BIO Web of Conferences **73**, 01013 (2023) https://doi.org/10.1051/bioconf/20237301013
CTReSS 5.0

The Growth Performance of Pineapple Seedlings Planted with Mycorrhizae and Different Rates of Phosphorus Fertiliser

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Abstract. Pineapple stands as a promising crop with potential for widespread cultivation across Malaysia. Nevertheless, factors like the elevated cost of fertilisers and certain environmental challenges have acted as obstacles to pineapple production within the country. The application of mycorrhiza presents an opportunity to curtail fertilisers usage and thereby mitigate environmental strain. This study seeks to assess the impact of mycorrhiza on pineapple growth and determine an optimal Phosphorus (P) fertilisers rate that complements mycorrhizal activity, all while enhancing pineapple growth. A randomised block design with six replications was employed. The study maintained a consistent mycorrhiza application rate of 5 g/plant but varied the Phosphorus fertilisers rate. Data on leaf length, plant height, fresh weight, and dry weight were collected and subjected to analysis. The study, conducted over a four-month period at UiTM Jengka, Pahang, culminated in results analysed through Microsoft Excel and MINITAB. Notably, Treatment 3 displayed the most robust growth performance across leaf length, plant height, and fresh weight. However, Treatment 5 emerged as the optimal choice for enhancing dry plant weight.

1 Introduction

In Malaysia, pineapple (*Ananas comosus* L. Merr.) is the first crop grown as a commodity crop with high export potential. Malaysia emerged as one of the top three

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exporters of fruit worldwide between the late 1960s and early 1970s [1]. In Malaysia, 90% of pineapples are planted on peat soil, while the rest are on mineral soil. In 2021, Malaysia produced 375, 423. 24 metric tonnes with an acreage of 16, 203.72 acres. Currently, 95% of canned pineapple production is for the export market and 5% is for the domestic market. While 30% of fresh pineapple contributes to export, another 70% is consumed domestically [2]. The pineapple industry in Malaysia plays a significant role in the country's agriculture sector. As one of the largest producers of pineapples globally, it generates revenue for the country's foreign exchange earnings. The export market for Malaysian pineapples includes countries in Asia, such as Singapore, China, and Japan, as well as the Middle East and other regions. The Agriculture and Food Security Ministry (MAFI) through the Malaysian Pineapple Industry Board (MPIB) recorded that the export of pineapples has continuously shown signs of increasing from RM64.2 million in 2020, RM1.1 billion in 2021 and RM1.2 billion in 2022 [3]. This was in line with the government's target to increase pineapple farmer income to RM8,000 per month under the 12th Malaysia Plan (RMK12) (2021-2025) from the previous RM5,000 under the 11th Malaysia Plan (RMK11) (2016-2020) [4]. With a diverse climate and fertile soil, it allows for the cultivation of different pineapple varieties, each with its own unique taste, texture, and culinary uses. The most popular pineapple varieties in Malaysia include MD2, Moris, Josephine, N36, and Sarawak, which are mostly grown across Sarawak, Johor, Negeri Sembilan, and Selangor [5]. The Sarawak pineapple is characterised by its cylindrical shape, spiky skin, and vibrant yellow flesh. It is known for its sweet taste and is commonly consumed fresh or used in traditional dishes and desserts.

Pineapple cultivation requires proper soil nutrition and the application of suitable fertilisers to ensure healthy growth and maximise yield. The fertiliser requirements for pineapple cultivation typically depend on factors such as soil fertility, nutrient content, and specific regional conditions. According to a study, limitations on soil fertility have an impact on the output and quality of pineapple fruits [6]. To sustain growth and crop productivity, pineapple plants require nutrients such as nitrogen (N), phosphorus (P), and potassium (K) [7]. These nutrients have a specific role and must be provided to the plant in sufficient quantities and at the proper time [8]. For example, before planting, a balanced fertiliser with a higher phosphorus (P) content, such as NPK 15-15-15 or 16-20-0, can be applied at the recommended rates. Adequate phosphorus in the soil enhances the development of both shoot and root systems of crop yields [9]. Nevertheless, many soils in farming environments lack P, and this deficiency substantially reduces crop yield [10] leading to a higher fertiliser requirement. In such cases, farmers often resort to using additional fertilisers to meet the phosphorus demand of the crops.

1.1Detrimental effects of excessive use of chemical fertiliser

Due to the long growth cycle of pineapples and the generally poor nutrient contents of soil in tropical places, farmers typically use fertilisers in excess for the cultivation of tropical pineapples [11]. The intensive use of N and P fertilisers on farmland has prompted eutrophication, a process in which a water body becomes overly enriched with nutrients, thus resulting in excessive algae growth, oxygen depletion, and declining aquatic biodiversity [12]. Moreover, continuous use of chemical fertilisers without proper management practices can lead to soil degradation. Findings demonstrate reduced size and number of macropores in the soil, which led to the physical deterioration of soil attributable to the increased soil bulk density and penetration resistance [13]. Accordingly, the structural degradation of soil caused compaction due to the inability of the soil water to drain away freely and the restricted air movement in the soil. Reliance on chemical

https://doi.org/10.1051/bioconf/20237301013

fertilisers also can increase the cost of pineapple production. The continuous need for purchasing and applying chemical fertilisers adds a burden for farmers, especially small-scale ones. A previous study has revealed the cost of input was identified as the factor affecting pineapple supply among pineapple growers in Johor [14]. Most of the farmers agreed that the high costs of fertiliser have a direct effect on the quantity and quality of their farm produce. Therefore, the combined application of chemical fertiliser and organic fertilisers is the way forward to reduce the costs of fertiliser as well as to support sustainable agriculture.

1.2 Benefits of arbuscular mycorrhizal fungi (AMF)

Many efforts are being made to minimise the environmental impact of pineapple production. For example, adopting integrated nutrient management practices. This practice involves a combination of organic and inorganic fertilisers and other nutrient sources. The use of arbuscular mycorrhizal fungi (AMF) as a biofertiliser in the nursery phase can indeed promote the production of high-quality plants while reducing the reliance on chemical fertilisers [15]. AMF forms a symbiotic association with plant roots, facilitating nutrient uptake and promoting plant growth. The benefits of mycorrhizae are it is suitable for tropical soil because phosphorus availability is limited due to P-fixation. Previous research has demonstrated the advantages of inoculation with AMF in low-fertility soils [16]. Additionally, research by [17] highlighted that the inoculation with mycorrhizal fungi in a pineapple at the acclimatization stage is advantageous for growth and nutrient uptake enhancements by the plants, particularly under conditions with low P levels. AMF enhances nutrient uptake by increasing the root surface area for absorption causing improvement in plant growth [18]. These mycorrhizal fungi are particularly effective in enhancing various nutrient uptake hence improving the quality of soil [19]. Besides, AMF enhances the plant's ability to withstand stress factors such as drought, salinity, and diseases. They improve the plant's water and nutrient absorption capabilities, making it more resilient and less susceptible to environmental stressors [20]. Thus, the use of AMF as a biofertiliser aligns with sustainable agriculture practices as it can promote soil health, minimise environmental impact, and contribute to more sustainable plant production. Therefore, this study proposed the effect of mycorrhizae on the growth of pineapple with different rates of phosphorus fertiliser.

2 Methodology

The study was conducted on 100 acres farm at Universiti Teknologi MARA (UiTM) Pahang for the duration of four months to assess the growth of pineapple seedlings. Sarawak variety suckers, endomycorrhiza, and phosphate fertiliser have been used to evaluate their effects on the growth performance of pineapple seedlings during the early stage of planting. Randomised Complete Block Design (RCBD) was applied in the study on uncontrolled environmental conditions.

5 g of Arbuscular Mycorrhizal Fungi (AMF) were used [21] with different rates of Phosphorus fertiliser including 0.11 g/plant, 0.23 g/plant, and 0.34 g/plant [22]. There are five treatments in the study consisting of Treatment 1 (0 g AMF + 0 g/plant of Phosphorus as a control, Treatment 2 (5 g AMF + 0 g/plant of Phosphorus), Treatment 3 (5 g AMF + 0.11 g/plant of Phosphorus), Treatment 4 (5 g AMF + 0.23 g/plant of Phosphorus) and

Treatment 5 (5 g AMF + 0.34 g/plant of Phosphorus) with six (6) replications given in a total of 30 experimental units.

The parameter was recorded during the experiment and post-experiment. The parameters collected were the length of the leaves, the width of the leaves, and the height of the leaves. In the post-experiment, the fresh weight of the plant, the dry weight of the plant, and the moisture content are recorded. All the data was recorded using Microsoft Excel to describe tables and graphs. The data was then analysed using the MINITAB application to analyse the data accurately.

3 Findings

The length of leaves, the width of leaves, plant height, fresh weight, dry weight, and moisture content were recorded in response to the application of mycorrhizae and different rates of phosphorus. The data shown in Figure 1 were recorded in Week 16. Figure 1 displays that the longest length of leaves recorded is at Treatment 3 (20.0cm) followed by Treatment 4 which is 17.4 cm. Meanwhile, Treatment 1 recorded the lowest length of leaves which is 13.1 cm. It is shown that Treatments 2, 3, 4, and 5 did not show any significant difference between each other. However, Treatment 3 shows a significant difference when compared with Treatment 1. For the width of leaves, Treatment 3 shows the highest width (0.7 cm). Then followed by Treatment 4 (0.6 cm), Treatment 5 and Treatment 2 (0.5 cm), and Treatment 1 (0.4cm). The result shows that all treatments did not show any significant difference when compared to each other.

At Week 16, the highest plant height is recorded in Treatment 3 which is 22.0 cm. Meanwhile, a 17.0 cm plant height was recorded in Treatment 5. Even though the plant height in Treatment 3 is taller compared to Treatment 5, both results did not show any significant difference from each other. Plant height in Treatment 3 did significantly differ from Treatment 1, Treatment 2, and Treatment 4. The fresh weight of the pineapple seedling was taken at Week 16. From the results, Treatment 3 did not show any significant difference when compared to Treatment 5, Treatment 4, and Treatment 2. The fresh weight of pineapple seedlings recorded are 761.7 g, 698.3 g, 486.7 g, and 476.7 g respectively. The lowest fresh weight was recorded in Treatment 1 (413.3 g). The dry weight of the pineapple seedlings recorded for the study is Treatment 1 (248.3 g), Treatment 2 (255 g), Treatment 3 (330 g), Treatment 4 (216.7 g), and Treatment 5 (341.7 g). The highest dry weight was recorded at Treatment 5 and the lowest dry weight was recorded at Treatment 1. The variability in results however did not represent any significant difference in each treatment.

 https://doi.org/10.1051/bioconf/20237301013

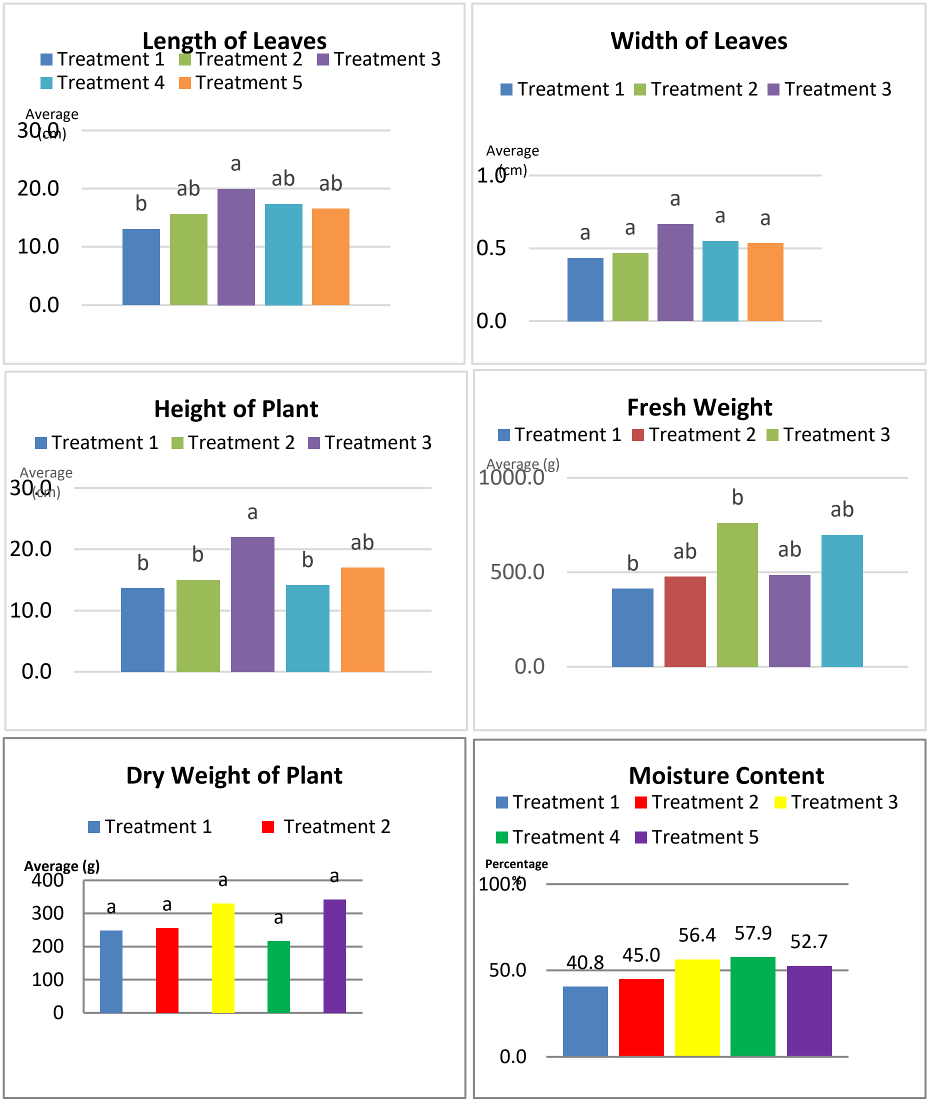

Figure 1. Mean Comparison on Parameters of Study

Treatment 4 has the highest moisture content compared to other treatments, which is 57.9 % (Figure 1). The lowest moisture content is Treatment 1 which is 40.8 %. The moisture content recorded for Treatment 2, Treatment 3, and Treatment 5 are 45.0 %, 56.4 %, and 52.7 % respectively. Table 2 shows the analysis of variance for the length of leaves, the width of leaves, and plant height. There was a significant difference in the length of leaves and plant height towards the application of mycorrhizae with different rates of phosphorus fertiliser on pineapple seedlings where the P value was 0.045 and 0.012 respectively. However, there was no significant difference in the width of leaves towards the application of mycorrhizae with different rates of phosphorus fertiliser on pineapple seedlings where the P value was 0.651.

Table 2. ANOVA on Parameters of Study

Source	DF	Length of leaves				Width of leaves				Height of plant			
		SS	MS	F	P	SS	MS	F	P	SS	MS	F	P
Block	5	143.18	28.64	2.24	0.090	0.48700	0.09740	1.25	0.324	89.60	17.92	1.10	0.389
Treatment	4	151.16	37.79	2.96	0.045	0.19467	0.04867	0.62	0.651	276.94	69.24	4.27	0.012
Error	20	255.57	12.78			1.56133	0.07807			324.56	16.23		
Total	29	549.92				2.24300				691.10			

DF= Degree of Freedom; MS=Mean Sum of Square; SS=Sum of Square; P= p value

4 Discussions

In this study, all plants showed an association with AMF, however, the response to phosphorus fertilization levels varied among treatments. The growth performance of pineapple seedlings was good with the application of mycorrhizae and the minimum level of P nutrient. This can be observed in Treatment 3 (5 g AMF + 0.11 g/plant of Phosphorus) as it showed significantly higher in terms of the length of leaves and height of the plant. Pineapples with the lowest P level were the most significant in terms of plant development and shoot content [23]. In addition, according to [24], the degree of fertiliser in the host plant affects the mycorrhizal activity where, if the P level is higher, the mycorrhizal symbiosis will not occur. It is known that when P availability increases plants do not produce the necessary signals for the establishment of mycorrhizal symbiosis [25]. Similar results have been reported for sugar cane [26], where the AMF inoculation and the application of half of the fertiliser dose promoted the highest values in leaf area, height, and diameter. According to [27] mycorrhizal effect on pineapple growth decreases in higher phosphate soil. Non-mycorrhizal treatment shows the lowest average growth of plant height which is 13.6 cm indicating the significance of mycorrhizae application. Hence, the results also show that inoculation of AMF improved the growth of pineapple during the first phase of growth as stated by [28]. This can be proved by the result of this study as Treatment 3 recorded the highest length and width of the leaves, the high plant height, and the high fresh weight of the pineapple plant as compared with other treatments. Mycorrhizae associations help pineapple plants uptake water and improve soil structure. A better root system that is adaptive for water uptake emerged from Endomycorrhizal modification on root architecture [29] to support the result. Based on [30], growth and plant bio-productivity are frequently quantified based on dry matter accumulation such as carbon, protein, and carbohydrates. In this study, the dry weight of mycorrhizal plants in Treatment 5 was higher than in other treatments. [31] stated, the mycorrhiza association helps the plant to obtain water which is critical for plant growth and survival. As stated in a book titled 'Pineapple Production and Post-Harvest Handling' published by the Ministry of Agriculture in Guyana in 2014 [32], water is important to ensure good growth of the pineapple plant although the pineapple plant is resistant to drought. Thus, mycorrhiza's association with pineapple can help water uptake. Pineapple has low P requirements [24], and a high sensitivity to excessive P [25], same as observed in this study.

5 Conclusion and Implication

The application of mycorrhiza can improve the growth of pineapple plants in the early stage of planting. Mycorrhization significantly increased plant growth as shown by the results of Treatment 1 where it gave the lowest result in most of the parameters. Besides, moisture content also was affected by the mycorrhization where all treatments with mycorrhizae showed a higher percentage than non-mycorrhizal treatment. According to [28], mycorrhizal plant grows better than nonmycorrhizal plant. The height of the plant, leaves length and width react differently to varying rates of P fertiliser. Based on the result, Treatment 3 is the best combination for the length of leaves and height of plant parameters. Treatment 3 has mycorrhiza application with low P fertiliser input. Based on [31], a low but sufficient level of P in the soil is needed to have a beneficial association between the fungus and plant roots. Thus, based on this study, 0.11 g/plant is sufficient for the pineapple plant to benefit from mycorrhiza. Based on the results of this study, it can be indicated that mycorrhiza association may become a substitution for commercial fertiliser application while allowing high-quality plant material production within a sustainable production process. [15] stated, that the application of mycorrhiza application can replace fertilization. Thus, it can be concluded that the application of mycorrhizae improves the growth performance of the pineapple plant such as the length of the leaves, the width of the leaves, the height of the plant, the fresh and dry weight of the plant, and the moisture content. As a recommendation, further studies on the interaction between mycorrhiza and pineapple plants need to be conducted to increase their effectiveness. For instance, research on the compatibility between different pineapple varieties and types of mycorrhiza fungi must be done. Different dosages of mycorrhiza also can cause different growth performances of pineapple plants.

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