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Physical and chemical properties of oil palm land which overgrown with weeds at different plant age

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Abstract. Large plantations such as oil palm plantations are usually covered by several weed species which occasionally function as a land cover. Soil samples were obtained through Simple Random Sampling on various types of ground cover weeds, e.g *Asystasia intrusa*, *Eleusine indica*, *Cyperus kyllingia* Endl. and *Cyrtococcum oxyphyllum* Stapf., in 7-year old oil palm stands, and *Asystasia intrusa*, *Cyperus kyllingia* Endl., *Cyrtococcum oxyphyllum* Stapf. and *Cyperus rotundus*, in 6-year old stands. Each sample was randomly obtained from each replicate plot at a depth of 0-20 cm (layer 1) and 20-50 cm (layer 2) at 5 points. Variables of soil chemical properties observed were N-total, P-available, K-total, C-organic and soil pH, while the physical properties observed were water content (%) and volume weight, using the gravimetric method. The results showed that the presence of weeds beneath the oil palm stands in plantation areas did not continuously have a negative effect on the growing environment. In this study, the presence of 4 (four) weed species under 6 and 7 years old were found around old oil palm stands and classified as dominant existences actually have a positive tendency to influence the quality of physical and chemical properties of soil under oil palm stands.

1. Introduction

Oil palm (*Elaeis guineensis* Jacq) is an annual plant of the *palmae* family endemic in the tropics and is able to develop healthily at optimum temperatures ranging from 29-30°C. The optimum rainfall required for its growth is between 2000-2500 mm per year with an even distribution of rain all year round without an arid month. The ideal land conditions for oil palm are those that have fertile loose soil, a pH between 5.0-5.5, an effective depth without solid layers, and slope between 0-15% [1]. The soil height required for its growth is between 0-400 m above sea level [2, 3].

The area of oil palm plantations in 2010 totaled 9 million hectares [4], and subsequently increased to 12.3 million hectares, consisting of 42% community plantations, 7% state-owned plantations and 51% private plantations. In Aceh Province, total cultivation area is 458,619 ha, with a proportion of 50.89% community and 39.87% private plantations [5]. Of the total national oil palm plantation area, about 2.7 million ha is immature oil palm, while 118,173 ha found in Aceh.

Large plantations such as oil palm are usually overgrown with several weed species that function as ground cover. Often, weeds found in these plantations are *Psophocurphus palustris*, *Pueraria javanica*, *Colopogonium mucunoides* [6], *Asystasia gangetica* [7], *Asystasia intrusa*, *Eleusine indica*



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and *Cynodon dactylon* [8]. They are often used as Land Cover Crops (LCC), in addition to other ground cover species. Land cover crops on plantations protect the soil from erosion, reduce evaporation of water from the soil surface, help store water within the soil, and increase nutrients through weathering of organic matter [9]. The improvement of soil ecosystems will affect the physical, chemical, biological and microbiological properties within it. [10] Shows that *Wedelia* plants contribute higher amounts of available N to the soil than *Chromolaena* and *Melastoma*. Furthermore, [11] shows that *Chromolaena* increases soil C levels. Whereas in rubber plantations, the weed *Panicum muticum* and *Calopogonium mucunoides* have a better potential in the improvement of chemical properties than *Pueraria javanica* and *Wedelia trilobata* [12]. Such plants emerge as the dominant agricultural weeds. The best growth conditions are at an average temperature of 25°C. Tubers or rhizomes germinate at temperatures ranging 10-40°C. Soil pH for growing grass weeds is between 4.0 - 7.5 [13]. The purpose of this study is to show the effect of weeds on the physical and chemical properties of soils in oil palm stands.

2. Research Methods

2.1. Soil Sampling

This research was conducted in the community plantations at the Almuslim University in the South Peusangan Sub-district and Peusangan Siblih Krueng Sub-district, Bireuen District, Aceh. The area of the study site is 250 ha, while its height ranges between 100-200 m above sea level. There are two groups of oil palm plantations which were classified based on the year of planting, which included the crops planted in 2012 (7-year) and 2013 (6-years), respectively. Soil samples were obtained using Simple Random Sampling on various species of ground cover weeds, such as *Asystasia intrusa*, *Eleusine indica*, *Cyperus kyllingia* Endl. and *Cyrtococcum oxyphyllum* Stapf. in 7-year old stands, and *Asystasia intrusa*, *Cyperus kyllingia* Endl., *Cyrtococcum oxyphyllum* Stapf and *Cyperus rotundus* in 6-year old oil palm stands. The choice of weeds is based on the dominant weed in both plantation groups. The soil sampling plot is around 5x15 m, and each was subdivided into 3 small plots with a 5x3 m replication size, bringing the number of replicate plots to 24. Soil samples were obtained from each plot at a depth of 0-20 cm (layer 1) and 20-50 cm (layer 2) at 5 points randomly. Next, they were dried, composited, and filtered with a 0.5mm sieve. Analysis of samples was conducted at the Laboratory of Agriculture, Almuslim University in accordance with the observed variables.

2.2. Variables and Data Analysis

The soil chemical variables observed in this study include the N-total analyzed by the Micro Kjeldahl method, P-available analyzed by the Bray-Kurtz method, K-total by Gravimetry and Titration, C-organic using the Kurmies method and pH, analyzed via the electrometric method at a ratio of soil and water 1: 1. Meanwhile, the physical features observed were water content (%) measured using the gravimetric method of weighing each soil sample before and after drying (in the oven) at 105°C for 24 hours. Furthermore, the volume weight was obtained by gravimetric method. Rainfall was absent during the collection of samples.

3. Results and Discussion

3.1. General situation of research location

The research location was the community oil palm plantation in Almuslim University, South Peusangan Sub-district with Ultisol soil type. This soil has a pH range of 5.13-5.8, and a type B (wet) climate classified according to the Schmidt and Ferguson categories, with an average monthly rainfall of 209 mm. The age of cultivated oil palm plants varied between 2-7 years, but the soil sampling location ranged between 6 and 7 years.

3.2. Soil characteristics on oil palm stands

In general, the chemical and physical properties of soils at a depth of 0-50 cm in 7-year old oil palm plantations containing various weed species beneath their stands, are more favorable than those of 6-

year old plantations (Table 1-4). *Asystasia intrusa* contributes more C-organic, N-total, and P-available than other weed species. In addition, the physical characteristics show slightly better conditions, especially the soil volume weight and water content.

Table 1. Soil properties in the 0-20 cm layer of a 7-year-old oil palm plantations land which overgrown with several species of weeds (2012 planting year)

Weed Species	C-organic (%)	N-Total (%)	P-available (ppm)	K-exchanged (me / 100 gr)	pH	BV (gr/cm ³)	Soil Water Content (%)
<i>Cyperus kyllingia</i> Endl	1.54	0.22	1.20	0.28	5.41	1.34	16.11
<i>Eleusine indica</i>	2.70	0.29	1.89	0.36	5.20	1.33	17.30
<i>Cyrtococcum oxyphyllum</i> Stapf	2.40	0.31	1.78	0.42	5.18	1.33	17.91
<i>Asystasia intrusa</i>	3.29	0.43	2.47	0.32	5.52	1.32	20.80

Table 1 shows that in the 0-20 cm layer soil, the N-total in *Asystasia intrusa* was nearly twice (95%) greater than that of *Cyperus kyllingia* Endl, whereas in *Asystasia intrusa*, it was only 48%; 38% greater than in *Eleusine indica* and *Cyrtococcum oxyphyllum* Stapf. On the other treatment, an increase in N-total of the soil was consistent for both treatments. This phenomenon is in line with the results obtained by [14], that the presence of *Asystasia* land cover crops increases 43.7% N, 112.5% P₂O₅, and 162.6% K₂O. An increase in N-total is associated with increased amounts of organic matter (C-organic) which then experiences weathering. According to [15], the soil is categorized as fertile when C-organic content is above 3%. The main source of organic matter is litter / humus derived from leaf drops of *Asystasia intrusa*, which produces the highest value of C-organic content. Other study have equally affirmed that forage plants *Arachis glabrata* and *Stenotaphrum secundatum* in oil palm stands produced which increases soil P levels [16].

Table 2. Soil properties in the 20-50 cm layer of a 7-year-old oil palm plantations land which overgrown with several species of weeds (2012 planting year)

Weed Species	C-organic (%)	N-total (%)	P-available (ppm)	K-exchanged (me / 100 gr)	pH	BV (gr/cm ³)	Soil Water Content (%)
<i>Cyperus kyllingia</i> Endl	1.65	0.15	3.93	1.10	5.61	1.33	13.41
<i>Eleusine indica</i>	1.47	0.14	2.39	0.93	5.50	1.32	14.60
<i>Cyrtococcum oxyphyllum</i> Stapf	1.30	0.17	1.95	0.91	5.30	1.33	13.20
<i>Asystasia intrusa</i>	2.72	0.24	4.07	1.16	5.80	1.31	18.32

The N-total in the 20-50 cm layer of soil has a lower value than the 0-20 cm layer (Table 2). The decrease of C-organic and nitrogen is due to leaching. This is supported by [17], which states that obstruction of the infiltration process results in surface runoff during rainfall; the resulting flow transports the soil, eroding it. This occurs because this species is a weed in the narrow leaf grass group. However, the levels of P-available and K-exchanged are higher in the 20-50 cm layer than the upper layers. Another possibility is that the C-organic content of the top soil is higher than the sub-soil which is related to the mineralization and nutrient absorption process occurring in the lower layer closer to the plant roots.

Based on the criteria for soil chemical fertility classification in a 7-year old oil palm stand, it is deduced that: a) the *Cyperus kylingia* Endl weed cover falls into the low category for C-organic, P and K, and moderate category for N-total with acidic pH; b) *Eleusine indica* and *Cyrtococcum oxyphyllum* Stapf. belong to the moderate category for C-organic and N-total, and low category for P and K with a slightly acidic pH; c) soil fertility in stands with *Asystasia intrusa* fall into the high category for C-organic, moderate category for N, and low category for P and K, with slightly acidic pH. In the 6-year old oil palm stand, the distribution value of soil properties is also almost equal to the 7-year old stand, although the values are significantly lower in the 6 year old stand (Table 3-4).

Table 3. Soil properties in the 0-20 cm layer of a 6-year-old oil palm plantations land which overgrown with several species of weeds (2013 planting year).

Weed Species	C-organic (%)	N-total (%)	P-available (ppm)	K-exchanged (me/100 gr)	pH	BV (gr/cm ³)	Soil Water Content (%)
<i>Cyperus kylingia</i> Endl	1.32	0.24	1.67	0.56	5.30	1.35	15.41
<i>Cyperus rotundus</i>	1.41	0.27	1.79	0.54	5.40	1.32	16.61
<i>Cyrtococcum oxyphyllum</i> Stapf	1.60	0.33	2.33	0.67	5.70	1.35	15.70
<i>Asystasia intrusa</i>	2.83	0.56	2.49	0.78	5.80	1.32	19.30

Table 3 shows that *Asystasia intrusa* at 6-year old stand influenced the levels of chemical elements and physical properties in the soil more than other weed covers. As in the 7-year old stand, the 0-20 cm layer in this group also contributes to sufficient C-organic, and N-total among the four weed species is in the medium category. Of these four species, *Asystasia intrusa* contributed the highest C-organic and N-total compared to the other three species.

The decrease in N-total in the sub-soil layer (20-50 cm) indicates denitrification of the N elements in the top layer. Leaching of N can be in the form of N-inorganic which is the result of decomposition of organic matter in the first layer and N-organic leaching of organic matter from the top layer. In addition to N, the presence of weeds among 6-year old oil palm plants also contribute to P-available of soil as shown in Tables 3 and 4. The presence of weeds does not affect the level of P-available, although there is a downward trend. From tables 3 and 4, it is safely deduced that *Asystasia intrusa* produces the highest levels of P-available, which means that its weathering contributes P into the soil better than other ground cover weeds.

In the 20-50 cm layer, land cover fails to provide a significant increase in P-available. It shows that P is not leached from layers 1 to 2. This is related to the reaction of P with chemical compounds in the above layer. The P element reacts with Al, Fe, and Ca compounds to form Al-P, Fe-P, and Ca-P complex compounds, thus P is not available to plants as reported by [18].

The K-total of soil in the 0-20 cm and 20-50 layers slightly fluctuated and increased in *Asystasia intrusa*, *Cyrtococcum oxyphyllum* Stapf and *Cyperus rotundus*, but decreased in *Cyperus kylingia* Endl (Tables 3 and 4). The K-total in the 6-year old oil palm with *Asystasia intrusa* was 50.9% higher than *Cyperus Kylingia* Endl. It therefore shows that the weathering of *Asystasia intrusa* contributes K into the soil better than other weeds.

Table 4. Soil properties in the 20-50 cm layer of a 6-year-old oil palm plantations land which overgrown with several species of weeds (2013 planting year).

Weed Species	C-organic (%)	N-total (%)	P-available (ppm)	K-exchanged (me/100 gr)	pH	BV (gr/cm ³)	Soil Water Content (%)
<i>Cyperus kylingia</i> Endl	1.10	0.14	1.55	0.53	5.31	1.22	15.70
<i>Cyperus rotundus</i>	1.24	0.18	1.69	0.57	5.41	1.21	14.30
<i>Cyrtococcum oxyphyllum</i> Stapf	1.40	0.21	1.93	0.7	5.72	1.25	14.20
<i>Asystasia intrusa</i>	1.69	0.36	2.12	0.8	5.81	1.20	17.81

In the 20-50 cm layer (Table 4), it is obvious that with increase in K-total, the soil does not experience leaching from layers 1 to 2. Tables 1 - 4 also shows that the presence of weeds is unable to significantly increase C-organic content both in 0-20 cm and 20-50 cm layers. Therefore, weathering of organic matter and release of organic acids and nutrients into the soil also emits CO₂ into the air, thus C-organics experience less leaching.

The results of the study in general showed that the various weed species did not have a significant effect on soil pH (Tables 1 and 2). Previous studies conducted by [10] also stated that pioneer plants had no effect on pH. Also, it was observed that each species of land cover crops gave a relatively different effect on soil nutrients. *Asyatasia intrusa* weeds increased C-organic and N-total of soil more than other weeds. Weeds from the *Asyatasia* genus are used as land cover crops [19], which contain several nutrients including N, P, K, Ca, Mg, Fe and Zn in their plant tissues [20]. With this knowledge, *Asyatasia* weeds are to be easily applied as green manure or cover crops during cultivation of plantations. In terms of improving soil physical properties, the application of *Asyatasia* in laboratory scale is reported to increase the stability and percentage of soil aggregates formed [21]. Therefore, Tables 1-4 show that these weeds have a better potential in the improvement of the chemical properties of soil.

The physical properties however, on tables 1-4 show the ability of certain weeds to indirectly affect the physical condition of the soil that supports plant growth. Volume weight <1.2 for mineral soil is suitable for root development, especially where the formation of a soil pore is balanced, thus affecting the water content. It means that, with this volume weight value, there has been a compaction process on both top soil and sub-soil. This compaction occurs due to human activities on it, or is influenced by pore closure due to runoff erosion, especially during rainfall. Hence, it is consistent with [22] theory which states that BV > 1.2 g / cm³ exceeds the critical value for healthy agricultural soils, especially those containing clay. This high volume weight correlates with the water content which is below the optimal field capacity (25%), which is about 14.2 - 20.8% in top soil. However, in this condition, moisture is maintained in sufficient levels during the dry season. The results of this study when directly compared with the application of land cover crops from *Mucuna bracteata* in oil palm

plantations, obtained the same pattern, which is an improvement in soil physical properties such as water content and volume weight [23], although not as good as its influence [24]. Therefore, the weakness point of this study is the absence of a comparison with land conditions not planted with oil palm.

4. Conclusions

The presence of weeds beneath oil palm stands in plantations does not usually have a negative effect on their growing environments. In this study, the presence of 4 (four) weed species found under 6 and 7-year old oil palm stands classified as dominant, and actually had a positive influence on the quality of the physical and chemical properties of the soil. This research needs to be continued to obtain information related to the balance of nutrients between soil and oil palm plants, water balance, weed control and soil loss, and what is no less important is the dynamics of oil palm production.

Acknowledgments

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