IOP Conference Series: Earth and Environmental Science

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To cite this article: S Yusnaini *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **724** 012002

Changes in soil respiration after application of *in situ* soil amendment and phosphate fertilizer under soybean cultivation at Ultisol South Lampung, Indonesia

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Abstract. Several inputs are needed to increase the production of soybean in Ultisol. The Application of organic soil amendment will increase carbon, nutrients, and water stored in the soil. Besides, the soil structure becomes stable so that plants will be more tolerant of climate change. The higher organic C in the soil, the more fertile soils, the plants grow healthier and fertile, and then the emission of CO_2 gas into the air can be suppressed. Therefore, this study aims to determine soil respiration (CO_2) due to the application of *in situ* soil amendment and phosphate fertilizer. This research was conducted at the research station of BPTP Natar, South Lampung, from July to November 2019, arranged with random complete block design in two factorials. The first factor is the source of phosphate fertilizer is without P fertilizer, TSP fertilizer 200 kg ha^{-1}, and rock phosphate 5 tons ha^{-1}, and the second factor is the application of soil *in situ* amendments. *i.e.*: without the soil amendment, rice husk biochar 5 tons ha^{-1} (B1), organonitrofos compost 10 tons ha^{-1}, and cow dung manure 10 tons ha^{-1}. All experimental units were fertilized with urea at a dose of 50 kg ha^{-1} and KCl at a dose of 200 kg ha^{-1}. The result showed that the highest soil respiration was obtained in the plot treated with rock phosphate and cow dung manure at the single factor. The combination of rock phosphate and cow dung manure resulted in the highest of soil respiration.

1. Introduction

Ultisols is a type of soil that has several problems. Some common problems with Ultisol are high soil acidity, varied among pH 3.10-5.0, high Al saturation, poor macronutrient content, especially phosphor, potassium, calcium, and magnesium as well as low organic matter content [1], low base saturation value (<35%) and CEC (<16 cmol kg^{-1} clay), [2], which are often a barrier to plant growth and production. To improve the quality of ultisols can be done, among others, by rehabilitating using the soil amendment. Soil improvement technology with organic material is widely studied and reported to improve acid dry land. Rehabilitation of suboptimal soils can be done by adding soil ameliorating material before fertilization is given. Soil amendment is a material that is applied to the soil to improve the soil quality and health. Soil amendment is well applied to the soil, including compost, lime, and other organic matter. Many reports state that the application of soil amendment will improve soil quality such us soil physic, soil chemical, and soil biological,if done continuously over a long period time [3].

The low soil organic carbon (SOC) levels, caused by the result of low plant biomass C inputs, make soil respiration rates are low. Soil respiration reflects the amount of CO_2 released by the root of the plant and by soil organisms' activity during the decomposition of organic matter. Therefore, soil respiration can be used as an indicator of soil fertility, because through soil respiration, microorganism activity in the soil can be measured.

The soil respiration method can be an indicator of the health of the soil because the results obtained are quite sensitive, consistently simple, and do not require expensive and sophisticated equipment [4]. The rate of soil respiration depends on dynamic soil factors, i.e., organic matter content, temperature, soil moisture, and soil pH. Soil respiration reflects the soil capacity to support soil life, including crops, soil animals, and microorganisms. It describes the level of microbial activity, soil organic material (SOM) content, and its decomposition. Soil microbial activity is affected by the content of soil organic matter (SOM) and contributing to soil health and soil function by supporting crop performance and productive and mantainance of soil water content. Consequently, several soil properties i.e., soil temperature, soil moisture, aeration, and organic N affect on biological activity and decomposition of SOM. However, the dynamics of soil respiration are not well understood because soil respiration should change with climate. This has been difficult to confirm observationally because of the high spatial variability of soil respiration [5]. The present research aimed to examine soil respiration changes under several soil organic amendments and phosphate fertilizers at soybean cultivation in ultisol.

2. Material and methods

2.1 Experimental site and treatment

In July 2019, experimental was conduct on cropland fields at BTTP Natar, Negara Ratu Village, South Lampung District, Lampung Province, Indonesia. The major soil characteristics were measured at the start of the experiment (Tabel 1). A complete randomized block design was established with two factorial and three replications. The first factor is the source of phosphate fertilizer is without P fertilizer (P_0), Triple Super Phosphate (TSP) 200 kg ha^{-1} (P_1), and phosphate rock (PR) 5 tons ha^{-1}(P_2) and the second factor is the application of in situ soil amendments. i.e.: without the soil amendment (B_0), rice husk biochar 5 tons ha^{-1} (B_1), organonitrofos compost 10 tons ha^{-1}(B_2), and cow dung manure 10 tons ha^{-1}(B_3). All experimental plots were fertilized with urea at a dose of 50 kg ha^{-1} and KCl at a dose of 200 kg ha^{-1}. Grobogan soybean seed was sown at an inter-row spacing of 0.25 m and an intra-row spacing 0.40 m. The seeds are planted in a hole with a depth of about 2-3 cm. Each planting hole was given 3 seeds of soybean. Before planting the soybean seeds, furadan was applied to the walls and base of the planting medium. Applying furadan is to protect the soybean seeds from insect. The soybean seeds that have been treated with legin inoculum then planted in the existing planting holes. Thinning and gap filling was carried out in the first two weeks after planting.

Table 1. Basic soil properties before soybean planting at BPTP Natar, South Lampung, Indonesia

Soil properties	Value	Criteria *
Total-N (%)	0.02	Low
Avail-P (mg 100 g^{-1})	3.21	Very Low
Exc-K (me 100g^{-1})	1.05	Low
Org-C (%)	1.28	Low
pH (H_2O)	4.41	Low
CEC (me 100g^{-1})	10.78	Slightly low
Soil Respiration (C-CO_2 mg hr^{-1} m^{-2})	23.27	

Note: * Puslitbangtan [6]

2.2. Soil amendment and phosphate fertilizers application

The four kinds of soil amendments i.e., control, rice husk biochar, agronitrofos compost, and cow dung manure were analyzed before applied on the plot experiment (Table 2), and then soil amendments were spread by hand and then incorporated. Phosphate fertilizers (without, TSP, and PR) and organic soil amendments were applied one week before grobogan seed soybean planting.

Table 2. The chemical properties of various soil amendment content

Chemical properties	*Rice husk Biochar*	Cow dung Manure	Organonitrofos compost
pH	6.88	8.13	8.13
Total -N (%)	0.61	1.42	0.35
Organic -C (%)	22.20	22.52	3.09

2.3 Soil respiration determination

Determination of soil respiration was measured at the time of the initial soil before treatment, at the maximum vegetative period, and harvesting phase. The method for measuring soil respiration is the modified Verstraete method [7] using a 10 ml 0.1 N KOH for capturing the amount of CO_2 from the soil, then is closed with a jar. The jar is then pressed into the soil to inhibit gas from the air or gas out from the jar's lid. The same thing was done for the control, but the ground surface was covered using plastic so that KOH captured no CO_2 from the soil ground. This measurement was carried out for 2 hours; after that, the quality of CO_2 will be determined through titration at the laboratory using HCl, with phenolptalin indicators, and titrate again with methyl orange indicators. The amount of HCl used in the second stage of the titration is directly related to the amount of CO_2 captured. To support main variable, in this research also measure soil organic-C (Walkley and Black method), soil pH (electrometric method), soil temperature ^oC (soil thermometer), and soil water content % (gravimetric method).

2.4 Analysis data

The data were analysed by one-way analysis of variation (ANOVA), and the least significant difference (LSD) test at a probability level of 0.05 for means data. Correlation analysis was used to analyse the relationship between soil temperature, soil moisture, soil pH, soil organic carbon, and soil respiration.

3. Result and Discussion

3.1. Soil respiration at soybean cultivation caused by soil amendment and phosphate fertilizer

During the whole soybean growth, soil respiration rate varied under different treatments. Soil respiration was higher at the maximum vegetative stage of soybean growth than that of the soybean harvesting stage (Figure 1). The highest soil respiration was recorded under phosphate rock combine with cow dung manure treatment (P_2B_3) at the maximum vegetative stage. Moreover, soil respiration was lowest at the combination treatment without phosphate fertilizer and soil amendment application (P_0B_0) which is observed at the harvesting stage of soybean.

Based on analysis of variance, at the maximum vegetative stage of soybean, application of soil amendment had effect on soil respiration, however application of phosphate fertilizers and interaction between phosphate fertilizers and soil amendment there are no effect on soil respiration. Therefore, at harvesting stage, the application of phosphate fertilizers had a significant effect on soil respiration and there was a significant interaction between the application of phosphate fertilizers and soil amendment.

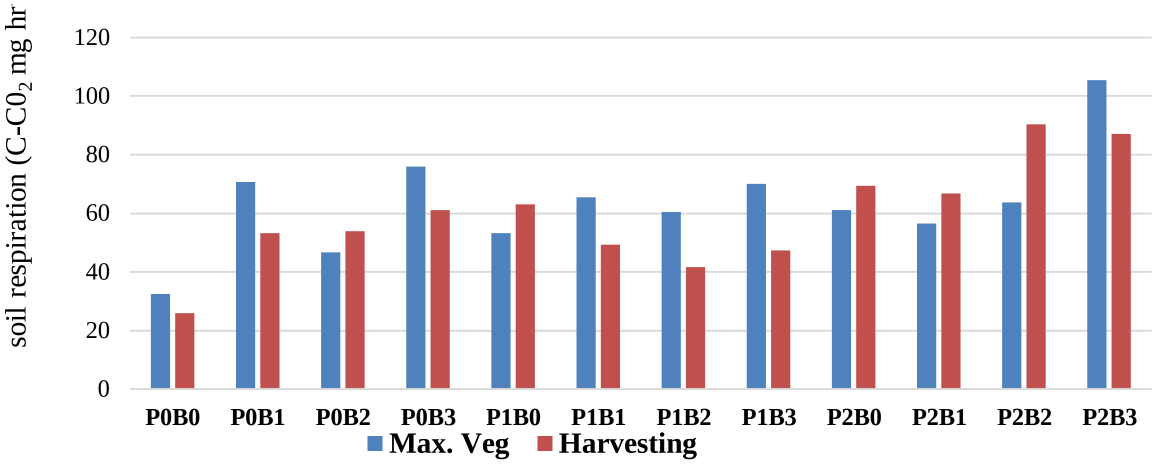

Figure 1. Soil respiration during soybean growth at maximum vegetatif stage and harvesting stage (without P fertilizer (P_0), Triple Super Phosphate (TSP) 200 kg ha^{-1} (P_1), phosphate rock (PR) 5 tons ha^{-1}(P_2), without the soil amendment (B_0), rice husk biochar 5 tons ha^{-1} (B_1), organonitrofos compost 10 tons ha^{-1}(B_2) and cow dung manure 10 tons ha^{-1}(B_3)).

Table 3. Effect of various soil organic amendment on the soil respiration at maximum vegetative stage of soybean cultivation.

Treatment	Soil respiration (C-CO_2 mg hr^{-1} m^{-2})
Without soil amendment	49.0 a
Rice husk biochar	64.3 ab
Organonitrofos compost	57.0 a
Cow dung manure	83.8 b
LSD 5%	18.4

Note: B_0= Without soil organic amendment; B_1=5 tons ha^{-1} *rice husk biochar*; B_2=10 tons ha^{-1} organonitrofos compost; B_3=10 tons ha^{-1} cow dung compost; value that followed by the same letter not significantly different by LSD test 5%.

Table 4. Interaction effect of various soil amendment and phosphate fertilizer on the soil respiration at harvesting stage of soybean cultivation.

Treatment	Soil respiration (C-CO_2 mg hr^{-1} m^{-2})			
	Without soil amendment (B_0)	*Rice husk biochar(B_1)*	Organonitrofos compost (B_2)	Cow dung manure (B_3)
Without P fertilizer (P_0)	26.0 a (A)	53.3 b (AB)	53.9 b (A)	61.0 b (A)
TSP (P_1)	63.0 a (B)	49.4 b (A)	41.6 b (A)	47.4 b (A)
PR (P_2)	69.5 a (B)	66.9 a (B)	90.3 b (B)	87.0 b (B)
LSD 5%	17.4			

Note: P_0=Without P Fertilizer; P_1=200 kg ha^{-1}TSP; P_2=5 tons ha^{-1}FR; B_0= without soil amendment; B_1=5 tons ha^{-1}*rice husk biochar*; B_2=10 tons ha^{-1} organonitrofos compost; B_3=10 tons ha^{-1} cow dung manure; value that followed by the same letter not significantly different by LSD test 5%, small letter for horizontal and capital letter for vertical.

Based on the 5% LSD test (Table 3), at the maximum vegetative stage of soybean, the soil respiration with the application 10 tons ha^{-1} cow dung manure is significantly higher than that without soil amendment and 10 tons ha^{-1} organonitrofos compost, however not differently significant with the application of 5 tons ha^{-1} rice husk biochar. Soil respiration varied among soil amendment applications might be caused by different organic carbon content in the soil amendment. Cow dung manure and rice husk biochar had similar carbon content 22.52 % and 22.20 % (Table 2). Higher SOM content and litter input increased soil respiration [8] especially the application of biochar could give beneficial for soil increasing soil quality, adding carbon and also reduce emission of CO_2 to atmosphere [9].

Interaction between phosphate fertilizers and soil amendment significantly affected soil respiration at soybean harvesting stages (Table 4). Soil respiration was higher at the combination treatment organanonitrofos compost and cow dung manure with phosphate rock (P_2B_2 and P_2B_3)

3.2. Soil organic-C, soil pH, soil temperature, and soil moisture content at soybean cultivations caused by soil amendment and phosphate fertilizer application

The soil organic carbon content in the experiment was an increase after the application of phosphate fertilizer. The highest content was in the treatment of 200 kg TSP ha^{-1} significantly different without phosphate fertilizer and 5 tons ha^{-1} PR at the vegetative maximum phase soybean, however not different effect at harvesting phase (Table 5). Moreover, at the harvesting phase, the application of various soil amendments had a significant effect on soil organic-C than without the soil amendment. It could be caused by the soil amendment to increase organic carbon in the soil [10]. Enrichment of soil organic matter can be by direct in field such as crop residue, crop rotation, cover crops as well as off field compost, manure, and biosolids. So that, organic waste can be incorporated to soil for restore soil and increase soil health. Table 6 shows that the soil amendment application gave different values on organic carbon content and soil pH than that without the soil amendment. Soil pH was higher after application with PR, and significantly different with TSP and without P fertilizers. Moreover, soil temperature was lower at the PR application. Soil temperature which observed at the maximum vegetative phase, shows the minimum soil temperature was found at PR treatment (P_2) and gave significantly different with TSP (P_1) and without phosphate fertilizer treatment (P_0).

Table 5. Effect of phosphate fertilizer on soil organic- C, soil pH and soil temperature at the vegetative maximum stage of soybean

Treatment	Soil organic-C (%)	Soil pH	Soil Temperature (°C)
Without P fertilizer	1.39 a	4.59 a	31.5 b
TSP (Triple Super Phosphate)	1.54 b	4.60 a	31.4 b
PR (Phosphate Rock)	1.37 a	4.74 b	30.9 a
LSD 5%	0.12	0.13	0.26

Note: value which followed by the same letter is not significant different by LSD test 5%

Table 6. Effect of soil amendment on soil organic-C and soil pH at harvesting phase soybean cultivation

Treatment	Soil organic-C (%)	Soil pH
Without soil amendment	1.32 a	4.68 a
Rice husk biochar	1.51 b	4.90 b
Organonitrofos compost	1.60 b	4.74 ab
Cow dung manure	1.57 b	4.91 b
LSD 5%	0.14	0.17

Note: value which followed by the same letter is not significant different by LSD test 5%

3.3. Correlation between soil organic- C, soil pH, soil temperature, and soil moisture content with soil respiration

The results showed that the soil pH, soil temperature, and soil moisture content had positively correlate with soil respiration. Soil temperature, soil moisture, and soil pH had a more substantial effect on soil respiration than soil organic carbon. The soil amendment application increased the soil organic carbon content (Table 4), but the correlation between soil respiration and the soil organic carbon content was not found (Table 7). Applying of rice husk biochar could increase the soil's organic carbon content. However, relationship between soil respiration and the soil organic carbon content was not found [11]. In general, modifying C input to the soil by varying soil amendment practices management impacts were sensitive to climate [12], and moreover, soil respiration strongly correlated with the temperature. This indicating that increasing of soil surface temperature may lead to a increase of soil respiration rate [13] moreover soil respiration had positively correlations with both soil temperature and soil moisture content.

Table 7. Correlation between soil organic-C, soil pH, soil temperature, and soil moisture content with soil respiration.

Soil characteristic	coefficient correlation (r) soil respiration (C-CO_2 mg $hr^{-1}m^{-2}$)	
	max. vegetative	Harvesting
Soil organic- C (%)	0.15^{ns}	0.08^{ns}
Soil pH	0.53^{**}	0.90^{*}
Soil temperature (^oC)	0.70^{*}	0.31^{ns}
Soil moisture content (%)	0.84^{**}	0.06^{ns}

Note: ^{ns}= not significant correlation; *= significant correlation at 5% level; **= highly significant correlation at 1% level

Soil temperature and soil moisture content are commonly considered to be the key environmental factors that responsible for variation in soil respiration [14]. Fluctuations of soil temperature and/or soil moisture content can well explain the temporal variation of soil respiration. The process of soil respiration is affected by various abiotic and biotic factors. A combination of soil temperature and soil water content can usually improve the estimation of soil respiration. The sensitivity of soil respiration to temperature frequently increases as soil moisture content increases [15] and high soil temperature suppressed soil respiration which was mainly because of drought stress.

4. Conclusion

The soil respiration varied greatly during the whole soybean cultivation and varied under different treatments. Soil respiration was higher at the maximum vegetative stage of soybean growth than that of the soybean harvesting phase. The minimum soil respiration appeared at the harvesting stage of soybean under the without phosphate fertilizer and soil amendment application (P_0B_0). Moreover, the maximum rate of soil respiration was recorded under phosphate rock combine with cow dung manure treatment (P_2B_3) at the maximum vegetative stage. The higher in soil pH, soil water content, and soil temperature, will promote the higher the soil respiration rate. Increasing soil pH will increase the activity of soil microorganisms, so that more CO_2 will be released into the atmosphere. Similarly, with rising temperatures, more CO_2 will be produced. Therefore, it is necessary to make efforts to have less CO_2 released into the atmosphere compared to the CO_2 sequestration.

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