EFFECTS OF GOAT MANURE ON GROWTH, YIELD, AND ECONOMIC IMPACTS OF VEGETABLE INTERCROPS IN YOUNG COFFEE PLANTATION

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ABSTRACT

When facing crisis, coffee growers are diversifying by cultivation of cash crops as new intercrops for alternate sources of revenues. Growing vegetable intercrops is one option in order to obtain maximum benefits of idle existing space, season, soil, moisture, nutrients, and to increase the productivity per unit of land. The objectives of the study were to show the effect of goat manure on the growth and yield of vegetables and to show the benefits of manure application on vegetable as intercrops in young coffee plants. The study was located in Sumberjaya West Lampung, at the altitude of 735 m asl, and conducted from December 2007 to June 2009. The treatments were arranged in a split plot design where the main plot was three dosages of goat manure (0, 5, and 7.5 ton/ha) and the subplot was three types of vegetable crop rotation (legume-legume, legume-non legume, and non legume – non legume), which were implemented for four consecutive plantings. The legume vegetable were green bean (*Phaseolus vulgaris* L.) and yard long bean (*Vigna sinensis* L), while the non legume vegetable were cherry tomato or “rampai” (*Lycopersicum pimpinellifolium* L), chilly pepper (*Capsicum anuum* L), and eggplant (*Solanum melongela* L.). Results showed that goat manure increased the growth and productivity of vegetables intercropped within young coffee plants. The yield gain varied between 2.7 to 5.1 times greater at 7.5 ton manure per ha than control. The revenue/cost (R/C) ratio was up to 1.8 with the manure application of 7.5 ton/ha. Organic matter was highly correlated with the yield of legume vegetable and was correlated with the yield of non legume vegetable crops. The benefit of goat manure was not only to provide essential trace nutrient needed by the plant but also to improve soil structure, and this effect lasted until the subsequent vegetable growing season.

Keywords: goat manure, vegetable intercrops, growth and yield

INTRODUCTION

Coffee based agriculture is commonly practiced among farmers in Sumberjaya,West Lampung. Most coffee plantations in West Lampung are originated from either forest or shrubs. Forest or shrub conversion into coffee is driven by many factors but primarily due to socio-economic pressure and opportunity to occupy previously forested land. Whenever coffee is grown as new plantation of rejuvenating ones, there is a choice for farmers either to make a use of or to allow an open space within coffee stands.

During economic difficulty, coffee growers are diversifying by cultivation of cash crops as new intercrops for alternate sources of revenues. Growing an intercrops is one option in order to obtain maximum benefits of empty space, season, soil, moisture, nutrients, and biodiversity, too. The interest in vegetable plants has been generated among the planter’s community and the actual demand of these profitable products in the local and regional market. However, as production costs become more and more expensive, it is necessary to come up with practical solution, *i.e.* as intercrops. Intercropping vegetable plants provide some advantages such as weed control, nutrient recycling, low-external input farming and extra income (Hussain, 2003).

One of the most important reasons to grow two or more crops together is the increase in productivity per unit of land (Sullivan, 2003). Vegetables are the most common cash crop grown within young coffee plantation (< 4 year olds) or in a newly opened area. The choice of vegetable crops are mostly based on price value and the farmer’s capital ability rather than integrating both cash value and considering benefit to the ecosystem thereafter. Due to their wide adaptability and availability, vegetables can fit into cropping systems under diverse agro-ecological conditions.

The practice of applying manure in the field needs to be revitalized since land degradation continues to occur even at a faster rate than before. The implementation of manure must be put forward to alleviate excessive use of inorganic fertilizers which believed by many in offering quick responses on plant growth and yield, instead of slow and gradual responses emanating from manure application. Other than its positive effect on soil physical properties and nutrient value, manure also contains microorganisms that may directly or indirectly improve soil biodiversity through interactions with beneficial soil organism(s). It seems that manure management is one of the best practices in vegetable production especially for an increasing interest and demand for organic products (Rosen and Bierman, 2005).

The objectives of the study were to see the effect of goat manure on growth and yield of various vegetable plants and to show the economic impacts of manure application on vegetable production.

MATERIALS AND METHODS

Time and Place

The research was conducted at young coffee garden in Sumberjaya, West Lampung from December 2007 to June 2009. The altitude in the area is 735 m asl, with the average temperature of 24^{o}C, and the average rainfall of 2000 mm/year.

Land preparation and maintenance

At the beginning of the study, the coffee plant was approximately one year old and planted by 2m x 2 m, which provided enough space to grow intercrops. The land was divided into 9 plots of 10 m x 10 m each, and between two plots was separated by an area of 1 x 1 m^{2} for maintenance purpose. Land for vegetable cultivation was prepared manually using hoe approximately two weeks before seed sowing (for bean and/or yard-long bean) or transplanting (for cherry tomato, chilly pepper and egg plant that have been seeded in a nursery for 3 weeks). Weeds, mostly *Chromolaena odorata* and *Imperata cylindrica*, were hand-rooted one week prior to vegetable cultivation and whenever necessary during the growing season.

Experimental method

The experiment was laid out in a split plot design where goat manure as main plot and vegetable rotation as subplot. Goat manure was given at three different dosages, i.e. 0 ton/ha, 5 ton/ha, or 7.5 ton/ha. Naturally decomposed goat manure (1.24 % N – 0.5 % P – 1.10 % K, with the C/N ratio 22.7) was obtained from the nearby farm. The pattern of vegetable crop rotation was shown at Table 1. Goat manure was applied as a banded fertilizer, prior to the first vegetable plantings, following a row of vegetable crops. Inorganic fertilizer (NPK: 16-16-16) was applied a week after planting or transplanting with a dosage of 200 kg/ha. The application of inorganic fertilizer was needed to promote the initial growth and development of the vegetable plants.

Plant material consisted of existing one-year-old Robusta coffee and local varieties of green bean, small or cherry tomato, chilly pepper, yard-long bean, and eggplant. The planting distance of bean and yard-long bean were 60 cm x 25 cm, cherry tomato and chilly pepper were 50 cm x 30 cm, and eggplant was 80 cm x 80 cm.

Table 1. The legume-based rotation of vegetable crops intercropped within one-year-old coffee.

No	Type of rotation	1st planting	2nd planting	3rd planting	4th planting
1	Legume - legume	Bean*or green bean	Yardlong bean	Bean	Bean
2	Legume – non legume	Bean	Chilly	Yardlong bean	Cherry tomato
3	Non legume – non legume	Cherry tomato	Eggplant	Cherry tomato	Cherry tomato

Note: Green bean (*Phaseolus vulgaris* L.), cherry tomato (*Lycopersicum pimpinellifolium* L.), yard-long bean (*Vigna sinensis* L.), chilly peppers (*Capsicum annuum* L.), and eggplant (*Solanum melongela* L.).

Common crop maintenance included irrigating and stacking the plants. All plants were watered regularly with a sprayer or drip irrigation whenever necessary. Except for eggplant, all others crops needed supporting stand which made from bamboo. A tripod support was made from bamboo stick for a climbing of green bean and yard-long bean starting from 2 weeks after planting. Cherry tomato and chilly peppers were stacked to prevent lodging and each plant was individually stacked before flowering stage.

Data collection and analyses

A. Crop growth. Random samples of ten plants were taken at early development of green bean pod and cherry tomato fruit to measure shoot and root dry weight, leaves nutrient content, and leaf greenness by using Minolta SPAD 502.
B. Crop yield. Crop production (kg/m2) was measured as total marketable yield of each crop, i.e. green bean, yard long bean, cherry tomato, chilly pepper, and eggplant.
C. Crop quality. The quality of harvested product was represented by green bean pod and cherry tomato fruit which were collected at the peak harvest (second picking out of four). Pod quality in terms of pod length (cm) and pod diameter (mm) were measured by taking a random sample of 20 green bean pods from each experimental unit. Fruit quality, i.e. fruit diameter (cm) and fruit volume (ml), was obtained from a random sample of 20 cherry tomato fruits from each plot.

The acquired data were statistically analyzed by using computerized statistical program, SAS 9.12 version. The economic impact of manure treatments was measured in term of revenue/cost (R/C) ratio for green bean and cherry tomato production.

RESULTS AND DISCUSSION

Soil physical and chemical entities data prior to the implementation of the study were presented elsewhere (Karyanto *et al.*, 2009). In general, soil texture was dominated by clay (60%) and followed by silt and sand (20% each), soil pH 4.2, moderate organic matter content (1.62%), and low soil fertility parameter in term of P, CEC and bases. The low soil CEC may be due to intensive soil weathering process and the soil is more developed (Afandi *et al.*, 2004).

Legume and non legume vegetables were grown as intercrops in one year old coffee stand from December 2008 to June 2009 and applied as three distinct vegetable rotation schemes as shown in Table 1 (see material and method section). At the first season of vegetable planting, the height of the coffee plants was approximately 30-40 cm and at the end of the demo-plot (after 4th vegetable planting) the average coffee heights at 7.5 ton/ha manure were more than one meter and started to bloom.

Crop growth and yield were measured for all vegetable crops at four seasons. However, for growth parameters we will only present data from the first season, *i.e*. green bean (*Phaseolus vulgaris* L.), representing legume-type vegetable, and small (cherry) tomato (*Lycopersicum pimpinellifolium* L.), as an example of the non legume vegetable.

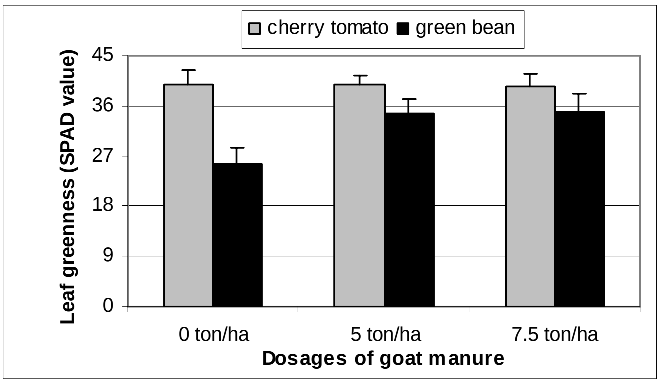

Figure 1. Leaf greenness measured at early reproductive stages of both cherry tomato and green bean in response to goat manure application. Error bars indicate ± SE value

The value of leaf greenness, measured with hand-held chlorophyll meter named SPAD Minolta 502 (*soil-plant analysis development*), of cherry tomato was not significantly different among treatments, whereas in green bean leaves showed a gradual increase in leaf greenness with increasing the dosage of manure (Figure 1). Yellow leaves were predominant for green bean plant that received low manure. It seemed that bean (legume types) was more sensitive to nutrient deficiency than that of cherry tomato. Other reason for the differences in green bean leaf greenness rather than in cherry tomato may be due to the leaf morphology; green bean has bigger and thinner leaves whereas leaves of cherry tomato were thicker rather than slimmer. Leaf greenness, here measured as SPAD-index, is just one way to look at the plant performance through it leaves. Green and healthy leaves indicated that plants could absorb available nutrients in the soil especially nitrogen, wherever their sources were, and utilize them to make chlorophyll in leaves. SPAD-index measured on plant leaves were positively correlated to N sufficiency for various crops such as in maize or corn (Piekielek and Fox, 1992; Blackmer and Scherpers, 1995) and in tomato (Sandoval-Villa *et al*., 1999; Fontes and Rochi, 2002).

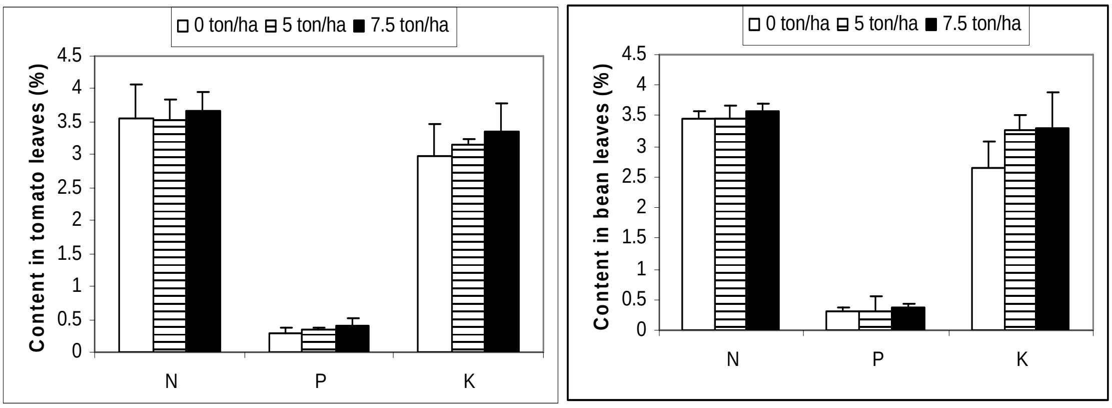

Figure 2. Nitrogen, phosphorus, and potassium content in leaves of cherry tomato (left) and green bean (right) in response to goat manure application. Error bars indicate ± SE value

The mineral content of nitrogen, phosphorus and potassium in cherry tomato leaves was variable among treatment, without any significant trends (Figure 2, left). Nitrogen content (%) in green bean was not different among treatment, as it does so for phosphorus content. On the other hand, potassium (%) in leaves was higher when plant received more manure (Figure 2, right). The variability on leaf mineral content might be due to sampling limitation as each sample was taken at duo rather than triple. The analysis of manure or compost provides total nutrient content, but availability of the nutrients for plant growth will depend on their breakdown and release from the organic components. Generally, 70 to 80% of the phosphorus (P) and 80 to 90% of the potassium (K) will be available from manure the first year after application (Rosen and Bierman, 2005).

The application of goat manure increased plant biomass for both cherry tomato and green bean (Figure 3). Plant biomass was obtained after oven drying of the plant samples at 70°C for 3 days. Dry weight of root and shoot as well as shoot/root ratio increased as a result of manure application. The application of goat manure increased plant growth (plant height, number of leaves, data not shown) compared to control. The increase in number of leaves must have led to an increase in total leaf area hence higher intercepted light and photosynthesis. These effects are explained in terms of total fresh and dry weights of the plant which showed a positive response to increasing goat manure application. Goat manure effect on crop growth was also translated in the quality of cherry tomato fruit and bean pod (Figure 4 and Figure 5). Tomato fruit size increased as dosage of goat manure increase. The size of small tomato fruit was indicated by measurement of average fruit diameter and fruit volume. Cherry tomato fruit diameter increased from 1.8 cm at control to 2.4 at 7.5 ton/ha, whereas its fruit volume increased from 4.4 ml at control to 7.5 ml at 7.5 ton/ha (Figure 4). Increment of fruit diameter as increasing dosage of inorganic fertilizers was less pronounced in fruit diameter than that of fruit volume. Experimentally, fruit volume may indicate the thickness of the fruit flesh and the amount of soluble solids inside the loci. The increment in green bean pod quality was presented in Figure 5. The diameter, width, and length of green bean pod showed a positive response with goat manure increment.

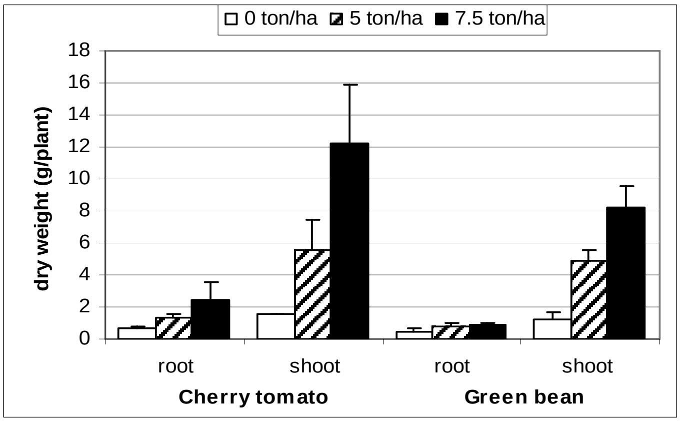

Figure 3. Root and shoot dry weights of cherry tomato and green bean in response to goat manure application. Error bars indicate ± SE value

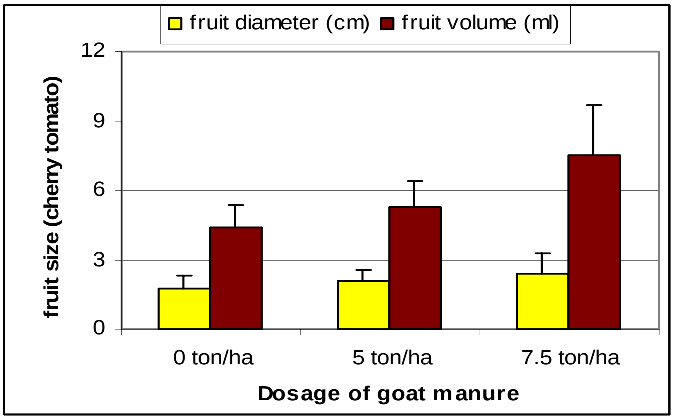

Figure 4. Cherry tomato fruit size in response to goat manure application. Error bars indicate ± SE value.

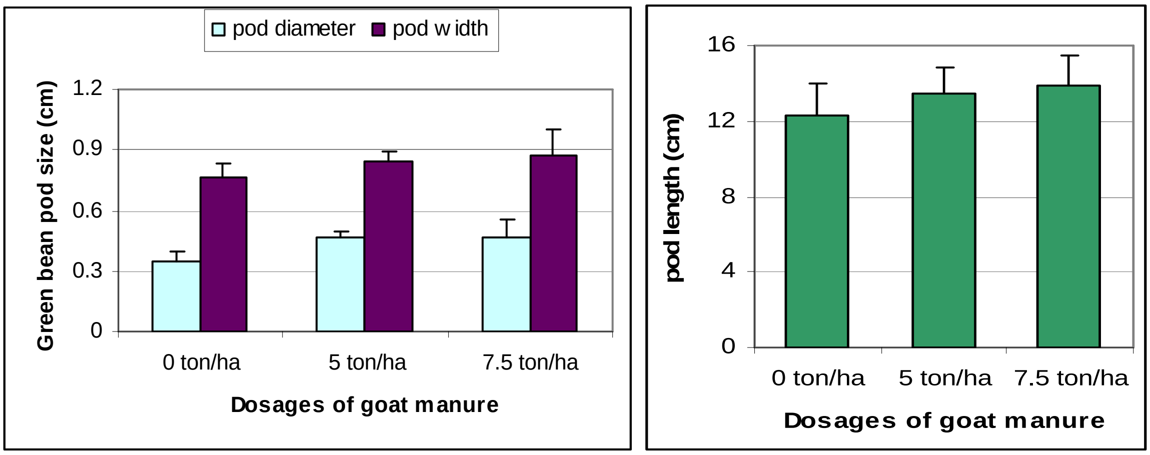

Figure 5. Green bean pod quality in response to goat manure application. Error bars indicate ⬅ SE value

The first vegetable season was green bean and cherry tomato. The second vegetable seasons were yard long bean (legume), chilly pepper (non legume), and eggplant (non legume). The goat manure was not given into the soil, thus the manure dosages implied as residual effect of previous manure application. Crops yield increased as an increasing (residual) of goat manure (Figure 6). The third vegetable plantings were green bean (legume), yard long bean (legume), and cherry tomato (non legume). In general, crop yield were higher at manure dosages of 7.5 ton/ha than that of other treatments. This result was similar to finding by Abdel-Mawgoud (2006) where compost significantly improved green bean yield. Goat manure applied at 5 and 7.5 ton/ha did improve yield of all vegetable crops cultivated during this study (Figure 6), although these dosages were still below the optimum recommended practices for vegetable growing which is 10-15 ton of manure per hectare. For the crop rotation study, the goat manure was implemented only prior to the first vegetable season, hence, the subsequent vegetable planting should be interpreted as having residual effect of goat manure since all crops received the same amount of inorganic fertilizers (compound NPK) at the rate of 200 kg/ha. As shown in Figure 6, the positive effect of (goat manure residue tended to lessen as the sequence of crop rotation progressed. The residual effects of the manure and compost are important. Some benefit was obtained in the second and third years following application as showed in this study. When manure and compost are used to fertilize crops, soil organic matter will increase over time and subsequent rates of application can generally be reduced because of increased nutrient cycling. General rules of thumb for N are that organic N released during the second and third cropping years after initial application will be 50% and 25%, respectively, of that mineralized during the first cropping season (Rosen and Bierman, 2005).

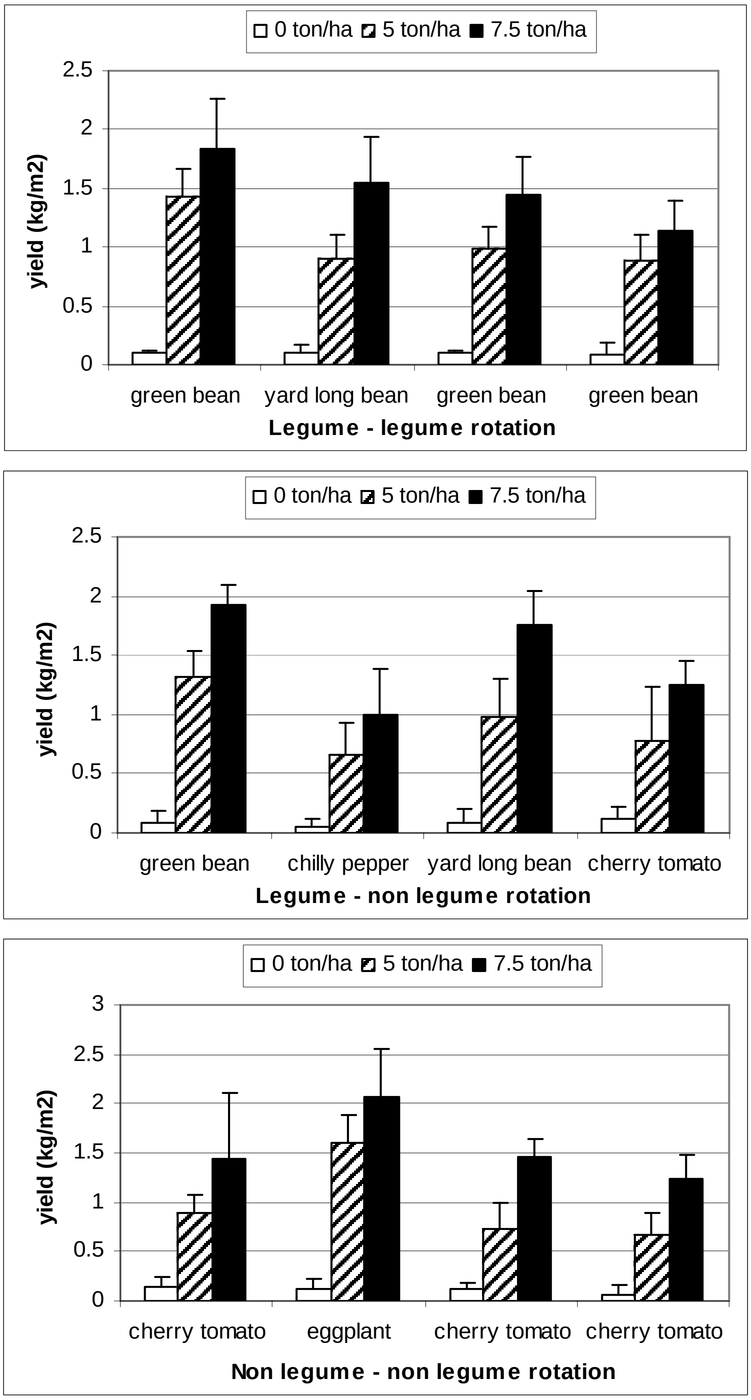

Figure 6. Crop yield (kg/m^2) of vegetables in response to goat manure application. Data were presented based on type of vegetable crop rotation, i.e. legume – legume (top), legume – non legume (middle), and non legume - non legume (bottom), where the sequence of rotation was indicated by crop's name given by order from left to right. Error bars indicate ± SE value

Table 2 showed the results of correlation test. Vegetable crops production was highly correlated with the application of goat manure. Apparently, goat manure could improve soil quality in term of physical, chemical, and biological properties. This study is in accordance with the finding of Mikha and Rice (2004), where they stated that manure was significantly increase C and N total in compare to chemical fertilizer application. A study by Rochette and Gregorich (1998) indicated that about half of the applied manure was left as residue in soil at the end of the growing season. Besides manure application, the incorporation of plant residue after harvesting the economical yield into the soil was another way of adding organic matter into the soil. Aoyama *et al*. (1999), however, reported that increase in accumulation of soil organic matter was merely due to applied manure than that of the change of plant biomass. Since most vegetable crops return small amounts of crop residue to the soil, so manure, compost, and other organic amendments help maintain soil organic matter levels.

Table 2. Result of correlation analyses of goat manure and vegetable yield

Correlation between variable	R2	t-calc	t-0.05	t-0.01
Goat manure with bean yield (season 1)	0.90**	5.46	2.36	3.50
Goat manure with cherry tomato yield (season 1)	0.89**	5.12	2.36	3.50
Goat manure with chilly pepper yield (season 2)	0.85**	4.35	2.36	3.50
Goat manure with yard-long bean yield (season 2)	0.90**	5.46	2.36	3.50
Goat manure with egg plant yield (season 2)	0.70*	2.59	2.36	3.50
Goat manure with bean yield (season 3)	0.88**	4.90	2.36	3.50
Goat manure with yard-long bean yield (season 3)	0.82**	3.79	2.36	3.50
Goat manure with cherry tomato yield (season 3)	0.78*	3.30	2.36	3.50
Goat manure with bean yield (season 4)	0.88**	4.90	2.36	3.50
Goat manure with cherry tomato yield (season 4)	0.92**	6.21	2.36	3.50
Goat manure with cherry tomato yield (season 4)	0.89**	5.16	2.36	3.50

Notes: * significant at 5% level and significant at 1% level

The economic impact of goat manure application was interpreted as revenue/cost (R/C) ratio as presented in Table 3. The R/C value more than one indicated there was a benefit obtained from the crop production. The highest benefit was obtained from highest goat manure level (7.5 ton/ha), which its value 1.35 in green bean and 1.81 in cherry tomato. Thus manure application was beneficial to the soil, and subsequently translated into the growth and yield of vegetable plants, and to the farmer as an increase in economic return.

Table 3. Economic impact of goat manure on green bean and cherry tomato production.

Crop	Dosages of goat manure		
	0 ton/ha	5 ton/ha	7.5 ton/ha
Green bean			
Total production cost per/ha (Rp)	2665000	3165000	3365000
Total revenue	1845000	3532500	4545000
Benefit (Revenue - Cost)	-820000	367500	1180000
Revenue/Cost (R/C) ratio	0.69	1.12	1.35
Cherry tomato			
Total production cost per/ha (Rp)	2696000	3196000	3396000
Total revenue	1545000	5280000	6153000
Benefit (Revenue - Cost)	-1151000	2084000	2757000
Revenue/Cost (R/C) ratio	0.57	1.65	1.81

CONCLUSION

Dosage of goat manure at 7.5 ton/ha significantly improved the growth of vegetable as shown in biomass of green bean and cherry tomato. There were no differences in leaf greenness and nutrient content (nitrogen, phosphorus, and potassium) in leaves. Vegetable yield increased as dosages of goat manure increased. The yield gain varied between 2.7 to 5.1 times greater at 7.5 ton manure per ha than control. The quality of green bean pod and cherry tomato fruit was better at higher dosages of goat manure. Organic matter was highly correlated with the yield of legume vegetable and was correlated with the yield of non legume vegetable crops. The revenue/cost (R/C) ratio was up to 1.8 with the manure application of 7.5 ton/ha.

ACKNOWLEDGMENT

This publication is part of the outcomes of the international project "Conservation and Sustainable Management of Below-Ground Biodiversity (CSM-BGBD)" executed in seven tropical countries – Brazil, Cote d'Ivoire, India, Indonesia, Kenya, Mexico, and Uganda. The project is coordinated by the Tropical Soil Biology and Fertility Institute of CIAT (TSBF-CIAT) with co-financing from the Global Environment Facility (GEF), and an implementation support from the United Nations Environment Programme (UNEP). We also thank to our students, Listya Herawati and Eva Hanggraeni, especially for helping us during the field work, *i.e.* in crop maintenance and data collection.

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