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by Yuni R

Submission date: 16-Apr-2020 09:21AM (UTC+0700)

Submission ID: 1298797852

File name: 3_Yuliani_2018_IOP_Conf._Ser.__Mater._Sci._Eng._288_012158.pdf (433.72K)

Word count: 3781

Character count: 17939

PAPER ² **OPEN ACCESS**

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To cite this article: Yuliani and Y S Rahayu ⁵ 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **288** 012158

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The Role of Teak Leaves (*Tectona grandis*), Rhizobium, and Vesicular-Arbuscular Mycorrhizae on Improving Soil Structure and Soil Nutrition

Yuliani* and Y S Rahayu

Department of Biology, Faculty of Mathematics and Natural Sciences,
Universitas Negeri Surabaya, Indonesia

*yuliani@unesa.ac.id

Abstract. Calcium is the largest mineral in calcareous soils. High levels of calcium carbonate lead to phosphate deposition. Nutrient deficiencies in calcareous soil (mainly Phosphate and Nitrogen) resulted only certain crops with a wide range of tolerances that can grow. Meanwhile, dynamics nutrient in calcareous soils also depend on the topography and decomposition of the litter in the growing vegetation. The purpose of this study was to describe the pattern of nutrient enhancement and soil-texture structures on calcareous soils after littering the teak leaves, Rhizobium and Vesicular Arbuscular Mycorrhiza. The research parameters were the concentration of N, P, K; C/N ratio, humid acid content, and soil structure, which measured at days 30, 60, and 85 of soil decomposition process. The results showed that at days 30, the texture and structure of the soil tend to be stable (porosity 31.2, DMR 1.93, moisture content 0.36, sandy clay) while at days 85 has been very stable (porosity 49.8; Water content 0.28, sandy clay). While C and N organic, N and K concentration at days 30 showed low value (C organic 1.03, N 0.12, K 0.49, C / N ratio 9). This condition is almost unchanged at days 85. While the P value shows very high value (60.53) at days 30 although after 60 days the P content showed a decrease.

1. Introduction

The soil nutrient content on calcareous soils and pH above 7 (base) is low that caused these soils cannot be used optimally as a planting media. It should be processed with special treatment to be able to use it for plants cultivation. The utilization of calcareous soil as agricultural land has some difficulties and obstacles on growing media conditions. Moreover, the content of the soil nutrient could affect the plants' metabolism, growth, and development. Efforts of improving texture-structure, soil nutrient content, can be done by adding organic matter. Considering the presence of organic matter in the soil has functioned not only as a source of nutrients but also as the physical and biological characteristic of soil [1].

Calcareous soils have a very low phosphorus content and soil moisture level, so phosphorus mobility and root growth would be inhibited [2]. In calcareous soils, phosphorus is available in the form of H_2PO_4 - which could be absorbed by plant slowly [3]. Frequently, it reacts with Ca^{2+} ions and its carbonate salts, resulting from phosphate sedimentation. Since phosphorus exists in an unavailable form, the plant metabolism such as cell division, and root development becomes inhibited. In addition, high level of calcium content affects the deficiency of Fe, Mn, Cu, Zn and disrupts the Boron absorption [4]. Generally, organic phosphorus in plants and soil micro-organisms are present in the form of nucleic acids, nucleotides, phospholipids and sometimes present in inositol phosphate form.



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Inositol phosphate in the soil contains 25% of total organic phosphate. A small part of organic phosphorus occurs as nucleic acids (RNA, DNA) and phospholipids [5].

The addition of teak leaf (*Tectona grandis*) which grow on calcareous soils can increase the soil nutrient content and reduce Ca^{2+} levels by 13.21% [6]. Teak leaf (*Tectona grandis*) is a type of low-quality organic matter in P provider but has high C/N ratio. *Tectona grandis* biomass gave the highest organic soil C within 10 weeks after planting. Organic materials have a function maintaining soil stability and as water storage [1]. In addition, teak leaf provides not only nutrient supply to the plants but also provide an allelochemical compound that inhibits growth in the plants, therefore it is required organisms that are able to overcome the obstacles of allelopathy.

Vesicular Arbuscular Mycorrhiza (MVA) is known as a solution that able to cope with the environmental disadvantage conditions (stress), including the ability to increase nutrient absorption, both macro and micro, to the plant [7,8]. MVA is able to increase the absorption of N and P nutrients on soil marginal, water absorption and other nutrient elements, especially immobile nutrient [9,10,11]. The provision of MVA, phosphatase activity increases by catalysing the hydrolysis of phosphorus complexes that is insoluble in the soil so can increase the P to be available in root areas [12,13,14]. [6] stated that *T. grandis* litter could increase to the highest number of MVA spores by 430%.

Another organism that are capable on increasing the availability of soil nutrient is Rhizobium. Rhizobium bacteria can form a symbiosis with legumes plant to form root nodules and bind free N_2 from the air. Rhizobium infections may also provide opportunities for colonization of Arbuscular Mycorrhiza in the legumes plant root system. The formation of root nodule and fixation N_2 from the air affects the absorption of phosphorus.

This study aims to describe the pattern of nutrient enhancement and soil structure-texture on calcareous soils after littering the teak leaves, rhizobium and Vesicular Arbuscular Mycorrhiza. This research used soybean as a cultivation plant that improves the process of soil texture structure and soil nutrient content. The result of the dynamics studies of calcareous soil can be used by farmers in calcareous soils areas to diversify food crops. Therefore, the farmer can plant legume that has higher economic value in calcareous soils by minimizing various physiological inhibitors.

2. Methods

This study is an experimental, with Randomized Block Design, including two factors, those are the type of organisms and the factor of soil with three repetitions. The type of organism consists of 4 levels: rhizobium, mycorrhizal, rhizobium and mycorrhizal combination, and without organism. Meanwhile the soil type consists of two levels: calcareous soils without teak leaves litter and calcareous soils with teak leaves litter. The frequency of repetition is 3 times so there are 24 treatment combinations. The stages include the mycorrhizal and rhizobium breeding, the making of soybean seedlings as experimental plants, the experimental treatment and the measurement of the research parameter which include the increase of soil nutrient of N, P, K, C/N ratio, structure-texture soil. Nutrient content of N, P, K is the amount of N, P and K (in total) content on planting medium and measured at days 30, 60 and 85 after planting. Data on the soil chemical and physical character will be analysed by using descriptive-qualitative method.

3. Results and discussion

The data results showed that the chemical and physical soil character at days 30, 60 and 85 as in table 1, 2 and 3.

Table 1. Physical and chemical soil data at days 30

Analyze type	Treatment								
	Initial soil	KO	KR	KM	KRM	KSO	KSR	KSM	KSRM
Porosity (% vol)	16,9 medium	42,6 medium	36 medium	38,3 medium	39,4 medium	39,1 medium	41,5 medium	31,2 medium	43,3 medium
DMR (mm)	2,21 Stable	1,92 stable	1,31 very stable	1,53 stable	1,77 stable	2,06 stable	1,22 stable	1,93 stable	1,68 stable
Water content (pF (cm ³ .cm ⁻³))	0,33	0,26	0,29	0,28	0,28	0,35	0,29	0,36	0,33
C Organic (%)	0,90 very low	0,73	0,73	0,73	0,91	1,20 low	1,15 low	1,03 low	1,21 low
N Total (%)	0,12 low	0,11	0,10	0,10	0,11	0,09 very low	0,14	0,12	0,15
C/N Ratio	8 low	7	7	7	8	14 medium	9 low	9	8
P Olsen (mg kg ⁻¹)	71,33 very high	51,34 very high	51,17	58,94	54,42	60,33 very high	51,32	60,53 very high	49,49
K (NH ₄ OAC1N pH:7)	0,20 very low	0,40	0,31	0,41	0,23	0,65	0,49	0,49	0,34
Organic matter (%)	1,57	1,26	1,26	1,25	1,57	2,08	1,99	1,78	2,09
Proportion soil fraction									
sand	55	58	62	68	64	63	67	67	63
Dust	30	27	27	16	16	21	21	21	30
Clay	15	15	11	16	20	16	12	12	7
Class	Sandy clay	Sandy clay	Sandy clay	Sandy clay	Sandy clay	Sandy clay	Sandy clay	Sandy clay	Sandy clay

Description: K= calcium; O = without microorganism; S=litter leaves; M=Mycorrhiza; R= Rhizobium physical soil data = Porosity, DMR (land structure), water content, texture; chemical soil data = C Organic, organic matter, N Total, C/N Ratio, P Olsen, and K.

Table 2. Physical and chemical soil data at days 60

Analyze type	Treatment							
	KO 2	KR 2	KM 2	KRM 2	KSO 2	KSR 2	KSM 2	KSRM2
Porosity (% vol)	64,4 high	41,9 medium	40,3	47	53,2 medium	45,7	41	52,1
DMR(mm)	0,62 rather stable	0,43 less stable	0,81 very stable	0,63 rather stable	0,59 rather stable	0,72 stable	0,79 stable	0,87 very stable
Water content (pF 6 m3.cm-3)	0,21	0,24	0,25	0,25	0,25	0,26	0,30	0,24
C Organic (%)	0,66 very low	0,73	0,60	0,96 very low	1,06 low	1,20 low	1,07	1,03
N Total (%)	0,10 low	0,11	0,10	0,11	0,09 very low	0,12	0,10	0,13
C/N Ratio	7	7	6 low	9	11 medium	10 low	10	8
P Olsen (mg kg-1)	40,14	43,82 medium	41,77	41,65	38,60 medium	32,54 medium	40,25	34,16
K (NH4OAC1N pH:7)	0,31 very low	0,48	0,29	0,28	0,44	0,35	0,17	0,26
Organic matter	1,15	1,27	1,05	1,66	1,83	2,07	1,85	1,79
Proportion soil fraction								
Sand	64	67	62	62	63	63	56	66
Dust	23	26	23	23	25	22	32	25
Clay	13	7	15	15	12	15	12	9
Class	Sandy clay	Sandy clay	Sandy clay	Sandy clay	Sandy clay	Sandy clay	Sandy clay	Sandy clay

Table 3. Physical and chemical soil data at days 85

Analyze type	Treatment							
	KO 3	KR 3	KM 3	KRM 3	KSO3	KSR 3	KSM 3	KSRM3
Porosity (% vol)	49,9 medium	43,7 medium	47,3 medium	47,6 medium	49,9 medium	47,2 medium	49,8 medium	46,1 medium
DMR(mm)	0,96 very stable	0,83 very stable	1,00 very stable	1,10 very stable	0,94 very stable	1,58 very stable	1,44 very stable	1,65 very stable
Water content	0,25	0,26	0,27	0,25	0,27	0,32	0,28	0,32
C Organic (%)	0,88 very low	0,74 very low	0,69 very low	0,75 very low	1,00 low	1,06 low	1,17 low	1,25 low
N Total (%)	0,12 low	0,10 low	0,09 low	0,10 low	0,12 low	0,13 low	0,13 low	0,14 low
C/N Ratio	8 low	7 low	7 low	8 low	8 low	8 low	9 low	9 low
P Olsen (mg kg-1)	55,67 high	48,73 high	52,18 high	42,68 medium	36,29 medium	50,58 high	43,84 medium	47,45 high
K (NH4OAC1N pH:7)	0,30 very low	0,23	0,25	0,17	0,05	0,06	0,06	0,05
Organic matter	1,52	1,29	1,19	1,30	1,73	1,83	2,03	2,16
Proportion soil fraction								
Sand	55	61	61	50	61	51	61	64
Dust	30	27	28	33	27	41	25	24
Clay	15	12	11	17	12	8	14	12
Class	Sandy clay	Sandy clay	Sandy clay	Sandy clay	Sandy clay	Sandy clay	Sandy clay	Sandy clay

Generally, the results of physical and chemical soil character analysis at days 30 showed better results compared with early calcareous soils. It is because of the vegetation that grows on the soil which used as a media could give a major contribution to the soil stability improvement. As it is known, the presence of vegetation in the top-soil area, caused a better interaction between the soil as planting media, plants, and microorganisms that live in the soil, so the tripartite symbiotic relation between soybean, Rhizobium and mycorrhizal bacteria and other soil bacteria becomes an important consideration to build the dynamics pattern of soil nutrient. Thus, the physical and chemical character of the soil will also be affected. Good porosity will cause the rhizosphere area become better and stable in aeration, root respiration process and life of micro-fauna/micro-flora [15,16].

Those matters support the micro and macro organism to occur in the rhizosphere that leads to the soil stability, as well as the availability of soil nutrients. For example, in the treatment by using mycorrhizal was found that it provides a better availability of P results compared with other treatments. The suggestion of giving mycorrhiza is to contribute the availability of P better than other treatments. This is possible by considering the mycorrhizal function that helps the plants increase the availability of P compounds in the soil [17]. Meanwhile, the treatment with Rhizobium and Mikoriza gave the best N total on soil compared with other treatments. This is accordance with the role of Rhizobium in fixating free N in the air causing the total of N content in soil to be better and continuous, thus, it provides N availability continuously and stable. Therefore, although it has been used by plants as proven by well-growing plant, N contents in the soil are also high, considering the activation of Rhizobium bacteria which is assisted by a continuous supply of mycorrhizae in providing P that much needed for the fixation process of N Rhizobium bacteria that present in the soybean plant root nodule.

However, based on the soil nutrient content such as organic C, N total and K are classified as very low and low respectively. This is because the soil nutrients have been used for plant growth, considering the plants that grow on the plant media for all treatment relatively good at 30 days. Meanwhile, for P showed high availability on the soil. This is related to the role of the mycorrhiza that show its high effectiveness when the soil has deficiency P element, so that the mycorrhiza will work effectively by helping the availability of P become available in the amount that relatively high [11,18].

The dynamics pattern of soil nutrient at days 60 shows that the physical and chemical character is relatively better than the initial phase before planting and the pattern of soil nutrient at days 30. If the soil physical characteristic reviewed in terms of porosity, it shows that the condition from medium to high. While soil structure has shown stable conditions with medium water content and sandy-clay soil.

The dynamic pattern of calcareous soils at days 85 shows that its physical characteristic porosity is similar to the dynamic pattern at days 60 for the porosity and water content in medium position with the composition of sandy-clay soil. Meanwhile, the soil texture is in very stable condition. This shows that the longer period of the treatment is the more stable structure and texture of soil, by considering the formation of soil aggregate between calcareous soils, litter leaves and soil microorganisms (in this case mycorrhiza and rhizobium). So, that the composition ratio between aeration component and the ability of keeping groundwater, gives a better life for microflora and macrofloral of soil. Furthermore, this will affect to the chemical characteristic of soil which show that the organic C is already in the low and very low position as well as organic matter as a whole. This can be understood by the teak leaves litter given in decomposed form went through a continuous decomposition during 85 days, so it causes the value of C/N ratio about 7-9. Meanwhile, P content showed a medium level and very high despite the low degree of total N and K. This condition indicates a consistent condition with the dynamics position of soil nutrient at days 60. N and K elements are the elements needed by the plant in relatively high quantities and consumed by plants in relatively high amounts, so that the removal of N or K in the soil will occur very quickly. As known that the element N in the generative period is needed when the process of flowering, fruits, and seeds. In general, it can be said that the dynamic pattern of soil nutrients is still consistent at days 30, 60, and 85 through the stability of physical and chemical soil character that showed the presence of vegetation on the soil. It also contributes

positively on improving the physical and chemical character of calcareous soils with a very high content of Ca^{2+} levels.

4. Conclusion

The dynamics pattern of soil nutrient and physical soil on calcareous soils media shows that the physical and chemical characters of the soils are relatively better than the initial phase before planting. In the vegetative period (30 days) the physical character of the soil (texture and structure) tend to be stable, while in the generative phase (60 days and 85 days) the soil physical character is very stable. From the study of the dynamics of soil nutrient showed that in the vegetative period, the content of organic C, N, and K showed low values, it didn't show any change until 85 days even though the range numbers fluctuated, meanwhile for P value showed changes that is very high at days 30, medium at days 60 and high at days 85.

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