Effect of Different Types of Mulching on Soil Properties and Tree Growth of *Magnolia champaca* Planted at the Montane Rainforest in Cameron Highlands, Pahang, Malaysia

Wahidullah Rahmani, 1 Mohd Nazre Salleh, 1 Mohd Zaki Hamzah, 2 Aminu Abdu, 1 Mohamad Fakhri Ishak, 1 Wan Rasidah Wan Abd Khadir, 3 Mohd Ridza Awang, 3 Zahari Ibrahim, 3 Ahmad Fadzil Abd Majid, 3 Mohd Shahrir Azrin Salleh, 3 Azhar Anuar, 2 and Mohamad Azani Bin Alias 1

1 Faculty of Forestry, Departement of Forestry Science and Biodiversity, Universiti Putra Malaysia, UPM Serdang 43400, Selangor, Malaysia
2 Forest Research Institute Malaysia, Kuala Lumpur, Malaysia
3 Forestry Department of Peninsular Malaysia, Kuala Lumpur, Malaysia

Correspondence should be addressed to Mohamad Azani Bin Alias; azani@upm.edu.my

Received 3 February 2021; Revised 10 May 2021; Accepted 30 July 2021; Published 7 September 2021

Academic Editor: Qing Lai Dang

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Tropical Montane Cloud Forest (TMCF) is among the most vulnerable habitats to fragmentation, deforestation, and global climate change. A successful restoration program requires a comprehensive understanding of variables influencing seedling efficiency. This study was conducted on Sg. Terla Forest Reserve Cameron Highlands, Pahang, Malaysia. In this study, we used a randomized complete block design (RCBD) and measured the *Magnolia champaca* height, root collar diameter, diameter at breast height, plant survival, root diameter, main root length, lateral root length, root coiling, root direction, and chlorophyll content. The soil samples were taken to study the effect of different mulching materials on soil characteristics. We also measured soil compaction, soil texture, soil colour, soil moisture content, soil organic carbon, total nitrogen, total sulphur, available phosphorus, and exchanged potassium. This study indicates that mulching had no significant effect on plant height, diameter breast height, root collar diameter, and chlorophyll content between treatments. Although mulching had a significant effect on root diameter, main root length, and root distributions among treatments while for lateral root length and root:shoot ratio did not show a significant effect among treatments. However, oil palm mulching treatment had a greater effect on plant height, root collar diameter, and diameter at breast height growth, among treatments. Mulching significantly affected soil pH, soil moisture content, total sulphur, and potassium exchange. In contrast, mulching did not significantly affect soil organic carbon, total soil nitrogen, and soil available phosphorus between treatments.

1. Introduction

The protection of young plants from noncrop plant species is essential for the sustainability of new tree planting in both open-field nurseries and natural environments (including some hardwoods, shrubs, grasses, and forbs). These fast-growing plants often eliminate or severely suppress desirable trees by competing for light, water, and nutrients. As a consequence, nurserymen, landscapers, and forest managers commonly use herbicides to manage noncrop vegetation [1]. As a result, environmental friendly, secure, cost-effective, and socially appropriate methods for managing noncrop vegetation are needed to protect young trees [2]. In this circumstance, we concentrated on the need for environmentally sustainable establishment and low-cost restoration area management techniques. Mulching and its skilled
application can lead to such development by increasing organic matter content in soils and influencing other soil characteristics [3]. Mulches have been commonly used in forests, agricultural land, orchards, and landscapes in many parts of the world [4, 5]. Mulches are widely divided into three important groups: organic, inorganic, and living mulches. Green mulches are obtained from organic products such as crop waste (straw and rice husks), waste from the timber industry (sawdust and bark), and green waste (leaves and wood chips) [4]. Inorganic mulches involve gravel, film, bricks, and cobblestones made of polyethylene. Clover, Manila grass, dwarf lily turfs, ryegrass, and other kinds of grasses include living mulches [6]. Each category of mulch has a particular set of characteristics. In general, mulches have beneficial effects such as improved early growth of trees, seed germination, increased root growth, higher water availability, maintaining good soil structure and porosity, minimizing soil erosion, reducing weed competition, maintaining soil temperature, reducing soil evaporation, enhanced root establishment and transplant survival, and increased overall plant performance [7, 8]. Mulching has been shown to improve survival in nursery and field production [9], Silvopasture systems [10], woodland plantations [11], and restoration sites [12]. Researchers discovered that mulched trees grew 67% faster than bare soil trees as early as 1942 [13]. Many others have since shown similar increases in tree, shrub, and other plant material development in field and nursery conditions [11, 14, 15]. Specifically, increases in plant height [1, 10], stem or trunk diameter [16], leaf size and/or number [17], and flower, fruit, and/or seed production [18] have all been reported because of mulching with appropriate materials.

Various studies have shown that increased root growth and exploration by desirable plants is associated with better water retention and reduced weed growth [19]. As compared to bare soil [20], mulches allow tree and shrub roots to extend and establish far beyond the trunk, leading them to become more stable. Root development and density were greatest under organic mulches compared to that under plastic [19], bare soil, or living mulches. Mulches protect soils from extreme temperatures through maintaining soils cooler in hot conditions [21]. Temperature extremes will kill fine roots and while rarely killing established plantings, they can induce a chronic stress as the plant utilizes energy to generate new fine roots. Mulch protects soils from erosion and compaction caused by water, wind, and traffic, all of which contribute to root stress and poor plant health. Bare soil loses water by evaporation when exposed to wind, sun, and compacting forces and is less able to absorb rainfall or irrigation as it becomes rapidly compact. As compared to bare soil, a layer of straw only 3.8 cm (1.5 inch) thick reduced evaporation by about 35%, according to an early study [20]. Later, McMillen [22] demonstrated that most mulched soils have greater water retention than bare soil. In general, inorganic and organic mulches are most effective in weed control when applied at sufficient depth and are least susceptible to compaction [14]. Living and organic mulches decompose under appropriate water and temperature levels and nutrients are released into the soil and become available for root uptake or microbial use. However, few studies have examined the impact of mulching in the restoration area under tropical climates. The study objectives were (1) to determine the effects of three types of mulches (organic, inorganic, and living) on soil properties and (2) to recognize the effects on the growth performance and (3) root development of Magnolia champaca in tropical montane rainforests, and to provide a preliminary recommendation for the selection of acceptable mulches based on our research.

2. Materials and Methods

2.1. Study Site. The present study was conducted in a former agriculture area located in the montane rainforest at Terla Forest Reserve Cameron Highlands (Figure 1). It is located on the main range between 4°20'N–4°37'N and 101°20'–101°36'E. The Cameron Highlands’ mean temperature is between 17°C and 20°C all year round, situated on a highland elevation. However, local temperatures rose to 5°C in 2014, relative to the last 15 years (RTD 2003). The maximum rainfall (wet season) is from April to May and October to November, while January to March and June to August have the minimum rainfall (dry season). The mean elevation of the study site is 1404.5 m above sea level.

2.2. Experimental Design. The experiment was designed in a randomized complete block design (RCBD) with four replicates. The four treatments include:

- (i) Coconut mulching treatment (CM)
- (ii) Plastic mulching treatment (PM)
- (iii) Oil palm mulching treatment (OM)
- (iv) Control treatment without any cover (CK)

Only one plant species, namely, Magnolia champaca, was used in this study. Each treatment contains four rows of 10 trees, which is 40 trees in total. The space between rows and plants was 4 m × 4 m, with a total of 160 trees (4 treatments × 40 trees each).

2.3. Soil Sampling and Analysis. The soil was collected at a depth of 20 cm at four random positions in each plot. In each treatment, eight samples were taken from below the mulch layer in the plots where the mulch was added. There were 32 soil samples gathered and analysed in total. Soil samples were air-dried at room temperature and then sieved through a 2 mm sieve. After sieving, the physical and chemical properties of the collected soils were determined. The pipette method was used to determine soil texture [23]. Soil compaction was measured by UTS-0075 Pocket Dial Penetrometer (range 0–6, 0–11 kg/cm) on the topsoil (0–5 cm) once at the end of data collection. Available P value was determined with a spectrophotometer using the Olsen method [24]. Soil organic C was determined using the Walkley–Black technique [25]. The pH was determined by an Orion Analyzer (Model 901) pH meter in a soil:water ratio of 1:2.5. Total N was measured using the Kjeldahl method [26]. The soil moisture content was determined by the gravimetric method [27].
Exchanged potassium was determined by flame atomic emission spectrometry (AES), and the turbidimetric method was used to determine the total sulphur [28].

2.4. Tree Growth. The survival of trees was recorded twice at the beginning and the end of the study. Meanwhile, we took the growth performance of *M. champaca* on the fourth week of every month for one year (July 2019–July 2020). A telescopic measuring pole recorded seedlings’ height. In the meantime, we measured root collar diameter at 10 cm and diameter breast height at 130 cm above the soil with a Digital Vernier Caliper (Mitutoyo UK Ltd., Hampshire, UK). We determined the chlorophyll content of the SPAD 502 Plus Chlorophyll Meter (Spectrum Technologies Inc., Aurora, IL) between 8:00 a.m. and 11:00 a.m. The leaves are found in the centre of the third vine. From each tree, we chose three leaves to compose the repetition, and the average was recorded.

2.5. Root System. We used the excavation method for the root system, and digging took place from the trunk, which was removed for safety purposes, with the incremental removal of the soil layer by layer before finding the first main roots. Standard excavation tools have been used to prevent root destruction. After uncovering the first layer of horizontally growing roots, a grid of rope was spread across the soils surface. The width of the grids was 10 × 10 cm. We mounted a wooden framework directly above the grid net to provide convenient access to all parts of the root system, and root diameter, lateral root length, main root depth, root coiling, and root direction were recorded for each seedling moreover the root system direction [29].

2.6. Data Analysis. The experimental design was randomized complete block design, whereby plots were randomly assigned to the treatments. Generalized linear modelling (GLM, one-way analysis of variance) was applied to relate growth performance and soil properties responses with treatment. When the ANOVA analysis found significant differences between treatments, post hoc comparisons of the treatment group means were performed using Tukey test with a 95% confidence level. Treatment effects were considered statistically significant when $p \leq 0.05$. SPSS (release 17.0; Chicago, IL, USA) statistical package was used for analyses. All statistical analyses were performed at a 95% confidence level.

3. Results

3.1. Effect of Different Types of Mulches on Survival, Growth Performance, and Chlorophyll Content. In this study, plant survival, plant height, root collar diameter, and diameter at

![Study site located in Terla Forest Reserve Cameron Highlands, Pahang, Malaysia.](image-url)
breast height were monitored as growth parameters. Based on the observation during 12 months of study, *M. champaca* showed 100% survival between treatments. The variance analysis (Table 1) revealed that plant height, root collar diameter, and diameter at breast height of *M. champaca* were not affected by different mulching types. None of the treatments increased the plant height, root collar diameter, and diameter at breast height significantly. Plant height in OM indicates the highest increment grown in 1.47 m and slightly higher than PM (1.43 m), CK (1.43 m), and CM (1.42 m), respectively (Figure 2). The breast height diameter was greater in OM (1 cm) than CM (0.98 cm). We found the lowest diameter breast height value in PM between different treatments (Figure 2). OM’s root collar diameter showed a greater value of 2.36 cm and the lowest value of 2.25 cm was recorded in PM (Figure 2). Hence, OM had a greater effect on plant height, root collar diameter, and diameter at breast height on *M. champaca* than CM, PM, and CK. Chlorophyll content was measured as growth performance for *Magnolia* spp. The data (Figure 3) show none of the mulching treatments significantly affected chlorophyll content, although PM showed the highest chlorophyll content 21.3 compared to OM (19.9), CM (19.8), and CK (19.16), respectively.

3.2. Root Development. In this study, the root diameter was recorded during the study as root development parameters. Results show (Figure 4) there was a significant difference between treatments. We found the highest root diameter grown increment (0.66 cm) in CM, and it was higher than OM (0.50 cm), PM (0.39 cm), and CK (0.38 cm) treatments, respectively. The lowest root diameter increment was recorded in CK. The lateral root length increment did not show a significant difference among different mulching treatments (Figure 4). The highest lateral root length increment is shown in CM (65.83 cm) and slightly higher than PM (64.70 cm), CK (62 cm), and OM (59.42 cm) respectively. There was a significant difference between treatments for main root length increment. CM treatment was significantly higher than PM and CK treatments, but there was no significant difference between CM and OM treatments. The main root length increment in CM treatment was slightly higher than OM (41.33 cm), CK (37.76 cm), and PM treatment (36.67 cm), respectively (Figure 4).

The root direction was significantly different from the sun directions. The direction of the roots varied toward the sun between directions. Results show (Figure 5) that 35% of roots were toward the north, 14.7% south, 14.7% west, 11.7% south-west, 8.82% east, 8.82% north-west, 2.94% northeast, and 2.94% south-west, respectively. On the other hand, 35% of the root system were toward the north direction. Moreover, there was no correlation between root direction and soil compaction among treatments. The horizontal and vertical roots were significantly different between treatments (Figure 6). The horizontal roots were significantly higher in CM (65.8 cm) than PM (64.7 cm), CK (62 cm), and OM (59.4 cm) treatments, respectively. In other words, CM (65.8 cm) treatment showed the highest value and OM 59.4 cm treatment showed the lowest value among treatments. Moreover, the root system in the vertical direction CM (49 cm) treatment compared to OM (41.3 cm), CK (37.6 cm), and PM (36.6 cm) treatments showed higher horizontal root distribution, respectively. The root distribution was affected by CM in horizontal and vertical directions between different types of mulching treatment.

Results (Figure 7) show there was no significant difference between treatments for root/shoot ratio. Compared between treatments, OM treatment (3.40 g) was significantly higher than CM (3.17 g), PM (2.85 g), and CK (2.11 g) treatments, respectively. Moreover, significant coiling was observed for *Magnolia* spp. after three years. The root pictures show 75% of the tree had significant coiling, and 25% show no coiling among trees.

3.3. Effect of Different Types of Mulches on Soil Physical Properties. The results indicate that the soil colour was between yellow and brownish-yellow for all treatments. There was no significant difference in soil texture between treatments. The soil content was 60% of silt, 20% clay, and 20% sand for all blocks and treatments. Therefore, the soil texture was silt loam among blocks and treatments. There has been a significant difference in soil compaction for various types of mulching. The maximum value of soil compaction was shown in CK, while the minimum value was in CM treatment. In another word, CK showed higher (2.46 kg/cm³) compacted soil than PM (2.05 kg/cm³), OM (1.79 kg/cm³), and CM (0.94 kg/cm³) treatments, respectively (Figure 8).

3.4. Effect of Different Types of Mulches on Soil Chemical Properties. The pH value was significantly different between treatments (Figure 9 and Table 2). We found the minimum pH value in PM (4.28 pH), and the maximum value was found in CM (4.57 pH). In other words, there was a highly significant difference between CM and OM treatments, while there was no significant difference between CM and PM treatments. The difference in soil moisture content (Figure 9 and Table 2) was highly significant between treatments. Soil moisture in PM (17.92%) was significantly higher than CM (17%), CK (16.16%), and OM (16.12%) treatments. There was no significant difference between treatments for soil organic carbon (Figure 10 and Table 2). PM treatment (0.13%) was slightly higher than OM (0.09%), CM (0.05%), and CK (0.04%), respectively. Moreover, different mulching did not lead to a significant difference in available phosphorus between treatments (Figure 9). PM (4.59 ppm) showed a greater value than CM (3.96 ppm), CK (3.26 ppm), and OM (3.23 ppm) between treatments, respectively. However, mulching had a significant effect on the exchange of potassium between treatments (Figure 10 and Table 2). We found the highest value in CM (0.07) compared to CK (0.06), PM, and OM (0.05) treatments, respectively. There was no significant difference between treatments for total nitrogen (Figure 10 and Table 2). CM treatment (0.05%) showed greater value of total nitrogen than PM.
Based on Figure 10, there was a highly significant difference for total sulphur between treatments. We found the highest value in CM treatment and PM (0.02%) than CK and OM (0.01%) treatments.

### 4. Discussion

#### 4.1. Tree Growth.

The application of different mulching had different effects on tree growth. Several studies indicated that mulching had no significant impact on tree growth [30–32].

Many studies have demonstrated that mulching, especially with organic mulching, can improve tree growth [33–35]. Moreover, previous studies [34, 36] indicate that mulching did not significantly affect the diameter at breast height, although mulching had greater value than the bare soil. The root collar diameter studies have shown that mulching did not significantly influence root collar diameter (RCD) growth [37, 38]. However, several studies found that organic mulching affected root collar diameter compared to inorganic mulching [8, 30]. Moreover, Amin et al. [35] found...
that mulching treatments significantly affected the stem diameter of coffee seedlings compared to no-mulching. However, the present study agreed with the earlier studies and indicates that organic mulching did not show significant effect, although mulching treatments improved plant height, diameter at breast height, and root collar diameter. The growth of Magnolia spp. enhanced by the mulched treatments could be attributed to the fact that mulching provides favourable conditions for growth and development of the plant by providing improved soil moisture conservation, reduced soil temperature, and reduced weed infestation and nutrient availability as a result of reduced leaching of nutrients. For the chlorophyll content, several studies have reported that black plastic mulching results in a greater value of chlorophyll content than control treatment [39–41]. Marichamy et al. [42] and Yang et al. [43] reported that black plastic mulching had the highest value of chlorophyll than organic mulches and found the lowest value of the control treatment. Zhang et al. [44] also reported that straw mulching significantly increased the chlorophyll content compared to no mulching. The beneficial impact of polyethylene mulching on photosynthetic pigments may be attributed to the hypothesis that light reaction of photosynthesis is an important compound of Chlorophyll A. Chlorophyll B is a light-harvesting pigment who’s absorbed light energy has been converted to Chlorophyll A [45]. Besides, the increase in total chlorophyll according to the use of black plastic mulch might be because plastic mulching improves the microbial population of the soil and increases the absorption of nitrogen and hence the plant leaves chlorophyll content [46]. The present study, combined with the earlier studies, indicates that black plastic mulching had a better effect on chlorophyll content than organic mulching and organic mulching had a better effect than control.

4.2. Root Development. The roots’ ability to explore the underground ecosystem in forest settings influences tree fitness, stability, and survival. Previous studies demonstrated that lateral root diameter increased under different types of mulching [47, 48]. Gao et al. [49] found that plastic mulching had a greater effect on root diameter than control. Moreover, Bécel et al. [50] stated that with soil penetration resistance, the mean diameters dramatically increased. An improvement in the ratio reveals that the lateral root diameter improves more than the parent’s root diameter. However, this study indicates that root diameter in organic mulching treatments had better growth, probably due to more organic matter, less soil compaction, and high soil carbon than no-mulching treatments. Gough [51] demonstrated that plastic mulch had a better effect on lateral roots than bare soil. Moreover, Schenk and Jackson [52] demonstrated that annual succulents had larger lateral root

![Figure 6: Horizontal and vertical root development.](image)

![Figure 7: Root-shoot ratio among treatments.](image)

![Figure 8: Soil compaction under different mulching.](image)

![Figure 9: Soil moisture content, pH, and available phosphorus.](image)
spreads than rooting depths in water-limited ecosystems. This study found that lateral root length in organic mulching treatments was higher and it may be due to more soil moisture content, organic matter, and soil carbon and less compaction in the topsoil than control treatments. Main root length is a stronger root growth metric compared to the absorption of water and nutrients, as a high root length is associated with a short distance of water and solutes [53]. The early studies [48, 49, 54, 55] indicated that root length increment was higher in mulching treatment, especially in organic mulches than bare soil. However, these study findings are by the earlier studies that main root length decreased in control treatments. The key factors are presumably due to the limitations of gas diffusion [56], the higher accumulation of CO₂ in the topsoil [57], and lower soil respiration rate [56], which contributes to reducing root respiration and microbial activity across the root system [58]. When roots expand through the soil, they must either follow pores or canals or infiltrate and displace the soil layer. Mechanical impedance refers to the resistance against deformation given by the soil matrix and has a major impact on root growth [59]. Root elongation is increasingly delayed as soil impedance grows due to naturally high bulk density, soil dryness, or soil compaction [60]. Nevertheless, roots are growing where the resources of life are available. They are not rising toward anything. Generally, if there is little oxygen or where the soil is compacted and difficult to penetrate, they do not grow [61]. Root development is opportunistic, only if the soil condition will support it [62]. Tree roots are the key contributors to soil structure development and, in the longer term, to soil composition. The most significant root concentration is located at the soil surface where the soil is loose, and water, oxygen, and nutrients are most easily accessible [62]. Thidar et al. [63] and Yao et al. [54] observed that most vertically found roots were in organic and plastic mulching treatments at the top 0–30 cm soil depth and horizontally 0–15 cm distance from the plant foundation. Also, Schenk and Jackson [52] reported annual succulents had very shallow rooting depths. Still, sizeable lateral root spreads in water-limited ecosystems; therefore, the present result is consistent with those of Chalker-Scott, [64] who found that in soil treated with organic mulches, root growth density is more significant than in those treated with nothing or plastic.

The volume of the root system and the root/shoot ratio demanded the supply of nutrients, water, and the chemical, physical, and biological properties of the substrate that affect root growth and new roots. Thidar et al. [65] and Zhang et al. [66] indicated that mulching especially organic mulching had a significant effect on root/shoot ratio compared to control treatment. The root/shoot ratio is related to the nutrient supply/fertilization ratio, with a higher ratio at low nutrient supply [60]. Moreover, Agele et al. [67] pointed out that the root/shoot ratio did not reveal any significant values in both trials (first and second years) with the highest values obtained from soil plots. However, this study’s findings attribute to the level of resources, as Ong and Julia [68] stated that with increased resources, both shoot and root biomass increases, but the maximum root biomass is typically obtained at a lower resource level than maximum shoot biomass. Hence, according to the availability of resources, the shoot:root ratio changes. Root coiling happens when seedlings are left too long in the greenhouse; the roots do not find any way to extend their way down in the restricted area. Davis and Jacobs [69] stated that poly bags and plastic containers experienced low seedling growth and root coiling. However, the seedlings root coiling was due to using small size of poly bags in the nursery, old seedlings, and poor management practices.

4.3. Soil Physical Properties. Cameron Highlands soil texture is mainly derived from granite, sandy to sandy clay loamy [70]. However, silt loam has a medium infiltration rate, modest water-holding capacity available for plants, and nonrestricted root growth and is highly susceptible to compaction. Besides, the silt loam’s texture is highly susceptible to water erosion and hardening [71]. Moderate phosphorus fixation, low plant available water, and soil compaction are the characteristic of these soil colours [71]. Many studies have reported that mulches had significant advantages in bulk density and soil compaction [72, 73]. Moreover, soil compaction makes skid trails inhospitable to the roots in water and oxygen availability and can contribute

| Treatments | pH   | Soil moisture content (%) | Soil organic carbon (%) | Total S (%) | Total N (g kg⁻¹) | Available P (mg kg⁻¹) | Exchange K (cmol/kg) |
|------------|------|--------------------------|------------------------|-------------|------------------|----------------------|---------------------|
| CM         | 4.59 ± 0.15 | 14.32 ± 1.09 | 0.14 ± 0.22 | 0.01 ± 0.00 | 0.05 ± 0.04 | 3.34 ± 0.71 | 0.10 ± 0.04 |
| OM         | 4.51 ± 0.15 | 14.60 ± 1.10 | 0.07 ± 0.06 | 0.01 ± 0.00 | 0.02 ± 0.04 | 4.08 ± 1.88 | 0.09 ± 0.05 |
| PM         | 4.28 ± 0.13 | 20.49 ± 3.52 | 0.04 ± 0.03 | 0.02 ± 0.01 | 0.01 ± 0.00 | 3.88 ± 2.17 | 0.04 ± 0.02 |
| CK         | 4.31 ± 0.26 | 17.78 ± 0.90 | 0.07 ± 0.02 | 0.02 ± 0.00 | 0.05 ± 0.05 | 3.73 ± 3.73 | 0.02 ± 0.01 |

![Figure 10: Exchange potassium, total nitrogen, total sulphur, and soil organic carbon.](image)
The findings of this study are consistent with the general observations that the addition of litter mulch to compacted surface soils could accelerate regeneration and improve the physical properties of the soil by improving soil quality and stimulating biological activity [75].

4.4. Soil Chemical Properties. The previous studies have found that organic mulching significantly decreases soil pH [76, 77]. Also, many studies have found that organic and inorganic mulching increased soil pH [11, 78]. The results of the present study were synonymous with these reports. However, low pH levels may result in a lack of basic elements such as Ca, Mg, K, and N in the soil. These results with this study indicate that the impact of mulches on soil pH relies on the mulching content and the soil composition/type. Previous studies have generally indicated that mulches, including plastics, gravel, barks, wood chips, and grass can maintain soil moisture content by reducing the rate of evaporation [79–82]. However, soil moisture content in inorganic mulching was higher than organic mulches [30, 83]. Moreover, our findings demonstrate that the plastic mulching resulted in higher soil moisture than organic mulches. This might be because organic mulching (CM and OM) increased the rate of evaporation. Besides, organic mulching is hygroscopic, and therefore, they tend to absorb water from the soil, which in turn lowered the soil moisture. On the contrary, plastic mulching prevents soil exposure to solar radiation, and its resistance to the passage of water has decreased soil evaporation. Also, mulches reduce impact of raindrops and splash, thereby preventing soil compaction, reducing surface run-off, and increasing water infiltration. All these were combined to increase the soil moisture content and reduce moisture depletion. Bai et al. [83] revealed that inorganic and organic mulches had no significant effect on soil organic carbon. However, this study’s finding is in line with the earlier studies [30, 84–86] and confirmed that organic mulching improves the soil organic carbon due to the accumulation of carbonateous material. Organic mulch can improve the soil’s organic carbon because organic mulches provide carbonateous material to the soil upon decomposition. Many studies have demonstrated that mulching significantly affected the available P in different soil depths and surfaces [60, 80]. Qu et al. [30] indicated that available phosphorus content was significantly affected only by the organic mulches. Although Kumar et al. [87] demonstrated that available P was recorded significantly highest in black plastic in the first year. Both mulch treatments were statistically on average with each other during the second year. It can be due to improved hydrothermal regimes, more root system proliferation, and effective management of weeds that have reduced P mining. Previous studies [22, 87, 88] indicated that the level of soil potassium in organic mulches treatment increased compared to bare soil. Also, Jourgholami et al. [74] demonstrated that potassium’s lowest value was found in bare soil and higher in the undisturbed area in compacted soil. However, the improvement in the K content of mulching soils may be attributed to increased removal of competing weeds, enhanced hydrothermal regime, and higher root biomass release of potassium to the soil. Early studies found that total nitrogen increased in organic mulching than bare soil [6, 75]. The improvement in total nitrogen under mulch is consistent with the earlier studies that mulching resulted in significantly higher soil organic N mineralization, residual accumulation of nitrate in the soil profile, and decrease of soil profile N depletion. Saroa and Lal [89] reported mulch rate had no effect on the total sulphur concentration of particle size fractions for either mulching duration, but generally decreased with depth. Haque et al. [90] found that the highest sulphur contents were in bare soil (control) treatment in both years. However, in the present study, the sulphur was high in mulching treatments. It might be because majority of sulphur in soil is present in organic forms and not readily available for plant uptake.

5. Conclusions

The various mulching materials had a different effect on plant growth, root system and, soil properties. Our findings indicate that mulching did not significantly affect soil properties. However, mulches help create a healthy soil environment, especially organic mulches (coconut mulch and oil palm mulch), and various mulches have different effects on the soil properties. Soil moisture content, total sulphur, pH, and exchange potassium increased significantly between treatments. Moreover, mulching had a significant effect on root diameter, main root length, and root distributions.

In comparison, mulching did not significantly affect total nitrogen, available phosphorus, soil organic carbon, plant height, root collar diameter, diameter at breast height, chlorophyll content, lateral root length, and root:shoot ratio. OM mulching had a better effect on plant height, root collar diameter, and diameter at breast height. However, PM had a better effect on chlorophyll content among treatments and CM had a better effect on plant root system development. Therefore, considering the effect of mulching on soil properties, plant growth, and physiology, coconut mulching and oil palm mulching are better than plastic and bare soil in the degraded area at tropical rainforest plantation. Further studies are required to determine the long-term effect of mulching on the tropical restoration area.

Data Availability

All data used will be available on the corresponding author’s research gate page and also will be made available when requested.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

The authors would like to thank Dato’ Mohd Ridza Awang (Director General, Forestry Department of Peninsular
Malaysia) and Mr. Mohd Fakhri Ishak (Forest Research Institute Malaysia) for their contributions during data collection and the ideas developed for this paper. This research was funded by Forestry Department of Peninsular Malaysia.

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