure + banana stem dose 20 t ha\(^{-1}\)), T2: (chicken manure + plant residue) dose of 10 t ha\(^{-1}\) + arbuscular mycorrhizal fungus (CMA), T3: (chicken manure + plant residue) dose 10 t ha\(^{-1}\) + biofertilizer, T4: (chicken manure + plant residue) dose of 10 t ha\(^{-1}\) + Tithonia diversifolia 1 t ha\(^{-1}\), T5: vermicompost 12.5 t ha\(^{-1}\) and T6: vermicompost 10 t ha\(^{-1}\) + biofertilizer. Biofertilizer composition was Azospirillum, Trichoderma, sp. and Pseudomonas doses10\(^{7}\) to 10\(^{6}\) g\(^{-1}\). The plot size was 4 m x 5 m. Chinese lettuce (Brassica chinensis L.) intercropped with broccoli (Brassica oleracea var. botrytis L.). Plant spacing for broccoli was 70 cm x 40 cm and for Chinese lettuce 20 cm x 20 cm. The initial soil microbial activity (dehydrogenase enzyme) was 38.71 μg g\(^{-1}\) soil.

Compost of animal manures, plant residue, Tithonia diversifolia, vermicompost and biofertilizer were applied in planting holes one day before planting of broccoli, Chinese lettuce. Seedlings of each vegetable crops were prepared in a shaded nursery. Tithonia diversifolia green manure was incorporated into the top 20 cm of soil depth one week before vegetable planting. Pest and diseases were controlled by botanical pesticides (nimb oil) and by handpicking. The crops were watered using a watering hose at plant hills with about 3 mm ground well water every three days. The observed parameters consisted of soil biota populations before and after treatments, soil microbial activity (dehydrogenase enzyme), growth and yield of Chinese lettuce and broccoli. Parameters measured were analyzed using the analysis of variance followed by mean comparison using the Duncan Multiple Range Test (DMRT).

3. Results and discussion

3.1. Initial soil biota populations and microbial activity

Mostly this experimental site had been used for another experiment in 2008, therefore the plot size for the present experiment followed the previous one. The results of the initial soil biota population before the land clearing and processing are presented in table 1. It showed that the soil biota population was 26 m\(^{-2}\) with the diversity of 5 categories. Earthworms (Oligochaeta) are the most dominant biota of the soil (19 Earthworms m\(^{-2}\) including the Cocoon) followed by Collembola (4 Collembolas m\(^{-2}\)) and Coleoptera, Millipedes and Bothynus (each 1 species m\(^{-2}\)).

3.2. Population of soil biota and microbial activities

The effect of organic fertilizer and biofertilizer applications on soil biota population is presented in table 2. The population of earthworms ranged from 4 to 36 m\(^{-2}\). T2 treatment had the highest population of 36 m\(^{-2}\). Which increase up to 16 m\(^{-2}\) meanwhile at T4 and T5, the earthworm population is 24 m\(^{-2}\) and increase to 4 m\(^{-2}\) for each compared to T1. This could happen since the earthworms prefer a habitat with suitable humidity, soil organic carbon, types of gases from organic matter decomposition, the predator, and soil temperature.
Therefore, although vermicompost compare lettuce both treatments were significantly higher than could higher chicken manure + plant residue significantly different and biomass of crops at harvest. Table Assessment of the effect of treatment 3.3. Growth and yield of chinese lettuce
Assessment of the effect of treatments on Chinese lettuce plant growth is based on the high observation and biomass of crops at harvest. Table 3 shows the plant height of control (T1) is 25.8 cm and is not significantly different from that of chicken manure + plant residue dose of 10 t ha\(^{-1}\) + CMA (T2) and chicken manure + plant residue of 10 t ha\(^{-1}\) + biofertilizer (T3) and the T3 treatments were significantly higher with vermicompost treatment of 12.5 t ha\(^{-1}\) (T5) or vermicompost of 10 t ha\(^{-1}\) + biofertilizer (T6). A similar result also found for plant biomass, where T1 and T3 were the highest among treatments. The lowest height occurred on T5 and T6. Based on the results, it showed that application of biofertilizer could reduce the use of organic fertilizer as many as 10 t ha\(^{-1}\) for Chinese lettuce cultivation.

The yield of Chinese lettuce showed that T1 and T3 treatments gave the highest result of 13.32 to 13.83 t ha\(^{-1}\) compared to other treatments. Meanwhile T2 and T4 were not significantly different and both treatments were significantly higher than T5 and T6 with yield of 5.75 to 6.25 t ha\(^{-1}\) of Chinese lettuce. The use of vermicompost of 12.5 t ha\(^{-1}\) and vermicompost 10 t ha\(^{-1}\) + biofertilizer can’t be compared to organic fertilizer 20 t ha\(^{-1}\). This is due to the swelling of the root caused by the use of vermicompost. Using *Trichoderma* sp. in biofertilizers has less effect on controlling nematode attack, although this biofertilizers (T6) tend to increase the growth and yield of chinese lettuce (table 3). Therefore, a part increasing the chinese lettuce yield up to 13.8 t ha\(^{-1}\), biofertilizer can also reduce the

**Table 1. Initial soil biota population before land clearing.**

| No. | Types of soil biota      | Population (m\(^{-2}\)) |
|-----|-------------------------|-------------------------|
|     |                         | Number | Population |
| 1   | Earthworms (*Oligochaeta*) | 17\(^*)\) | 19          |
|     |                         |         | 2\(^*)\)   |
| 2   | Coleoptera              | 1\(****)\) | 1          |
| 3   | Millipedes              | 1\(^*)\) | 1          |
| 4   | Bothynus                | 1       | 1          |
| 5   | Collembola              | 4       | 4          |
|     | Total population        |         | 26         |

Note: \(^*)\) Imago phase, \(^**)\) Cocoon phase, \(^****)\) Larva phase.

**Table 2. Soil biota population after harvest.**

| Treatments                          | Population (m\(^{-2}\)) |
|-------------------------------------|-------------------------|
|                                     | Earthworms | others (*) |
| T1= Goat manure + chicken manure + banana stem | 20 | 12 |
| T2= Chicken manure + plant residue + CMA | 36 | 24 |
| T3= Chicken manure + plant residue + biofertilizer | 28 | 21 |
| T4= Chicken manure + plant residue + *Tithonia* | 24 | 60 |
| T5= Vermicompost                    | 24         | 24         |
| T6= Vermicompost + biofertilizer    | 4          | 20         |

Note: *) *Oligochaeta, Coleoptera, Millipedes, Bothynus, Collembola.*
organic fertilizer requirement by 10 t ha\(^{-1}\). Biofertilizer tended to reduce half the application rates of organic manure in semi-arid region of northeastern Nigeria [14].

Vermicompost application had caused the plant to get attack by nematodes, which could reduce the yield. The purpose of using *Trichoderma* sp. was to kill and control populations of soil infectious diseases, especially nematodes that cause root swelling. The use of *Trichoderma* sp has not been able to control the nematodes, however by adding biofertilizer it could increase the chinese lettuce yield (table 3).

**Table 3.** The effect of organic fertilizer and biofertilizer applications on plant height, biomass and yield of Chinese lettuce.

| Treatments | Plant height (cm) | Biomass (t ha\(^{-1}\))** | Yield (t ha\(^{-1}\)) |
|------------|------------------|----------------|------------------|
| T1= Goat manure + chicken manure + banana stem | 25.8 a* | 15.16 a | 13.83 a |
| T2= Chicken manure+ plant residue + CMA | 25.1 ab | 11.00 b | 9.42 b |
| T3= Chicken manure+ plant residue + biofertilizer | 26.1 a | 15.32 a | 13.32 a |
| T4= Chicken manure+ plant residue + *Tithonia* | 23.3 c | 12.08 b | 10.25 b |
| T5= Vermicompost | 20.9 c | 6.50 c | 5.75 c |
| T6= Vermicompost + biofertilizer | 21.0 c | 7.69 c | 6.25 c |

Notes: *The numbers in same column followed by the same letter are not significantly different according to Duncan Multiple Range Test (DMRT) at the 0.05 level. ** Plant residue of Chinese lettuce.

3.4. Growth and yield of broccoli
Among treatments, there were no significant differences in plant height at 45 days (table 4). At 60 days, the highest plant was 38.5 cm achieved at T2 treatment. The treatment was not significantly different from T1, T3, and T4 but was significantly higher than T5 or T6. At 75 days treatment, the T3 was the highest reaching 45.2 cm and is not difference from T1, T2 treatments; and T4, however, was higher than T5 and T6. Plant height increment occurred until 82 days, the highest plant reached 45.3 cm. Thus, T1, T2, T3, and T4 treatments were not significantly different for broccoli plants but those treatments were significantly different from T5 and T6 treatments.

*Pseudomonas* sp. and *Azospirillum* sp. were the P-solubilizing bacteria and N fixing bacteria and the producer of phytohormone especially auxin which has the function as a stimulant plant growth [15], however using bacteria could not stimulate the growth of broccoli plant, and it showed not significantly different from without using bacteria.

**Table 4.** Effect of organic fertilizer and biofertilizer applications on plant height of broccoli at 45, 60, 75, dan 82 days after planting (DAP).

| Treatments | Plant height (cm) |
|------------|------------------|
|             | 45 DAP | 60 DAP | 75 DAP | 82 DAP |
| T1= Goat manure + chicken manure + banana stem | 27.6 a* | 34.7 ab | 38.7 abc | 39.4 ab |
| T2= Chicken manure + plant residue + CMA | 27.9 a | 38.5 a | 43.1 ab | 43.7 a |
| T3= Chicken manure + plant residue + biofertilizer | 28.9 a | 37.1 a | 45.2 a | 45.3 a |
| T4= Chicken manure+ plant residue + *Tithonia* | 27.1 a | 33.8 ab | 39.5 abc | 40.5 a |
| T5= Vermicompost | 23.7 a | 21.5 c | 32.5 bc | 32.9 bc |
| T6= Vermicompost + biofertilizer | 23.6 a | 27.7 bc | 30.5 c | 31.0 c |

*)The numbers in same column followed by the same letter are not significantly different according to Duncan Multiple Range Test (DMRT) at the 0.05 level.
DAP= Day after planting.
Acknowledgments

The highest biomass and yield of broccoli were achieved for T4 (table 5) namely 6.95 t ha\(^{-1}\) and 3.80 t ha\(^{-1}\), respectively, and biomass is not significantly different from T1, T2, and T3, but is significantly higher than that of T5 and T6 treatments which produced 2.23 to 2.78 t ha\(^{-1}\). Green manure from Tithonia leaf effectively suppressed infection on *P. brassica* and was capable of increasing growth of cabbage [16]. While T6 treatment on yield of broccoli was significantly higher than that of T5. Thus, the use of biofertilizer for broccoli plants is better compared with the use of vermicompost in improving yield. Combined application of vermicompost and biofertilizers increased the growth and yield of tomato and french bean under mid hills of Himachal Pradesh [17]. Manipulation of husbandry encouraging improvements in soil structure, texture, nutrient composition and moisture content can reduce populations of *P. brassicae*. Integrating such strategies with rotation and crop management will reduce but not eliminate this disease. There are indications that forms of biological competition may be mobilized in addition to integrated control strategies [18].

**Table 5.** Effect of organic fertilizer and bio-fertilizer applications on biomass and yield of broccoli.

| Treatments                  | Biomass (t ha\(^{-1}\))** | Yield (t ha\(^{-1}\))*** |
|-----------------------------|---------------------------|--------------------------|
| T1= Goat manure + chicken manure + banana stem | 5.73 a*                  | 3.81 a                   |
| T2= Chicken manure + plant residue + CMA        | 4.85 ab                   | 2.04 c                   |
| T3= Chicken manure + plant residue + biofertilizer | 4.91 ab                  | 3.09 b                   |
| T4= Chicken manure + plant residue + *Tithonia*  | 6.95 a                    | 3.80 a                   |
| T5= Vermicompost              | 2.23 c                    | 0.10 d                   |
| T6= Vermicompost + biofertilizer          | 2.78 bc                   | 1.44 c                   |

Notes: * The numbers in same column followed by the same letter are not significantly different according to Duncan Multiple Range Test (DMRT) at the 0.05 level,
** Plant residue from stem and leaf of broccoli
*** Flower of broccoli.

4. Conclusions

The application of chicken manure + plant residue of 10 t ha\(^{-1}\) and biofertilizer gave yield of 13.3 t ha\(^{-1}\) of Chinese lettuce, and that chicken manure + plant residue of 10 t ha\(^{-1}\) + *Tithonia diversifolia* gave yield of 3.8 t ha\(^{-1}\) of broccoli and the diversity of soil biota is significantly higher than those of other treatments. Vermicompost gave the lowest yield of Chinese lettuce and broccoli due to root disease caused by parasite nematode.

Acknowledgments

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