Fertilizer placement in circle weeding vs. in interrow: which one is better for oil palm?

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ABSTRACT
Oil palm fertilizers are located in circle weeding because it is usually "cleaner" than interrow. However, many planters assumed that this method is inadequate. This is because the density of feeding roots, which play an essential role in nutrient absorption, continues to decrease due to intensive fertilizer input and weed control. Therefore, this research aims to determine the performance of oil palm under two different applications of fertilizer placement, namely in the circle weeding and in the interrow. It was carried out using a 9-year-old palm with a demo plot of 7.5 ha for five years. The treatments applied were 100% fertilization on circle weeding (A1) and interrow (A2), 50% on the circle weeding, and the rest on the interrow (A3), and 25% on the circle weeding and 75% on the interrow (A4). The parameters observed included soil and leaf nutrient content, root distribution, vegetative growth, and yield. The results showed that fertilizer placement in the circle weeding produced the best oil palm yield.

Keywords: *Soil nutrient, Leaf nutrient, Oil palm performance.*

1. INTRODUCTION

Oil palm (*Elaeis guineensis*, Jacq.) is a crop that has high productivity and produces up to 3–8 times more oil per hectare than any other temperate plant [1]. This crop also has wide environmental adaptability because it has reserves of non-structural carbohydrates (NSC) mainly located in the tree trunk as glucose and starch. The NSCs serve as buffers from environmental influences and can sustain oil palm growth for approximately 7 months [2]. Like other crops, oil palm plants require adequate nutrient uptake to maximize their potential yield. This can be achieved through proper fertilization to increase growth and productivity [3]. However, the deficiency of one type of nutrient can cause a decrease in production [4].

In less fertile tropical soils, the nutrient requirements to produce 20 tonnes of FFB/year/ha are 129.5 kg N, 16.4 kg P, 236 kg K, and 38 kg Mg per hectare [5]. Therefore, fertilization needs to be properly carried out in a balanced proportion to avoid adverse effects on oil palm and the environment [6]. Improper application of fertilizers will also lead to cost inefficiency because fertilization is relatively expensive, reaching more than 40% of the total production [7].

Previous research has shown that fertilizer placement will affect the efficiency and effectiveness of the plants [8]. Fertilization in circle weeding was relatively more protected from competition with other plants. However, many planters stated that the method is no longer adequate. This is because an area with more feeding roots and higher soil moisture is more effective. It was also reported that the denser feeding roots are located more than 150 cm from the trunk base [9], while soil moisture is higher at the edge of the circle weeding [10].

The planters also discovered that the continuous application of fertilizer in the circle weeding can lead to higher leaching losses and acidification [11], especially during the rainy season [12]. The placement of primarily N and K on 10-years-old palms and above is not a critical factor because these plants already have extensive and efficient root systems. However, placement outside the

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circle weeding or in the interrow is very vulnerable to severe competition with other ground vegetation [11].

There are limited reports about the effect of different fertilizer placements on the performance of oil palm. Therefore, this research was conducted to provide scientific answers about fertilizer placement. The results are expected to help planters determine how to place fertilizers according to the conditions of the land used for plantation.

2. METHODS

This research was conducted at the Padang Mandarsah Research Estate, Padang Lawas, North Sumatra, from May 2013 to June 2018. The estate has a soil type of Typic Dystrudepts, with an average, maximum, and minimum air temperature of 24.28°C, 30.49°C, and 21.63°C, respectively. The average relative humidity is 90%, while that of solar radiation is 17.52 $MJ/m^2/day$. Rainfall at the location has an equatorial type with an average of 3201 mm/year.

The experiment was carried out in a demo plot using a total of 960 nine-year-old trees in an area of 7.5 ha The plots selected had relatively uniform land and crop conditions. The treatments applied were 100% fertilization on circle weeding (A1) and interrow (A2), 50% on the circle weeding, and the rest on the interrow (A3), and 25% on the circle weeding and 75 % on the interrow (A4). The types of fertilizers applied are compound NPK 13-6-27+0.65B and Dolomite, which were given at a dose of 5 kg/palm and 1.75 kg/palm, respectively. The circle weeding condition is always protected from weeds, while the interrow is often shielded from woody and broadleaf weeds. The interrow were dominated by ferns, especially *Nephrolepis sp*.

Each treatment was applied to a plot with 16 trees, with 5 repetitions. Meanwhile, each plot is delimited by 2 rows of trees as borders. A simple schematic of the sample tree position and border is presented in Figure 1.

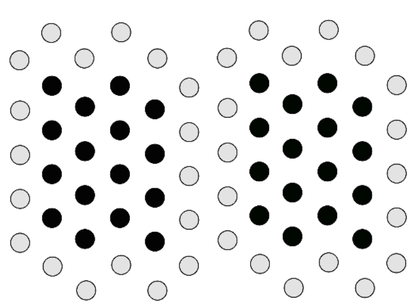

Figure 1 Schematic of determining sample tree and border. The black circle is the sample tree, gray circle is the border tree.

The parameters observed were soil and leaf nutrient content, root distribution, vegetative growth, and production. Soil nutrient levels were observed once a year and the samples were only taken from inside the circle weeding and were a composite of odd-numbered sample trees only.

The soil nutrient levels observed included pH, C-organic, N, C/N ratio, P, K, Ca, Na, Mg, amounts of base cation, cation exchange capacity (CEC), base saturation, and exchangeable Al. The leaf samples were taken from frond number 17 of all trees and the nutrient analysis included N, P, K, Ca, and Mg.

The roots sampling was carried out using a root auger inside the circle weeding (100 cm) and in the middle of the interrow between the sample trees as shown in Figure 2. The root auger used has a diameter of 10 cm and a depth of 20 cm. This was conducted only in the same position at the beginning and end of the research. Roots were taken on sample tree number 5 in each plot at a depth of 0-20 and were separated into primary, secondary, and tertiary. Furthermore, the roots were cleaned and oven-dried at 60°C until the weight was constant [9]. The estimated root distribution was obtained by dividing the dry weight of the roots (g) by the volume of the root auger (dm^3).

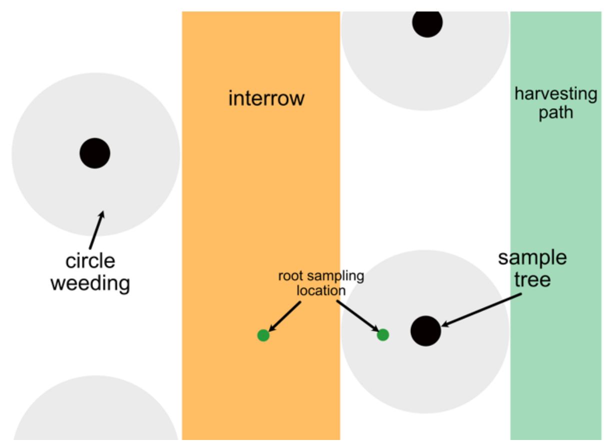

Figure 2 Root sampling scheme

The observations of vegetative growth were carried out every 6 months on petiole cross-section (PCS), rachis length, leaf area (LA), and leaf area index (LAI). Furthermore, production observations were conducted on the parameters of the number and weight of bunches from each plot.

Data obtained from the observations of all parameters for five years were averaged, except for vegetative growth and an analysis of variance (ANOVA) was carried out with a 5% significance level. Further tests were conducted using the Duncan Method and the statistical analysis as well as presentation of results were performed using MS. Excel, R-software version 4.0.4, and RStudio version 1.4.1106.

3. RESULTS AND DISCUSSION

3.1. Soil Nutrients Dynamic

The results of the analysis of the soil nutrient conditions during the research are presented in Figure 3. It was discovered that in the 100% fertilization in the circle weeding (A1), the nutrient content in the circle zone was higher compared to other treatments. The amounts of base cation, CEC, and base saturation were also increased, while the exchangeable Al tends to be lower than the others.

However, soil nutrients content in the 100% fertilization in the circle weeding (A2) was not too low and was higher than the A3 and A4 treatments, for example in Ca and Mg nutrients. The ANOVA test showed that the treatment only caused differences in the C-organic, K, Mg, amounts of base cation, base saturation, and exchangeable Al. However, further test results indicated that the difference between treatments was significant only in the K nutrient content.

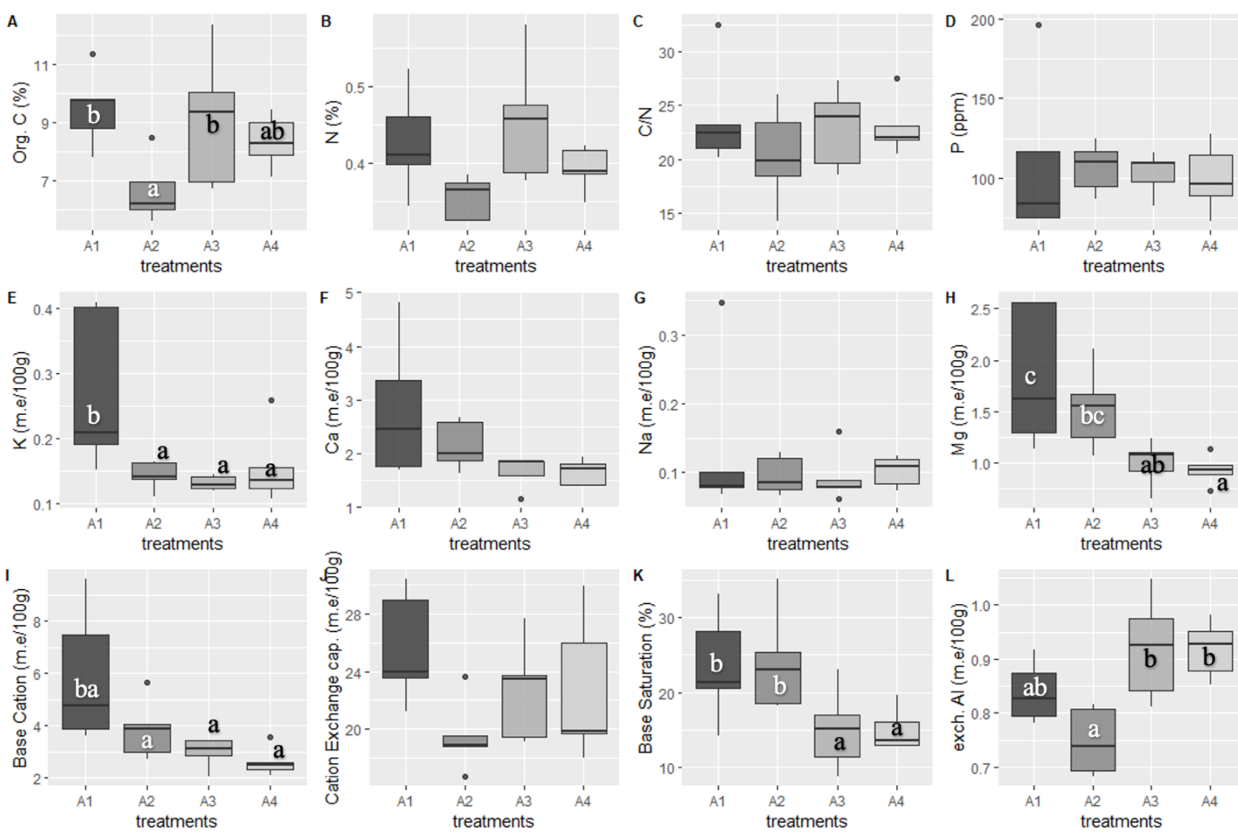

Figure 3 Soil nutrient content in various treatments, namely 100% fertilization on circle weeding (A1) and on interrow (A2), 50% on the circle weeding, and the rest on the interrow (A3), and 25% on the circle weeding and 75% on the interrow (A4). Organic C (A), Nitrogen (B), C/N ratio (C), Phosphorus (D), Potassium (E), Calcium (F), Sodium (G), Magnesium (H), Amounts of Base Cation (I), Cation Exchange Capacity (J), Base Saturation (K), and exchangeable Aluminum (L). Boxplots marked with different letters indicate that the mean values between treatments were significantly different at the 5% significance level based on the ANOVA and Duncan's follow-up tests.

Figure 3 shows the complexity of nutrient dynamics in the soil which is difficult to explain. This is because the availability of nutrients in the soil is a combination of biological, chemical, and physical properties [13,14]. Furthermore, soil nutrient availability is significantly influenced by water content, depth, pH, CEC, redox potential, the quantity of organic matter and microbial activity, season, and fertilizer application [14].

The results of the pH analysis in the circle weeding showed that the application of fertilizer will cause a decrease in pH (Figure 4). The more often chemical fertilizers are applied, the lower the pH of the soil. Furthermore, the use of chemical fertilizers in the long term can reduce soil health due to a decrease in organic matter and structural compaction [15,16].

There is a need to vary the application of organic fertilizers to anticipation the decrease in pH and soil fertility. Organic matter can be used in addition to soil organic matter to increase the nutrient release and retention [17], maintain soil moisture [18], increase CEC [19], enhance root growth and biomass [20], as well as microbial activities [21].

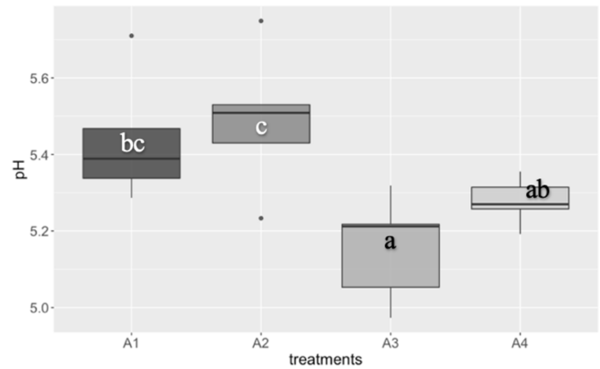

Figure 4 The pH levels in oil palm circle weeding in the treatment of 100% fertilization on circle weeding (A1) and on interrow (A2), 50% on the circle weeding, and the rest on the interrow (A3), and 25% on the circle weeding as well as 75% on the interrow (A4). Boxplots marked with different letters indicate that the mean values between treatments are significantly different at the 5% significance level based on the ANOVA and Duncan's follow-up tests.

3.2. Leaf Nutrients Content

Based on the average leaf nutrient content of each treatment as shown in Figure 5, there was no consistent pattern of leaf nutrient changes due to the effect of fertilization placement. The statistical analysis also showed that the treatment only gave a significant difference to the Ca nutrient.

The leaf nutrient content describes whether the plant has an adequate supply, is deficient, or experiencing toxicity [22]. The application of fertilizers in the circle zone, interrow, and their combination still met the standard for leaf nutrient content, especially for N, P, and Mg, however, K and Ca are low. The optimum leaf nutrient content in oil palm plants are N: 2.24–2.97%, P: 0.08–0.14%, K: 0.78–0.91%, Ca: 0.74–1.53%, and Mg: 0.25–0.98% [23].

Leaf nutrient content is significantly influenced by several factors, namely soil types, available water, yield, fertilizer application [24], plant age, and the presence of weeds. In this study, the leaf nutrient content especially Mg tends to be higher in circle zone fertilization due to the absence of competing weeds in the circle weeding. This is because weeds absorb nutrients through the competition when fertilization is carried out on oil palm plantations [25].

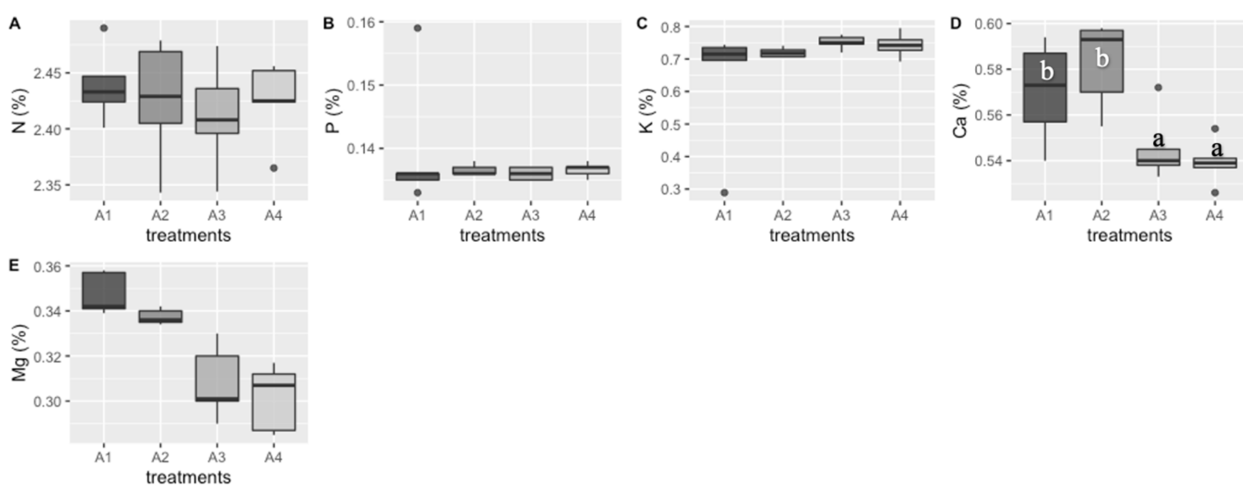

Figure 5 Nutrient content of leaves in the treatment of 100% fertilization on circle weeding (A1) and on interrow (A2), 50% on the circle weeding, and the rest on the interrow (A3), and 25% on the circle weeding as well as 75% on the interrow (A4). Nitrogen (A), Phosphorus (B), Potassium (C), Calcium (D), and Magnesium (E). Boxplots marked with different letters indicate that the mean values between treatments were significantly different at the 5% significance level based on the ANOVA and Duncan's follow-up tests.

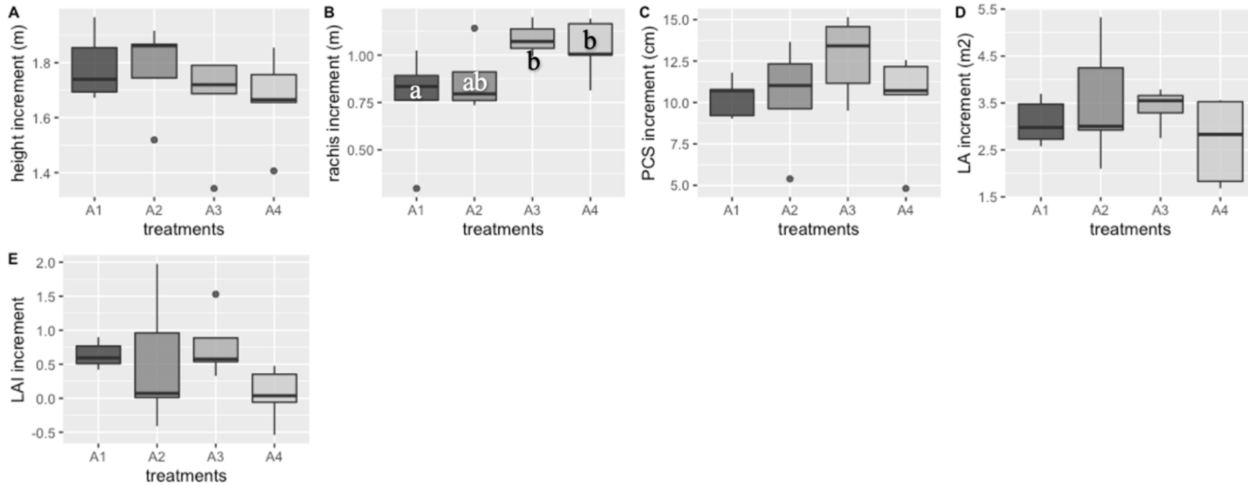

Figure 6 Increase in plant height (A), rachis length (B), petiole cross-section (C), leaf area (D), and leaf area index (E) in the treatment of 100% fertilization on circle weeding (A1), 100% fertilization on interrow (A2), 50% on the circle weeding, and the rest on the interrow (A3), and 25% on the circle weeding and 75% on the interrow (A4). Boxplots marked with different letters indicate that the mean values between treatments were significantly different at the 5% significance level based on the ANOVA and Duncan's follow-up tests.

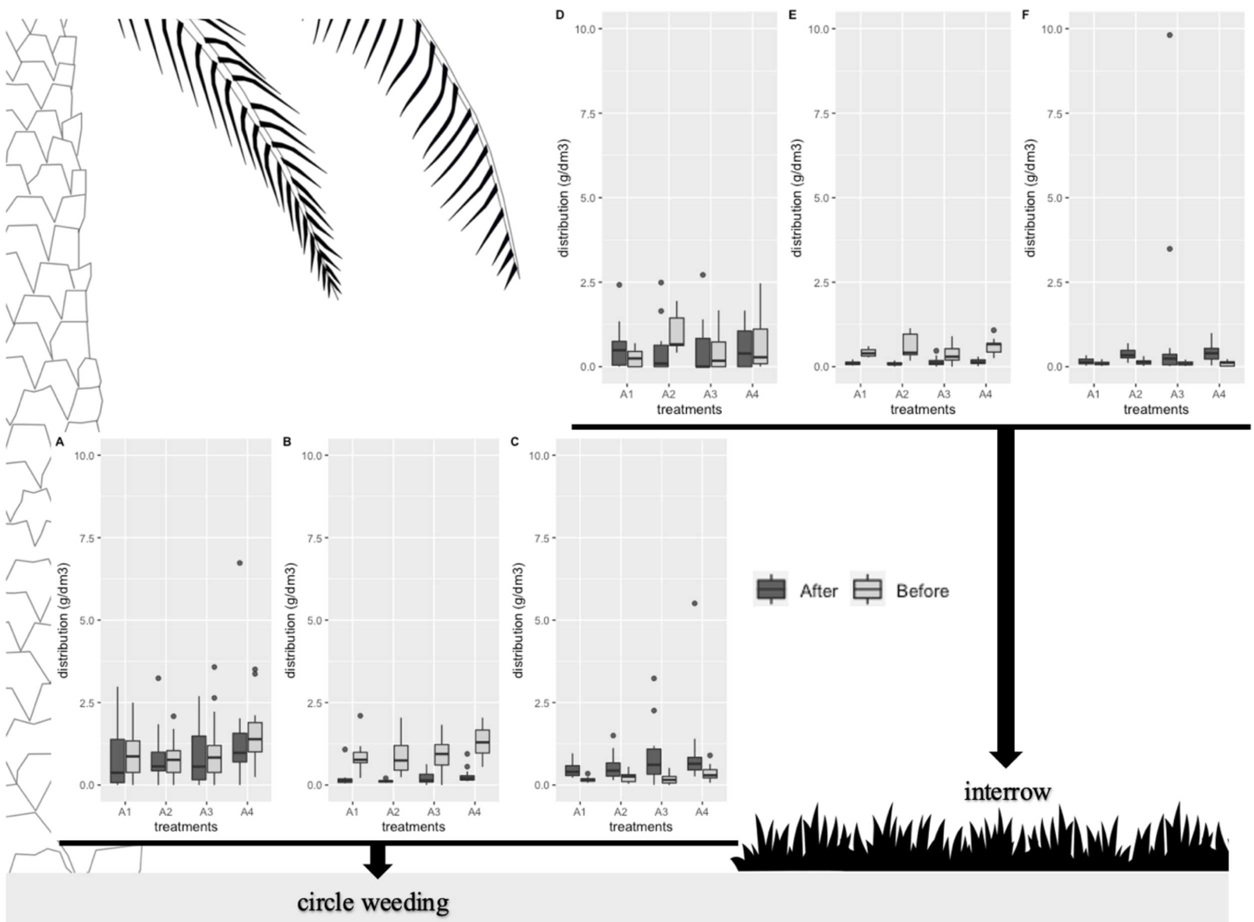

Figure 7 Distribution of primary (A), secondary (B), and tertiary (C) roots in the circle weeding. Furthermore, the distribution of primary (C), secondary (D), and tertiary (E) roots outside the circle zone before and after five years of fertilizer placement treatment. Boxplots marked with different letters indicate that the mean values between treatments were significantly different at the 5% significance level based on the ANOVA and Duncan's follow-up tests.

3.3. Oil Palm Growth

The vegetative growth of the plants was represented by height, rachis length, PCS, leaf area (LA), and leaf area index (LAI). Figure 6 shows the data on the increase in vegetative growth parameters from the beginning to the end of the research. There is no clear pattern due to the treatment of increased plant height. Meanwhile, the increase in length of rachis and PCS tended to be higher in the combination treatment of fertilizer placement in the circle weeding and interrow. The addition of LA and LAI was higher in the placement of fertilization in the circle weeding.

The statistical analysis showed that the placement of fertilization only caused a significant difference in the length of the rachis. However, there is a tendency that fertilization placement is closely related to LA and LAI. Previous investigations explained that the leaf area was affected by fertilization, but it was not very responsive to other external factors [26]. LA and LAI in oil palm were estimated from the number and total area of leaflets, and also number of fronds. During the research, the number of fronds in the location was kept the same in the range of 40-48 fronds/tree. Therefore, it was suspected that the fertilization placement will significantly affect the area and number of leaflets.

3.4. Root Distribution

It was discovered that primary roots are commonly found inside the circle zone based on the distribution of roots (g/dm3) inside and outside the circle weeding as shown in Figure 7. This is the same with the secondary and tertiary roots, although the difference in density between inside and outside the circle zone is not as large as in primary roots. This result was supported by statistical analysis which showed that the fertilizer placement did not cause a significant difference in root distribution. Pradiko [9] and Putri [27], also showed a similar condition, namely higher total root density in the circle zone than under the interrow.

The fertilizer placement did not cause changes in the primary, secondary, and tertiary root biomass. This shows that the growth and development of oil palm roots are not only influenced by the availability of nutrients. Furthermore, root development is also affected by the physical properties of the soil [9]. These include the soil texture, structure, permeability, and moisture [28].

3.5. Oil Palm Yield

Based on the average yield of each fertilization placement as shown in Figure 8A, it is discovered that the yield in A1 treatment is relatively the same as A2, while A3 and A4 are lower. The average yield range of all treatments is 120-150 kg/palm/year or ranges from 16.8-21.0 tonnes FFB/ha.

The increase in the average yield from the beginning to the end of the research was higher in A1 compared to other treatments. Meanwhile, the increase in production that combined the circle weeding and interrow fertilization placement was higher than with the A2 treatment (Figure 8B). This pattern of increasing yield corresponds to that of LAI (Figure 6E). In addition to the larger LAI, the higher production gain was also due to the greater distribution of total roots in the circle zone (Figure 7).

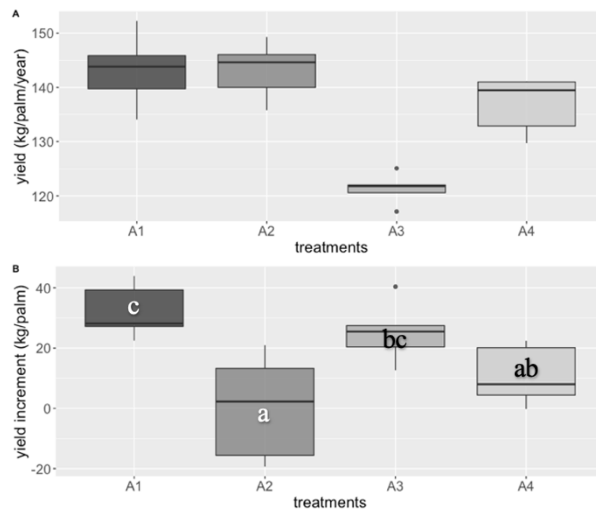

Figure 8 The mean yield of treatments was 100% fertilization on circle weeding (A1), 100% on interrow (A2), 50% on the circle weeding, and the rest on the interrow (A3), and 25% on the circle weeding and 75 % on the interrow (A4) (A). Yield increment of each treatment (B). Boxplots marked with different letters indicate that the mean values between treatments were significantly different at the 5% significance level based on the ANOVA and Duncan's follow-up tests.

Based on Figure 8B, it can be concluded that the placement of fertilizers in the circle weeding can increase production more than in other locations. The lack of a clear and consistent pattern of the influence of fertilization placement on other treatments was caused by the dynamics of nutrient availability in the soil, leaves, and the presence of an NSC reserve system in oil palm trunks [2].

The lower production of fertilizing in the interrow was also caused by competition with weeds. This is because the presence of weeds such as *Mikania micrantha* can lead to nutritional competition with oil palm plants [30]. These weeds are reported to inhibit the growth of other plants and reduce production. The invasion of *Mikania micrantha* has caused production losses of approximately 20% [29,30,31].

Fertilization in the circle zone does further increase productivity, however, selective weed control needs to be carried out when it is applied in the interrow area to avoid competition for nutrients between plants. The management of ground cover vegetation and competitive weed growth restriction can provide the highest oil palm yields after 4 and 6 years [2].

4. CONCLUSIONS

The results showed that the placement of fertilizers in the circle weeding, interrow, and their combination did not significantly affect soil nutrient availability. The continuous application of chemical fertilizers to the circle zone can cause a decrease in pH. Therefore, it is recommended that chemical fertilization is interspersed with the provision of organic materials.

There is no specific pattern of response to changes in leaf nutrient content due to differences in fertilizer placement. The general rate of palm growth was not different. However, there was a tendency that the circle weeding fertilization had a higher leaf area index growth rate than other treatments.

The distribution of roots inside the circle zone is higher than outside. The differences in fertilizer placement do not necessarily change the distribution of roots. This shows that fertilization placement is not the main factor that affects root density.

Different fertilizer placements did not cause significant changes in soil nutrient availability, leaf nutrient content, vegetative growth, and root density. However, it led to variation in production, where oil palm with more fertilizer in the circle weeding yield higher than others.

AUTHORS' CONTRIBUTIONS

IPO was recapitulated data, processed data, arranged, drafted, and finalized the manuscript. ENG set up research in the field, and corrected the soil analysis results. SMY was conducted the data collection in the field, while ADK did the initiation and site plotting. NHD made corrections to the draft. RDP and FAS conducted data analysis and drafted the paper. (IPO: Iput Pradiko, ENG: Eko Noviandi Ginting, SMY: Sumaryanto, ADK: Arsyad D. Koedadiri, NHD: Nuzul Hijri Darlan, RDP: Rizki D. P. Pane, FAS: Fadilla Sapalina).

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