Sustainable pineapple growth performance on mineral soil

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Abstract. In Malaysia, pineapple has been identified as a high-value non-seasonal tropic fruit, which is one of the top five fruits that shows a promising potential in the local and export markets. The variety of pineapple chosen in this study was MD2 hybrid. This variety is promoted for industrial cultivation by Malaysian Pineapple Industry Board (MPIB) because of its uniqueness as in uniformity and consistency for the size and ripeness compared to other varieties. Statistically, 90% of the pineapples in Malaysia are cultivated on peat soil while another 10% are cultivated on mineral soil. Highly weathered mineral soil lead to unfertile soil which inhibit crop growth. Thus, a field experiment was conducted to compare early growth performance of pineapple crop cultivated on mineral soil and peat soil. Based on t-test, growth performance including plant height, leaves length and leaves number showed no significant difference (p>0.05) except for leaf width. The leaf width of pineapple grown on mineral soil was significantly wider than cultivated on peat soil with significant difference of p = 0.015. The chemical analysis showed peat soil was significantly more acidic compared to mineral soil. Mineral soil was significantly higher in nutrients compared to peat soil especially the calcium (Ca) and magnesium (Mg). Meanwhile, peat soil was significantly higher in phosphorus (P) and potassium (K) content compared to mineral soil. From this study, it is found that with additional fertilizer, pineapple can be grown on mineral soil since the properties of soil can support the growth.

1. Introduction

Ananas comosus L. or commonly known as pineapple is one of the most popular tropical fruit in Malaysia. Many varieties are cultivated in Malaysia which includes Maspine, Sarawak, Gandul, Mauritius (Moris), N36, Josapine [1] and MD2. In Malaysia, pineapples are grown in wide area of around 10,847 hectares in 2016 and the cultivation area has expanded to 12,898.44 hectares as the production of pineapple was recorded at 340,721 metric tons in 2017 which was 20% higher than 2016 [2]. Normally, pineapple is consumed fresh or canned as slices, chunks, tidbits, fruit cocktail or juice. The Malaysian Pineapple Industry Board (MPIB) reported that Malaysia exported about 20,278.9 tons of fresh pineapples to several countries, like Singapore, followed by processed products such as canned pineapples (8,853.4 tons), pineapple slips (8,356.4 tons), and pineapple juice (1,461.6 tons) in 2015. The production of pineapple is 322,459 metric tan by year 2018 [2] and it expected the production will increased due to high demand from local and abroad especially from Singapore, Japan, Hong Kong, China, the Middle East and Europe.
Regarding on its propagation, peat soil is considered as marginal soil since the properties limit economic value for agricultural activity purposes. However, in Malaysia the peat soil is considered precious for farmers especially in Pontian, Johor where peat lands are widely used for pineapple plantation. This is due to the organic content in the peat lands that act as natural fertilizer which also can reduce the cost for inorganic fertilizer [3]. The formations of mineral soil are through high degree of weathering which has high acidity, high aluminium (Al), high iron (Fe) contents and low levels of [4]. Highly weathered soils in humid Asia are characterized by low soil fertility and high soil erosion potential. These characteristics require more fertilizer to ensure high yield of pineapple on mineral soils. Previous study had revealed that, application of nitrogen fertilizer on pineapple planted in mineral had increased the Total Soluble Solid (TSS) content [5]. Thus, the prospect and demand of pineapple industry has a bright future for the next 10 years [3]. However, the production of pineapple in this country need to be increased through the expansion of area planted especially mineral soils. It requires various strategies to strengthen the value chain especially on agronomic practices using mineral soil to ensure the sustainability production of pineapple. Therefore, this study was done to evaluate and compare growth performance of pineapple crop cultivated on mineral soil and peat soil.

2. Material and Methods
A field experiment was conducted at two different plots. First plot was conducted at Pontian, Johor, Malaysia and the type of soil are peat soil. The second plot was conducted at the share farm of UiTM, Malacca Branch, Jasin campus and the type of soil are mineral soil. The soil series of mineral soil was Gajah Mati series. Both plots were planted with pineapple MD2 hybrid. The planting distance within the rows and between the rows was 40.00 cm each and each row consisted of 10 suckers. A total of 60 plants were cultivated in each plot. Total area of both plots was 88.00 m². The pineapple sucker was selected as the planting material used for this experiment. The size per sucker was approximately 15.00 cm in height. Each of suckers received homogeneous rate of 14.00 g/plant of NPK fertilizer (15: 15:15) throughout the experiment. The growth performance of pineapple cultivated on both plots were observed and measured weekly for 3 months. The parameters of plant height (cm), D-leaf length (cm) (longest central leaf), number of leaves, and leaf width (cm) were recorded. All parameters were measured using a measuring tape.

Soil sampling were carried at both plot and soil samples were collected on the planting line at the depth of 0–15 cm (surface soils) at three random points and were mixed well to get a composite sample for each plot. The collected composite soil samples were air-dried for a week, crushed, and homogenized. The soil samples were analyses for electrical conductivity (EC), available phosphorus (P) content, and cation exchange capacity. Ten core soil samples were randomly collected and sampled from peat soil and mineral soil at depth of 0.00-15.00 cm. The soil pH was determined in soil solution with a ratio of 1:2 in 0.01M CaCl₂. Electrical conductivity (EC) analysis was measured using the EC probe with calibrated conductivity meter. Available P analysis was determined by extraction method where the exchangeable bases were extracted with neutral 1M NH₄OAc at a soil solution ratio of 1:10 [6] and measured by Inductively Coupled Plasma (ICP). Selected nutrient analysis of potassium (K), calcium (Ca), and magnesium (Mg) were determined by wet oxidation with HNO₃+HClO₄. Cation exchange capacity analysis was determined at pH 7.00 with ammonium acetate (C₃H₅NO₂) [7]. The collected data were analyzed using Microsoft Excel 2003 and Statistical Package for the Social Science (SPSS) 22.0 program. Mean comparisons were performed using t-test at 5.00% significance level.

3. Results and Discussion
Results showed that the pineapple cultivated on both type of soil grew successfully.

3.1. Plant Growth Performance
Figure 1 shows the leaf length of pineapple cultivated on mineral soil was higher when compared to pineapple cultivated on peat soil. There was no significant difference (p = 0.232). It was observed that
pineapple cultivated on mineral soil had a decreased in leaf length. The decreased in leaf length especially on mineral soil is due to heart rot diseases as shown in Figure 1b. According to the [8], pineapple is more suitable to be planted on hemic peat soil. In addition, [9] stated that there is emerging interest of planting fresh fruit varieties on mineral soil but, the average yield of pineapple cultivated on peat soil slightly was higher than mineral soil. According to [10], ‘Josapine’ pineapple grown on mineral soil is more susceptible to bacterial heart rot disease. Leaf number of pineapple cultivated on peat soil was shown to have gradually increased. Figure 2 shows the leaf number of pineapple has a similar pattern to leaf length cultivated on mineral which was more than cultivated on peat soil especially at the early growth of planting. In spite of that, the leaf number decreased due to heart rot disease. Statistical analysis based on t-test showed that there was no significant difference between both types of soil ($p>0.05$).

Statistical analysis indicated that leaf width of pineapple cultivated on mineral soil was significantly wider when compared with peat soil. Figure 3 shows in the early of planting, the leaf width of pineapple cultivated on mineral soil was higher than $p = 0.015$ on peat soil. Despite of that, there was not much differences from week 4 until week 11.

![Figure 1. a) Pineapple cultivated on mineral soil b) Pineapple grown on mineral soil infected by heart rot diseases.](image1)

![Figure 2. Average of pineapple leaf length.](image2)

![Figure 3. Average of pineapple leaf number.](image3)
Figure 4 shows in early growth stage of pineapple cultivated on mineral soil shows more wider leaf when compared to pineapples that cultivated on peat soil. T-test shows it was significantly wider when compared to pineapples cultivated on peat soil ($p = 0.015$). Unfortunately, the leaf width was reduced and slightly lower than pineapples cultivated on peat soil starting on week 10th. Figure 5 shows pineapple cultivated on peat soil had progressively increased in plant height compared to mineral soil which fluctuated between week 5 to week 7. However, there was no significant difference recorded in plant height on both types of soil. The plant height of pineapple grown on peat soil shows consistently increased in plant height.

Pineapple sucker significantly have a good growth performance on both types of soils. It is attributed to the properties of soils. Based on the observations, pineapples cultivated on mineral soil showed better growth performance compared to peat soil with only significance in leaf width. The finding was consistent and supported by previous study from [9] that claimed pineapple cultivated on mineral soil had better quality than those planted on peat soil. It is probably due to the pH of mineral soil which slightly acidic compared to peat soil that contained highly acidic condition. Acidic condition of peat soil is caused by the presence of several organic compounds such as the exchangeable hydrogen and aluminium, iron sulphide and other oxidizable sulphur compounds. The availability of nutrients for plant uptake is greatly affected by soil pH particularly macronutrients. For example, phosphorus is significantly affected by low soil pH because it reacts with Al and Fe oxides which formed insoluble Al or Fe phosphate and resulted P unavailable [11] and it subsequently may affect plant growth performance. Furthermore, nutrient availability in the mineral soil is generally high and pineapple grown on mineral soil is sweeter than those grown on organic peat [10]. The most likely reason for less pineapple growth on peat soil when compared with mineral soil is due to its low nutrient availability and also the source of nutrient that was derived from decomposition of organic materials which limited its potential for extensive agriculture use [12].
3.2 Soil Chemical Properties

The chemical properties of peat and mineral soil were evaluated. The pH of peat soil was significantly acidic compared to mineral soil. Table 1 shows the pH of mineral soil with 5.38 which is in the range of pH that is suitable for pineapple growth whereas, pH of peat soil was strongly acidic with 3.40. The acidity of peat soil is due to the presence of organic acid and abundance of H⁺ ion released from organic matter decomposition that can lead the soil to become acidic [13]. Soil pH determines nutrient bioavailability and hence fruit growth, yield, and quality. EC of peat soil was significantly higher than mineral soil. This observation indicated that the increase of microbial decomposition can lead to higher salinity in peat soil. Nonetheless, the salinity level of peat soil did not exceed the maximum level for plant growth (1 dSm⁻¹). From this study, the cation exchange capacity (CEC) of both type soils was consistent with soil pH. However, the capacity of mineral soil to hold exchangeable cations was low at 18.89 cmolc/kg. The CEC of mineral soil can be increased by application of organic matter especially N, P and K [14]. Soils with a low CEC are more likely to develop deficiencies in potassium (K⁺), magnesium (Mg²⁺) and other cations while high CEC soils are less susceptible to leaching of these cations [15].

| Soil type | pH    | Salinity (dSm⁻¹) | CEC (cmolc/kg) |
|-----------|-------|-----------------|---------------|
| Peat      | 3.49* | 0.23            | 2.83*         |
| Mineral   | 5.38  | 0.09*           | 18.89         |

*Notes within a column are significantly different by the t-test (p = 0.05)

Both type of soil had low available P probably due to acidic condition (pH<6.5). As presented in Table 2, the P, K and Ca nutrient contents of both soils showed significant difference except for exchangeable Mg. Available P of mineral soil was significantly low when compared with peat soil. This was probably due to high contents of Al and Fe which resulted from high degree of weathering of mineral soil [4]. The presence of Al and Fe oxides increases phosphorus fixation capacity and subsequently lead to yield losses in the range of 10% to 15% of the maximal yields [16]. Thus, cultivation of pineapple on both types of soil need to be supplied with phosphate fertilizer to promote plant growth because P is major element in the plant growth and metabolism especially for cell division and development, photosynthesis, breakdown of sugars, energy transfer, nutrient transfer within the plant and expression [16].

| Soil type | Available P (mg kg⁻¹) | Exchangeable |
|-----------|-----------------------|--------------|
|           |                       | K (mg kg⁻¹)  | Ca (mg kg⁻¹) | Mg (mg kg⁻¹) |
| Peat      | 23.51                 | 98.56        | 441.04*      | 43.82        |
| Mineral   | 0.40*                 | 91.61*       | 626.81       | 45.56        |

*Notes within a column are significantly different by the t-test (p = 0.05)

Statistical analyses showed that the exchangeable (K) was significantly higher on peat soil when compared with mineral soil (p<0.05). K is required in large quantity to sustain pineapple plant growth [17] and it also influenced acid contents of fruit but higher doses cause a depression in fruit yield [18]. The exchangeable Ca in both type of soils were related to soil pH. The presence of high Ca in mineral soil was contributed to slightly acidic condition while low Ca resulted strong acidic for peat soil. No significant difference was found in exchangeable Mg (p>0.05). The exchangeable Mg for peat and
mineral soil were 43.82 mg kg\(^{-1}\) and 45.55 mg kg\(^{-1}\) respectively. Even though the exchangeable of Mg is considered low there is no effect of magnesium on fruit quality on the peat soil.

4. Conclusion
Mineral soil particularly has a more suitable soil pH and higher nutrient contents which clearly contributes to the growth performance of pineapple seedlings. Besides, its soil fertility was better than peat soil, it can improve the growth performance and obtain high yield production. Thus, the production of pineapple in this country can be sustain not only rely on peat soil but through cultivation on mineral soil. Effective soil management and conservation especially fertilizer managements are required and need a proper identification to ensure high yield production as well as minimizing the production cost.

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