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EFFECT OF INDIGENOUS AND NON-INDIGENOUS ARBUSCULAR MYCORRHIZAL FUNGI ON GROWTH, SOIL FERTILITY AND PLANT NUTRIENTS UPTAKE IN TERUNG ASAM (Solanum lasiocarpum Dunal)

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By

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EFFECT OF INDIGENOUS AND NON-INDIGENOUS ARBUSCULAR MYCORRHIZAL FUNGI ON GROWTH, SOIL FERTILITY AND PLANT NUTRIENTS UPTAKE IN *TERUNG ASAM* (*Solanum lasiocarpum* Dunal)

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Terung asam (*Solanum lasiocarpum* Dunal) is a native fruit vegetable that is gaining interest as a commercial crop in Sarawak and Malaysia. Malaysia is covered by soils that are highly weathered, acidic and low in fertility and depend on chemical fertilizers to promote good plant growth. Alternative means to reduce dependency on chemical fertilizer e.g., arbuscular mycorrhizal fungi (AMF), must be sourced. Very little research on *terung asam* has been documented particularly on nutrient uptake. The objectives of this research were to: (i) determine the effect of indigenous and non-indigenous AMF on *terung asam*, (ii) investigate the effect of indigenous and non-indigenous AMF on soil fertility and nutrient uptake by *terung asam*, and (iii) evaluate colonization by indigenous and non-indigenous AMF on the root of *terung asam*. A greenhouse experiment was conducted using two indigenous AMF (T2 and T3), one non-indigenous AMF (T4) and one control (T1). The treatments were arranged in a complete randomized design with four subsamples and four replicates. Thirty-day-old seedlings were transplanted and measured for height, stem diameter, leaf chlorophyll for 90-days. Fresh and dry shoot and root weights were taken during harvesting. Plant nutrient analyses were conducted using Kjeldahl method for total N, single ashing for P and single ashing and double acid for K, Ca and Mg. Soil nutrients were extracted using Kjeldahl method for soil total N, aqua regia for total P, double acid for available P, aqua regia for total K, Ca and Mg and dilute double acid for exchangeable K, Ca and Mg. AMF root colonisation was conducted based on the gridline intersection method. Results revealed that the addition of AMF spores increased plant height by 13 to 33% and stem diameter by 5 to 25%. T4 plants showed dominance over T2 and T3. More leaves were retained by T4 plants at harvesting, an indication that the plant is stronger than other treatments. T4 recorded higher fresh shoot (11.27%) and dry shoot (14.98%) as well as fresh root (23.67%) and dry root (22.77%) weights than T1 plants. All potting media detected a decrease in total nutrient contents but increased in exchangeable K (88.55 to 158.88%), Ca (91.88 to 271.25%) and Mg (200.22 to 663.38%) were observed, with T2, T3 and T4 showing

higher values than T1. Addition of AMF in treatments T2, T3 and T4 promoted better nutrient uptake by aboveground and belowground biomasses particularly for K, Ca and Mg. T4 was superior in terms of nutrient uptake for most nutrients. T3 recorded higher root colonisation (69.32%) followed by T4 (64.71%) with structures like arbuscules, vesicles and hyphae observed. AMF in T4 showed better results as the AMF spores are proven effective in promoting plant growth while AMF used in T2 and T3 were obtained from the field and untested. Indigenous AMF in T3 showed better results than T2 which could be related to the source of the inoculum. Finding of this study showed the potential of indigenous and non-indigenous AMF in promoting growth and nutrient uptake by *terung asam* plants.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KESAN FUNGI ARBUSKULAR MIKORIZA TEMPATAN DAN ASING KE ATAS PERTUMBUHAN, KESUBURAN TANAH DAN PENYERAPAN NUTRIEN TUMBUHAN OLEH TERUNG ASAM (*Solanum lasiocarpum* Dunal)

Oleh

MUHAMMAD AKMAL BIN SHAHUDIN

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Terung asam (*Solanum lasiocarpum* Dunal) adalah sayuran buah asli, yang minat terhadapnya sedang meningkat sebagai tanaman komersial di Sarawak dan Malaysia. Malaysia dilitupi oleh tanah yang tinggi luluhawa, berasid dan kurang subur yang bergantung kepada baja kimia untuk menghasilkan pertumbuhan tanaman yang baik. Kaedah alternatif untuk pengurangkan kebergantungan kepada baja kimia seperti fungi arbuskular mikoriza (AMF) hendaklah dicari. Kajian mengenai terung asam terutama yang melibatkan penyerapan nutrien amatlah terhad. Objektif kajian ini adalah untuk: (i) menentukan kesan AMF tempatan dan asing terhadap terung asam, (ii) menyelidik kesan AMF tempatan dan asing terhadap kesuburan tanah dan penyerapan nutrien oleh terung asam, dan (iii) menilai kolonisasi oleh AMF tempatan dan asing ke atas akar terung asam. Satu ujikaji rumah hijau menggunakan dua AMF tempatan (T2 dan T3), satu AMF asing (T4) dan kawalan (T1) telah dijalankan. Rawatan telah disusun dalam rekabentuk rawak penuh dengan empat subsampel dan empat replikasi. Anak benih berumur 30 hari ditanam dan pengukuran ke atas ketinggian, diameter batang dan klorofil daun dilakukan selama 90 hari. Berat segar dan kering bagi pucuk dan akar dilakukan semasa penuaian. Analisis nutrien tumbuhan dibuat menggunakan kaedah Kjeldahl untuk total N, pengabuan ringkas untuk P dan pengabuan ringkas serta asid berkembar untuk K, Ca dan Mg. Nutrien tanah diekstrak menggunakan kaedah Kjeldahl untuk jumlah N tanah, *aqua regia* untuk jumlah P, asid berkembar untuk P tersedia, *aqua regia* untuk jumlah K, Ca dan Mg dan asid berkembar cair untuk K, Ca dan Mg tertukarganti. Kolonisasi akar oleh AMF dibuat berdasarkan kaedah silangan garisan grid. Keputusan menunjukkan penambahan spora AMF meningkatkan ketinggian tumbuhan sebanyak 13 hingga 33% dan diameter batang sebanyak 5 hingga 25%. Tumbuhan T4 menunjukkan dominasi ke atas T2 dan T3. Lebih banyak daun dikekalkan oleh tumbuhan T4 semasa penuaian, menunjukkan bahawa tumbuhan tersebut lebih kuat berbanding rawatan lain. T4 mencatatkan berat segar pucuk (11.27%) dan kering pucuk (14.98%) yang lebih tinggi, begitu juga dengan berat segar akar dan berat kering akar berbanding tumbuhan T1.

Semua media tanaman menunjukkan penurunan dari segi jumlah kandungan nutrien tetapi peningkatan dalam tukarganti K (88.55 hingga 158.88%), Ca (91.88 to 271.25%) dan Mg (200.22 to 663.38%) dengan T2, T3 dan T4 menunjukkan nilai yang lebih tinggi berbanding T1. Penambahan AMF dalam rawatan T2, T3 dan T4 menggalakkan penyerapan nutrien yang lebih baik oleh biomassa atas tanah dan bawah tanah terutama yang melibatkan K, Ca dan Mg. T4 adalah unggul dari segi penyerapan kebanyakan jenis nutrien. T3 merekodkan kolonisasi akar tertinggi (69.32%) diikuti T4 (64.71%) dengan struktur seperti arbuskul, vesikel dan hifa kelihatan. AMF dalam T4 menunjukkan keputusan yang lebih baik memandangkan spora AMF telah terbukti efektif dalam menggalakkan pertumbuhan tanaman manakala T2 dan T3 diperolehi daripada lapangan dan tidak teruji. AMF tempatan dalam T3 menunjukkan keputusan yang lebih baik berbanding T2 yang mungkin berkaitan dengan sumber inokulum diperolehi. Penemuan kajian ini menunjukkan potensi AMF tempatan dan asing dalam menggalakkan pertumbuhan dan penyerapan nutrien oleh tanaman terung asam.

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I certify that a Thesis Examination Committee has met on 18 February 2021 to conduct the final examination of Muhammad Akmal bin Shahudin on his thesis entitled "Effect of Indigenous and Non-Indigenous Arbuscular Mycorrhizal Fungi on Growth, Soil Fertility and Plant Nutrients Uptake in *Terung Asam* (*Solanum lasiocarpum* Dunal)" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

AMF	Arbuscular mycorrhizal fungi
PSB	Phosphate solubilizing bacteria
GI	Geographical Indications
MyIPO	Malaysian Intellectual Property Organisation
DAT	Day after transplanting

CHAPTER 1

INTRODUCTION

Malaysia is very much dependent on food imports. The import value of food to Malaysia in 2019 was valued at approximately 51.46 billion Malaysian ringgit. This value of imports of food has been showing an increasing trend since 2012 despite a decline in 2018 (Hirschmann, 2021a). Malaysia's over-reliance on imports makes the nation venerable to food shortages and large food import bills particularly in times of global crisis, as what had happened in 2007–2008. Such a scenario is of high concern to the country's economy especially with the weakening of the ringgit and more must be spent to purchase such commodities.

Malaysia is covered by soils that are highly weathered and acidic, namely the Ultisols and Oxisols which are not fertile for crop production. These soil groups are commonly found in the tropics and contain a low amount of organic matter thus making them insufficient in promoting plant growth (Shamshuddin and Anda, 2012). To alleviate the infertility issue, compost is normally applied to such soils (Anda *et al*., 2010). Another approach to manage such problems is by applying mineral fertilizers. In 2018, NPK fertilizers import for Malaysia was reported at 263,417 tonnes. Meanwhile, fertilizer consumption for the same year was 2,106.5 kilograms per hectare, an increase from 175.1 kilograms per hectare in 1969 at an average annual rate of 6.82% (Knoema, 2018). Dependency on mineral fertilizers has increased the cost of crop production. Furthermore, the application of fertilizers more than the recommended limits are known to cause undesirable effects such as decreasing soil pH, soil pollution, reduction in beneficial microbial activity and even soil compaction.

However, there is a gradual trend to complement or substitute mineral fertilizers with some form of organic fertilizers wherever feasible. Concerns regarding healthy food intake are on the rise and greater emphasis is made on food safety. Demand regarding the production of safe and healthy food among consumers and environmentalists has risen considerably. The application of chemicals in the food supply has triggered major public concern among consumers. Such growing awareness has brought about the concept of good agricultural practices that emphasizes the minimal use of external inputs such as chemical fertilizers, pesticides, and herbicides to produce healthier crops.

Soil flora or fauna communities directly affect soil functionality in terms of soil nutrient, carbon storage, decomposition and many more. Plants interact with these soil-dwelling organisms in a diverse array of possibilities such as commensal, mutualistic or competitive among many others. Arbuscular mycorrhizal fungi (AMF) are one of the many organisms that are abundant and found to colonise almost all land communities including 80% of all vascular plants (Smith and Read, 2008). These fungal symbionts are an integral component of plant communities in both natural and agricultural ecosystems. Various authors have documented that associations between plant species

and AMF are likely to increase the efficiency of fertilizer use and significantly enhanced plant growth (height, leaf area, root volume, shoot and root dry biomass) over uninoculated plants. Positive growth response of crops to AMF inoculation has been reported in many short-term and perennial crops.

Research on the effect of different AMF on host plants either using single or mix spore cultures and indigenous or commercial (exotic) species have been ongoing in the field of plant science. AMF have been inoculated on various types of crops namely tomato, cassava, chili, pepper, prune, avocado and many more. There have been many variations in the results with some showing positive relationships, others with no significant effect while others have a negative impact on plants. Some researchers reported better plant growth when inoculated with indigenous AMF than non-indigenous or commercial (exotic) AMF while others recorded that mixed-species inoculates are more effective than single spore culture in promoting better growth and nutrient uptake. Thus, it can be concluded that the relationships between a host plant and AMF are very much affected by multiple factors such as the environment where the host plant grows, the availability of nutrients especially phosphorus, water availability, growth phases of AMF and host plants and many more. Therefore, to gain better knowledge on the AMF-host relationship, studies on the effect of AMF inoculation on different host plants are necessary.

Cogill (2015) defined indigenous fruits and vegetables as foods that are locally produced through the traditional agricultural system. Indigenous fruits or vegetables are accepted socially and culturally by previous generations or have been introduced for a very long time as food sources among the communities. *Terung asam* (*Solanum lasiocarpum D*) is a popular native vegetable in Sarawak with a distinctive sour taste and is consumed as a vegetable or used as flavouring in many dishes. The humble *terung asam* was traditionally planted with hill paddy by local farmers but is now cultivated throughout the Sarawak. On 30 June 2011, Sarawak was granted the Geographical Indications (GI) certification by the Malaysian Intellectual Property Organization (MyIPO) to protect the authenticity and great value of *terung asam* to the state (Shariah, 2013). *Terung asam* can reach a price of RM6.00-10.00 per kg depending on the size and quality (Rahman *et al.*, 2019). Due to its good prospect, Sarawak has been promoting *terung asam* as a cash crop in the state.

Objectives

Being a traditional and endemic crop of Sarawak, to our knowledge, very few research records on *terung asam* were published and no study has ever reported on the effect of AMF, particularly indigenous AMF, in promoting nutrient uptake and growth of *terung asam* has ever been reported. Therefore, the objectives of this research were to:

1. determine the effect of indigenous and non-indigenous AMF inoculation in promoting growth of *terung asam*.
2. investigate the effects of indigenous AMF inoculation in increasing soil fertility and plant nutrient uptake by *terung asam*.
3. evaluate *terung asam* root colonization by AMF after inoculation using indigenous and non-indigenous AMF.

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