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Weeds diversity in oil palm plantation at Segamat, Johor

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Abstract. This research was conducted to study weeds composition and diversity with regards to management practices at three oil palm plantations in Segamat, Johor. Using nested quadrat sampling approach, a total of 19 families, 35 genera, 43 species and 4465 number of individuals of weeds species were found and recorded from the three plantations. The Shannon diversity index, H' was 3.45 whereas the Evenness index, EH for the overall weeds species was 0.92. The highest weed diversity was observed at Kg. Sri Rahmat oil palm plantation (H'=3.11) located at the lowest elevation with the least herbicide application and pruning practices followed by Kg. Logah (H'=3.07) and Felda Medoi (H'=2.83). The overall species evenness for this study area was 0.92 indicating that the species distribution was relatively high in monoculture system. At Kg. Logah, the species evenness was almost totally even (EH=0.98) followed by Kg. Sri Rahmat (EH=0.97) and Felda Medoi (EH=0.93). Both family Poaceae and Rubiaceae contributed to the highest species richness within the study area. Therefore, the composition and diversity of weeds recorded from this research was relatively high. There were several factors that could potentially affect the weeds diversity such as farming system, age oil palm plantation, pruning treatment (canopy), management through usage of herbicide, type and usage of fertilizer and location of oil palm plantation based on different elevations. This study is essential for sustaining oil palm production through successful weed control using diversity data and management histories as an indicator.

1. Introduction

The oil palm industry in Malaysia plays a significant role in agricultural and economic growth. Over the past several decades, the palm oil industry in Malaysia has grown remarkably. Up to 2010, Malaysia has 4.85 million hectares of oil palm [1], generating at about RM 60 billion export income for the nation in 2010. The main agricultural products in Segamat, Johor are oil palms and rubber trees [2] where a portion of this land is considered suitable for oil palm production due to its very similar soil, consistent accessibility to water, and levelness. Oil palm or *Elaeis* spp. is massive worldwide and studies examining the connection among ecosystem system and biodiversity services is highly significant. Nevertheless, as indicated by Yeow *et al.* [3] in oil palm ranches, weeds can result in 6-20% yield misfortunes.

Oil palm yields in Malaysia are gambled by the closeness of weeds. Weeds are able to decrease land value, reduce crop choice and act as other hosts for pests and infections in the harvest land. Weed advancement can decrease the making of Fresh Fruit Branch (FFB) by 20% in light of competition against enhancements and allelopathic substances that are destructive to plants. Additionally, weed invasions also fill in as host options to energize disease issues and pathogens, decrease the yield estimate of the industry, raise production costs, and increase the likelihood of fires in annual harvests and plantations [4]. *Asystasia gangetica* is frequently found among various noxious weed species in oil palm plantations [5].

During the immature process, weed control is a significant issue in the oil palm plantation. In order to prevent growth inhibition and late yield of the oil palm [6] herbicides are regularly used to control weeds. Changes in weed composition are the result of distinct herbicide determination and efficacy [7, 8]. Herbicides on transient weed dynamic impact is critical, yet it is once in a while assessed. In the environment, persistent herbicides can remain active for extensive stretches of time, possibly causing water and soil defilement as well as unfavourable impacts to non-target organisms. A common practice worldwide is the use of herbicides for crop protection, and 72 percent of the chemicals used in agriculture in Malaysia were recorded as herbicides in 2007 [9]. According to Radosevich *et al* [10] improper management decisions can be prompted by the vulnerability of the composition, density, community dynamics and population change of weed species. Thus, this study will highlight the identification of weeds diversity and weeds management at oil palm specifically at Segamat, Johor with regards to different management approach at three sampled locations. This finding would benefit smallholders in oil palm industry in terms of the impact of different management approaches on different weeds diversity.

2. Methodology

2.1. Study area

This study was conducted at Segamat, Johor (2°30`N, 102°50`E) from the 2nd until 8th of July 2019. Sampling was done at three oil palm plantation which are four acres plantation at Felda Medoi (2°31`47.22``N, 102°53`3.95``E), four acres Kg. Logah (2°31`36.50``N, 102°50`58.76``E) and two acres Kg. Sri Rahmat (2°28`38``N, 102°49`36.78``E) (Figure 1). The information on age, management history (i.e. herbicide, fertilizer application & pruning) is depicted in Table 1.

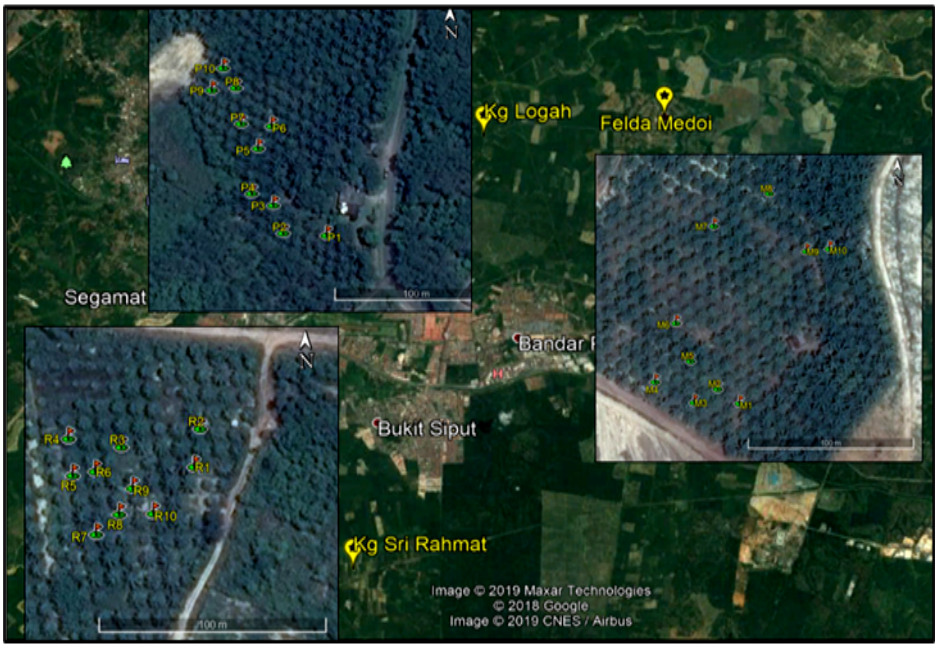

Figure 1. Google location of the three oil palm plantations at Segamat, Johor.

Table 1. Age, Elevation, Management and Treatment of three oil palm plantation.

Oil Palm Plantation	Kg. Sri Rahmat[a]	Kg. Logah	Felda Medoi
Age (years old)	10	19	9
Elevation (ft) above sea level	13.1134	25.8664	38.0728
Management (Herbicide)	2 × in a year	3 × in a year	4 × in a year
Management (Fertilizer)	3 × in a year	3 × in a year	4 × n a year
Type of Fertilizer	2 × Organic	Organic	Organic & Chemical
Treatment (Pruning)	1 × in a year	2 × in a year	3 × in a year

[a]Liming was also conducted once a year.

2.2. Sampling design

A total of 120 nested plots (1 m × 1 m) within 10 m × 10 m plot (i.e., 3 plantation sites × 10 plots × 4 nested plots) was established and random sampling was conducted in this study. According to Whittaker [11] there are several reasons that nested vegetation sampling configuration looks encouraging. In Modified-Whittaker plot the shape and spatial distribution of sub-plots in the main plot has been changed to overcome the problem of autocorrelation. Also, nested sampling approach captures a significantly higher percentage of total species richness than other techniques [12, 13].

2.3. Data Collection

2.3.1. Herbarium specimen collection. Plant specimens were collected by carefully removing the whole plant including roots, stem, leaves, or flower using shovel and secateurs. The plant was chosen based on its maturity such as the textures of the leaves and colours of the weeds, free from damages caused by diseases and insects to avoid misidentification. Each specimen was clearly labelled with field information that includes the ID number, sampled area, habitat, frequency, plant description, plant habitat, collector name, other authorities, collection number and date of collection. Every specimen was photographed against black cardboard for record keeping. General observation was made to provide supporting information and further characterisation on weeds species composition and diversity in the oil palm plantations outside the plotted area as well as the geographical factor. All specimens were then wrapped with newspaper, kept in zip lock bags containing ethanol (70%) and sealed tightly to prevent leaking.

2.3.2. Specimen preservation. Ethanol 70% preserved specimens with height around 15 to 20 cm or those with fruits were handled cautiously alongside the leaves and roots and kept in suitable position on blotting papers verified by another blotching paper to remove dampness. These papers were kept on a smooth surface and pressed by an adequate weigh that was placed on the uppermost blotching paper weigh was expelled temporarily on the following day and specimens were temporarily transferred to a dry blotting paper before placing the weigh again. This is to ensure that specimens hold its shaded and does not end up fragile or singed by removing the moisture quickly, while utilizing a moderate heat. Specimens were oven dried between 3-7 days at Universiti Malaysia Kelantan (UMK) laboratory.

2.3.3. Specimen identification. Dried specimens were collected and preserved for further identification as described by Marquard *et al.* [14]. The dried specimens were mounted on herbarium paper. Specimens were pre-identified according to their family, genus, and species with aid of the supporting information recorded on the pocketbook. The identification is accomplished with the utilization of dichotomous keys illustrations, photographs and distributed plant depictions and comparison with appropriately identified herbarium specimens. Identification of species unknown specimens was done using PictureThis application (Glority Global Group Ltd., China) and Flora of Peninsular Malaysia, Series I: Ferns and Lycophytes botanical book [15]. The pre-identified specimens were then cross

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verified by botanical expert, Dr Radhiah Zakaria from Faculty of Public Health at Muhammadiyah University of Aceh.

2.4. Data analysis

2.4.1. Diversity indices. The diversity index comprises of the Shannon Index [16], Shannon Evenness Index [18, 19] and Similarity Index. Shannon Diversity Index (H') was utilized to calculate the diversity of a species in community as in equation (1). Shannon's equitability (i.e., Evenness Index) was calculated to measure of the relative abundance of distinctive species making up the richness of an area [17] as in equation (2). The degree of similarity between the weeds communities at sampled locations was calculated using Sorensen Similarity Index as in equation (3).

$$H' = -\sum_{i=1}^{n} pi\, ln\, pi \tag{1}$$

Where:
H' = Shannon's Diversity Index
N = Total number of species in the community (richness)
Pi = The importance values of species as a proportion of all species

$$E_H = \frac{H}{H_{\max}} = \frac{H}{\ln S} \tag{2}$$

Where:
E_H = Shannon Evenness Index
H' = Shannon's diversity index from equation (1)
Pi = The importance values of species as a proportion of all species

$$\text{Sorensen's coefficient (Cs)} = \frac{2a}{2a + b + c} \tag{3}$$

Where:
a= the Total Number of Species Present in Location 1 and 2
b= the Number of Species Present in Location 1
c= the Number of Species Present in Location 2

2.4.2. Margalef Index or Richness Index. The species richness was estimated using Margelef Diversity Index [20] as in equation (4).

$$Margalef\text{'s } Index = \frac{S-1}{\ln N} \tag{4}$$

Where:
S = The number of species
N =Total number of individuals in the sample

2.4.3. Abundance Parameter. The vegetation data were analysed for % density (D) and frequency (F) [21] as in equation (5)(6)

$$Density = \frac{ni}{A} \tag{5}$$

Where:
ni = Number of individuals of a species in sampling unit
A = Total number of sampling units studied

$$Frequency = \frac{ji}{k} \times 100 \quad (6)$$

Where:
ji = Number of quadrats in which species occur
k = Total number of quadrats studied

2.4.4. Importance Value Index (IVi). The degree of dominance for a particular species in an area as in equation (7) was calculated from the values of relative frequency and relative density [22] as in equation (8) and (9), respectively.

$$\text{Important Value Index (IVi)= Relative Frequency + Relative Density/2} \quad (7)$$

$$\text{Relative Frequency} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100 \quad (8)$$

$$\text{Relative Density”} = \frac{\text{Density of species}}{\text{Total density of all species}} \times 100 \quad (9)$$

3. Result and Discussion

3.1. Species composition

A mixture of broadleaves, grasses and sedges frequently conforms to the stage of crop growth, which provides different climatic and environmental conditions suitable for particular weed growth. The shade provided by the canopy of the palm affects the composition of weeds, and grass species appear to dominate as oil palms grow larger [23]. Overall a total of 4465 weeds representing 43 species and 35 genera from 19 families had been recorded in this study (Appendix). The number of species found in this study was significantly lower than a study by Sikin [24] in Gedong, Kota Samarahan, Sarawak that reported a total of 48 species found belonging to 39 genera and 27 families within 50 quadrats of 1m x 1m that were established in each study area.

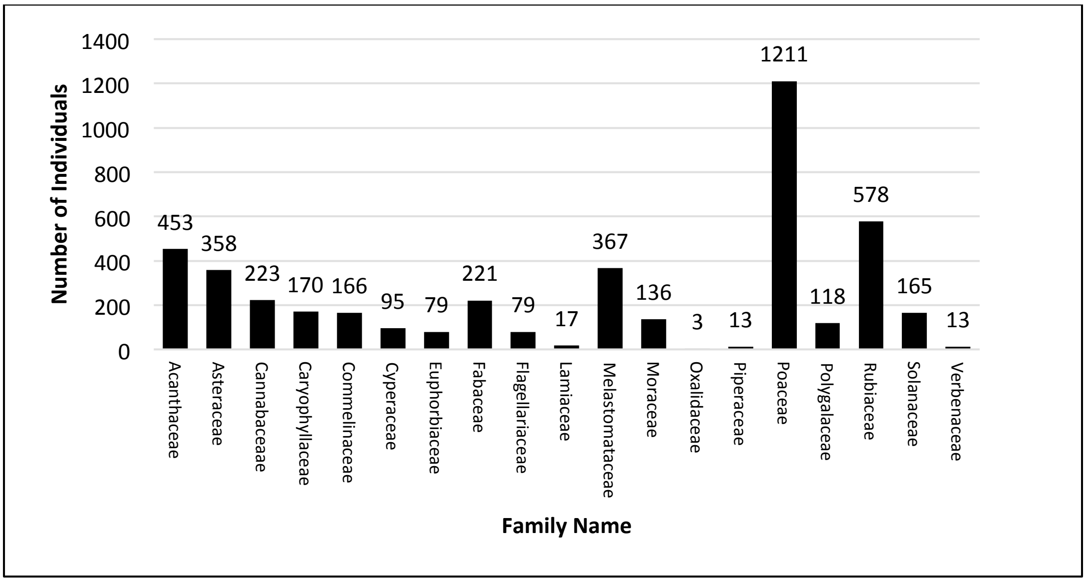

Figure 2. Total number of individuals for each family.

Based on the Figure 2, the largest families found in this study was Poaceae (27.12%) with 8 genera and 9 species followed by family Rubiaceae (12.95%) with 4 genera and 9 species and the third largest family that were recorded was Acanthaceae (10.15%) with 1 genera and 2 species recorded. Family Oxalidaceae had the smallest (0.07%) number of genera and species recorded. Other species found outside the plot area (excluded from calculation) from general observation included *Asystasia gangetica, Clidemia hirta, Axonopus compressus* and *Paspalum* spp. and seven weeds family that were commonly recorded outside the plotted area which were Poaceae, Rubiaceae, Acanthaceae, Melastomataceae, Asteraceae, Cannabaceaae and Fabaceae.

3.2. Diversity indices

3.2.1. Shannon Diversity (H') and Shannon Evenness (E_H) Indices. Based on Table 2, the H' value for overall number of species was 3.45 while H'_{max} value was 3.76 for all three oil palm plantations. Kg. Sri Rahmat was highly diverse with weed species (H'=3.11, H_{max}=3.22) followed by Kg. Logah (H'=3.07, H_{max}=3.14) and moderately diverse weed species at Felda Modoi (H'=2.83, H_{max}=3.04). Shannon index values are often found to fall from 1.5 to 3.5 in actual populations [25]. A value close to 4 would imply a uniform distribution of the number of individuals among all species. Therefore, the higher value of H' can reflect the diversity of any species within a group. Furthermore, from the result shown above, it was proven that the study areas were in the range of medium to high diversity since the value of H' gained are slightly approaching the value of H_{max} almost like the findings by Adnan *et al.* [21] on plants diversity in rubber plantations at Segamat, Johor.

Table 2. Shannon's Diversity, Shannon's Equitability (Evenness) Indices and H_{max} of weeds at all three oil palm plantations.

Oil Palm Plantation	Shannon's Diversity Index (H')	H_{max}	Evenness Index (E_H)
Overall	3.45	3.76	0.92
Kg. Sri Rahmat	3.11	3.22	0.97
Kg. Logah	3.07	3.14	0.98
Felda Medoi	2.83	3.04	0.93

The overall Evenness index (E_H) recorded from this study was 0.92 indicating a high degree of evenness in abundance of species but not completely abundant [26, 27] at all three plantations (Table 2). The high E_H value suggested that the species was extremely uniform and similar to total uniformity [25]. This is higher than the E_H reported by Adnan *et al*. [21] at rubber plantations, therefore suggesting an influence by crop type on species evenness. The E_H for Kg. Sri Rahmat and Kg. Logah oil palm plantations were 0.97 and 0.98 respectively, indicating that the species distributions of weeds were of high evenness among the other species. Apart from that, E_H for Felda Medoi oil palm was 0.93 and the lowest among three oil palm plantations.

3.2.2. Sorensen similarity index. The Jaccard and Sorensen beta diversity indices compares of area in terms of weeds population composition [28]. When the indices are above 0.5 (50%), a high correlation between areas can be concluded [29]. From Table 3, the Sorensen similarity index recorded for all three oil palm plantations were significantly low (0.30, 0.27, 0.37) indicating a low total dissimilarity. Dynamic Impact of Three Non-Selective Herbicides in Immature Oil Palm Plantation, the differential viability of applied herbicides applied could cause movements in the organisation of weeds and affect their level of similiraity [7, 8].

Table 3. Sorensen similarity index between oil palm plantations at Segamat, Johor.

Comparison of different oil palm plantation	Sorensen Similarity Index (Cs)
Kg.Sri Rahmat - Felda Medoi	0.30
Felda Medoi - Kg. Logah	0.27
Kg. Logah - Kg. Sri Rahmat	0.37

3.3. Margalef Index or Richness Index

Table 4 shows the Margalef's index with an overall value of 5.00 indicating a high number of species richness. Highest species richness was recorded at Kg. Sri Rahmat plantation (3.18) followed by Kg. Logah plantation (2.97) and Felda Medoi plantation (2.92). In natural plant communities, species richness has usually been found to peak at a low or intermediate level of productivity [30]. Plant species are predicted to be nutrient limited in low-productive and light limited in high-productive environments [31, 32]. Plants produce more biomass in high-productive environments than they do in low-productive habitats, resulting in less unequal distribution of resource supply rates and mild competition.

Table 4. Margalef's Index from total number of species and individuals at oil palm plantations in Segamat, Johor.

Oil Palm Plantation	Total number of species (S)	Total number of individuals in the sample (N)	Margalef's Index
Overall	43	4465	5.00
Kg. Sri Rahmat	25	1896	3.18
Kg. Logah	23	1667	2.97
Felda Medoi	21	942	2.92

3.4. Abundance parameter

3.4.1. Density and frequency. The overall frequency and density as recorded in Table 5 indicated that the highest density was *Asystasia gangetica* (11.50) followed by *Clidemia hirta* (9.80), *Drymariam cordata* (5.67), *Imperata cylindrica* (7.70) and *Trema cannabina* (7.43) with the frequency of 100%. The lowest density of species recorded was *Oxalis barrelieri* (0.10) with the frequency of 10%. The higher frequency showed that in wide range areas the species could adopt well, while the lower frequency means a clumped distribution caused by uneven resources such as mineral nutrients [33].

Table 5. Density and frequency of all recorded species.

No	Species	No of Individual	Density	Occurrence	Frequency (%)
1	*Asystasia gangetica*	345	11.50	30	100.00
2	*Clidemia hirta*	294	9.80	30	100.00
3	*Drymaria cordata*	170	5.67	30	100.00
4	*Imperata cylindrica*	231	7.70	30	100.00
5	*Trema cannabina*	223	7.43	30	100.00
6	*Oxalis barrelieri*	3	0.10	3	10.00

3.4.2. Species importance value index (IV_i). In Figure 3, *Asystasia gangetica* (6.31), *Clidemia hirta* (5.74) and *Imperata cylindrica* (5.03) were found to dominate based on their dominance and relative density, indicated by the importance value index (IVi). *Oxalis barrelieri* (0.28) had a low IVi and was possibly due to the sharing of resource spaces to restrict cooperation among the species, to encourage access to resources and many different species with few individuals were represented in each weed species [34].

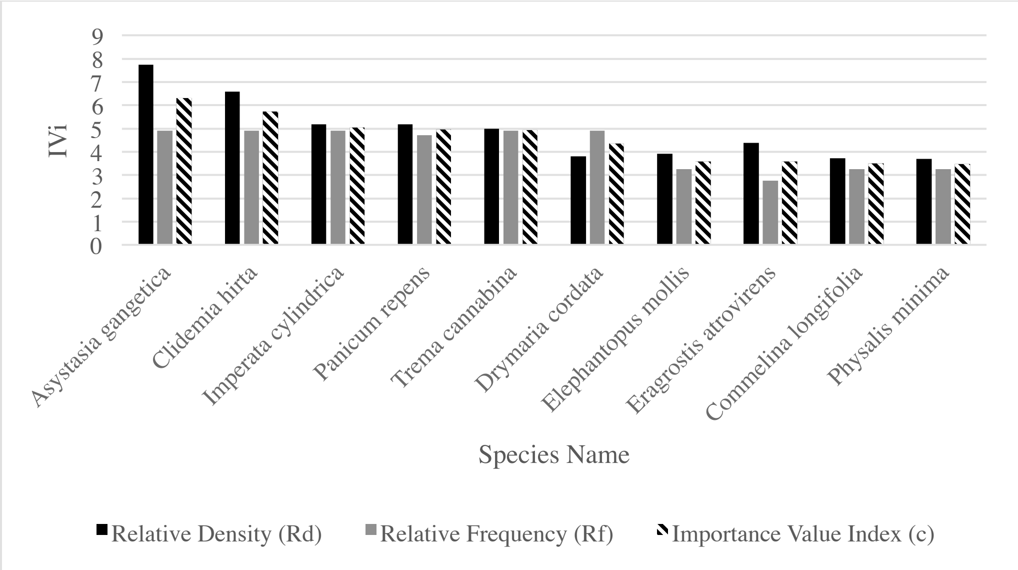

Figure 3. Total number of individuals for each family.

3.5. Management history of plantations and diversity of weeds

One of the keys for a successful weed management strategy is the knowledge of weeds in the field, and the density of each species present [35]. This includes the effect of cover crops on the weed community and diversity [36, 37, 38]. When the trees mature, the canopy prevents sunlight from reaching the weeds. This diminishes prolific growth of the weeds, allowing for insignificant herbicide application. All three locations were identified as matured oil palm plantations with Felda Medoi plantation being the youngest (9 years old) as compared to the other two plantations. Hence, pruning treatment for Felda Medoi oil palm was done three times every year while pruning treatment for Kg. Sri Rahmat oil palm and Kg. Logah oil palm were done once and twice a year respectively. The shade of the palm canopy affects the essence of the composition of the weed, and grass species appear to dominate as the oil palms grow larger [23].

Optimum growing conditions of oil palm (*Elaeis* spp.) are in lowland wet tropics of <1000 m elevation [39]. Elevation may influence the type and amount of sunlight that plants receive, the amount of water that plants can absorb and the nutrients that are available in the soil. The lowest number of species was found at Felda Medoi plantation. Hence, fewer weed can survive at high elevation and less energy is infused into the soil through decaying matter. Weed species and even weed biotypes collected from different environmental conditions can vary in their response to soil moisture [40].

Kg. Sri Rahmat plantation recorded the highest number of weeds species followed by Kg. Logah and Felda Medoi. This was probably due to lower herbicides application (twice a year) as compared to the other two plantations (3 – 4 times a year). For Felda Medoi plantation, weed management through the use of chemical herbicides was done four times a year and at some stages of crop production, it was the most common practice in oil palm plantations. However, weed populations have never been constant, especially in crop regions, but are in a complex state of flux due to shifts in climate, environmental conditions and methods of husbandry [41]. In certain stages of crop growth, weed control through the use of chemical herbicides is the most widespread practice in oil palm plantations.

In general, herbicide treatments are temporary and influenced by the dominance of weed species, crop cultivation and environment [42].

Common organic fertilizer was used in all three plantations. However, organic fertilizer was applied three times annually at both Kg. Sri Rahmat oil palm and Kg. Logah. Organic based fertilizers were less leached into ground water than the chemical fertilizers. At Kg. Sri Rahmat oil palm plantation, liming was done once a year to retain moisture and increase salinity (neutralize pH) at the soil due to excess chemical from weed. Lowering the rate of nitrogen fertilizer application could decrease soil acidification [39] and lime application. As high quantities of nutrients have already been stored in soils and palm trunks of mature oil palm monocultures from the organic based fertilizers, this will theoretically minimize nutrient management costs [43, 44].

4. Conclusion

From this study, weeds species composition and diversity could be a useful indicator to reflect on the management history and practices. Kg Sri Rahmat oil palm plantation has the highest diversity and evenness and shared the highest species and genus at 0.37 (Sorensen similarities index) with Kg. Logah as compared to Felda Medoi plantation. Monoculture farming system contributed to high species evenness and several factors relating to management histories have been identified as potential factors affecting weed species composition and diversity in oil palm plantations owned by smallholders. This includes the age of oil palm plantation, pruning treatment (canopy), management through usage of herbicide, type and usage of fertilizer and location of oil palm plantation based on different elevation. Therefore, adopting an ecological approach through diversity indices as an indicator could inform smallholders on the implication of management histories and practise on weed diversity in oil palm plantations. This study is important to sustain oil palm production through effective weed control. More study is needed with regards to identifying the key factor in driving weed diversity in oil palm plantations and effective weed management approach.

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Appendix

List of family, number of genus, species and individuals recorded at three oil palm plantations in Segamat, Johor.

No	Family	Number of Genus	Number of Species	Number of Individual
1	Acanthaceae	1	2	453
2	Asteraceae	4	4	358
3	Cannabaceaae	1	1	223
4	Caryophyllaceae	1	1	170
5	Commelinaceae	1	1	166
6	Cyperaceae	1	1	95
7	Euphorbiaceae	1	1	79
8	Fabaceae	3	4	221
9	Flagellariaceae	1	1	79
10	Lamiaceae	1	1	17
11	Melastomataceae	2	2	367
12	Moraceae	1	1	136

13	Oxalidaceae	1	1	3
15	Piperaceae	1	1	13
14	Poaceae	8	9	1211
16	Polygalaceae	1	1	118
17	Rubiaceae	4	9	578
18	Solanaceae	1	1	165
19	Verbenaceae	1	1	13
	TOTAL	**35**	**43**	**4465**

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