JPPIPA 9(6) (2023)

Jurnal Penelitian Pendidikan IPA
Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Stress Drought and Mycorrhizal Dose on the Growth Characteristics of Boci Sawala Pandanga Morotai Local Peanuts

Kisey Bina Habeahan[1], Sofyan Samad[2*], Rima Melati[2]

[1] BPTP Maluku Utara, Kompleks Pertanian Kusu No 1, Maluku Utara, Indonesia
[2] Khairun University Postgraduate Program, Ternate North Maluku, Indonesia

Received: April 12, 2023
Revised: May 03, 2023
Accepted: June 25, 2023
Published: June 30, 2023

Corresponding Author:
Sofyan Samad
sofyan.samad1970@gmail.com

DOI: 10.29303/jppipa.v9i6.3634

Abstract: Mycorrhizal can provide plant resistance when drought came. Thus, this study aims to examine the effect of stress drought and mycorrhizal dose on the growth of Boci Sawala Pandanga Morotai local peanuts. The study was conducted at the BPTP screen house North Maluku in Kusu Village, Tidore Kepulauan City, North Maluku Province from March to June 2022 with the elevation of 50m above sea level. It utilized a factorial design with 2 factors. The first factor is the drought (K) 2 levels (K0 = optimal and K1 = stress), and the second factor is mycorrhizal (M) 4 levels (M0 = 0 g/polybag, M1 = 20 g/polybag, M2 = 25 g/polybag, M3 = 30 g/polybag) with 3 replications. The parameters observed consisted of relative growth rate, flowering age, and number of gynophores. The fingerprint results showed that the Boci Swala Pandanga Morotai local peanuts cultivar is tolerant to drought conditions which can be seen from the relative growth rate, number of ginophores, and the fastest flower. With drought stress conditions by giving mycorrhiza 30 g/polybag of peanuts land, it still grew and worked.

Keywords: Boci Sawala; Growth Characteristics; Morotai Local Peanuts; Mycorrhizal Dose; Stress Drought

Introduction

Peanut (Arachis hypogaea L.) is a food crop for growth nutrition Public and based on the production of peanuts of local cultivars of 3.215 tons/ha. This number is still low. Thus, efforts are needed to increase production by increasing the area of planting peanuts on marginal land, one of which is the use of dry land for planting local cultivars (Hidayat & Suwitono, 2019).

Plant growth requires adequate macro and micro nutrients to support plant growth and development such as NPK (Dass et al., 2022; Venugopal & Rao, 2021). Element P is an essential nutrient needed by plants, this element is found in the soil from the results of decomposition and the release of organic matter (Baweja et al., 2020; Pahalvi et al., 2021), but available for plants is very low. Nutrient P in the soil moves by diffusion which is absorbed by plant roots.

In this study, Boci Sawala Pandanga Morotai cultivar would be utilized in the expectation that it may boost peanut production in North Maluku. Phosphorus is wiped away by precipitation. Mycorrhizal, which acts to absorb phosphorus and can be employed as an alternate remedy for phosphorus insufficiency on dry land, is utilized for the absorption of components lost owing to being submerged (Pasaribu, 2011; Simatupang, 2018; Yang et al., 2023).

Mycorrhizal can replenish depleted nutrients (Basri, 2018; Sosa-Hernández et al., 2019). In terms of root absorption, mycorrhizal promote the absorption of nutrients such as potassium, magnesium, phosphorus, calcium, nitrogen, copper, and manganese. On acidic soils, mycorrhiza can boost crop yields (Aggangan et al., 2019; Aguilera et al., 2022; Nurhayati et al., 2020).

Furthermore, mycorrhiza is a symbiotic association between fungi and plants that colonize the root cortex

How to Cite:
Habeahan, K. B., Samad, S., & Melati, R. (2023). Stress Drought and Mycorrhizal Dose on the Growth Characteristics of Boci Sawala Pandanga Morotai Local Peanuts . *Jurnal Penelitian Pendidikan IPA*, *9*(6), 4450–4456. https://doi.org/10.29303/jppipa.v9i6.3634

tissue of plants (Shi et al., 2023; Yan et al., 2022). Mycorrhizae that are introduced into the soil are more quickly decomposed and absorbed by plant roots. Therefore, the objective of this study is to examine the interaction on stress drought and several dosages of mycorrhizal on Boci Sawala Pandanga Morotai local peanuts. Based on the above background, attempts are made to increase peanut yield using the drought-tolerant local cultivar boci sawala Pandawa and mycorrhizal technology implementation, which can boost plant tolerance to drought.

Method

The setting of this study was at the BPTP screen house North Maluku in Kusu Village, Tidore Kepulauan City, North Maluku Province. It is specifically on the Agrotechnology Laboratory of the University of Khairun Ternate, the Laboratory of the Ternate Agricultural Quarantine Center and the Feed Chemistry Laboratory of Hasanuddin University from March to June 2022.

The materials were Boci Sawala Pandanga Morotai local peanuts, mycorrhizal, furadan, fertilizer N, P, K and soil. Mewanwhile, the others are fanny tools, polybags measuring 30 cm, digital HWH DJ203A, electric oven of Memmert brand, Genesis 20 spectrophotometer, measuring cups, tape measure, Trinocular compound microscope Olympus type CX33 brand and stationery.

The field research on screen houses used polybags to facilitate the regulation of environmental stress conditions. The design (RAL) was done with 2 factors (Perala & Wulandari, 2019; Ramadhani & Widawati, 2020; Warman et al., 2022), namely: mycorrhizal dose (M) 4 levels ie : M_0) Without Mycorrhizal, M_1) 20 gr/ poly bag, M_2) 25 gr/ poly bag, M_3) 30 gr/ poly bag; factor Condition Environment (C) with 2 levels : K_0) Optimal, K_1) Stress, total 8 combinations were namely :

K_0M_0	K_0M_1	K_0M_2	K_0M_3
K_1M_0	K_1M_1	K_1M_2	K_1M_3

Every combination was repeated 3 times or 24 trials. The optimal condition (K_0) was given water until harvest media until saturated and water stops dripping on the polybag. The field capacity was the soil capable of holding water (Sperdouli et al., 2021). Watering was done every three days. Drought plants (K_1) were maintained for 20 HST, after which they were watered every 7 days (50% of the symptoms of wilting of plant leaves appeared due to the lack of response of the roots to take up water (Kim et al., 2020). The research variables were namely: Relative Growth Rate (RGR) component variables, Flowering age, Ginophores, Number pods per plant, and Percentage Root Infected.

The research procedure was done in the screen house of the waste and measure the location of polybag media. The land preparation was done a week before the topsoil type. The soil was already mixed with compost with a ratio of 50:50. The purpose of labeling was to differentiate the peanuts, arranged randomly, and had the opportunity accept certain treatment. The goal was to avoid of difference bias among experiments.

Giving mycorrhizal dose immerse into the land on a polybag with dose namely 20g, 25g, 30g, per planting polybag (Nainggolan et al., 2020). One seed peanut was planted with the depth of 2 cm on each in a polybag. Then, the seed that was planted was closed with soil.

Optimum watering (K_0) was performed until the plants were gathered in polybags. Drought-stressed plants (K_1) were maintained until the age of 20 HST, seven days after watering 50% of the leaves exhibited wilting symptoms, and then irrigated with time intervals under the aforementioned stress circumstances until harvest. Depending on the presence of weeds in the polybag, weeding was performed. Peanuts were harvested at 90 HST. Data analysis technique was done with ANOVA. If the findings differed considerably, it would be proceed with the Duncan's Range Test (UJD) at the 0.05 significance level.

Result and Discussion

Result

Relative Growth Rate

Optimal environmental conditions (K_0) and drought stress conditions (K_1) with mycorrhizal doses affected the character of the relative growth rate of peanuts. The average relative growth rate of the local peanut variety Boci Sawala Pandanga under drought conditions and different doses of mycorrhizae results are presented in Figure 1.

The relative growth rate of the local cultivar of Boci Sawala peanut under optimal environmental conditions (K_0) and drought stress conditions and different mycorrhizal doses indicated that the relative growth rate of peanut plants would be higher under optimal environmental conditions accompanied by mycorrhizal administration. It can be seen that the provision of mycorrhizae of 30 g/polybag with the provision of water up to field capacity until harvest growth rates are relatively visible in optimal conditions (K_0) of 0.057 g/cm^2/day and drought stress conditions (K_1) were relatively the smallest without administration mycorrhiza that is equal to 0.027.

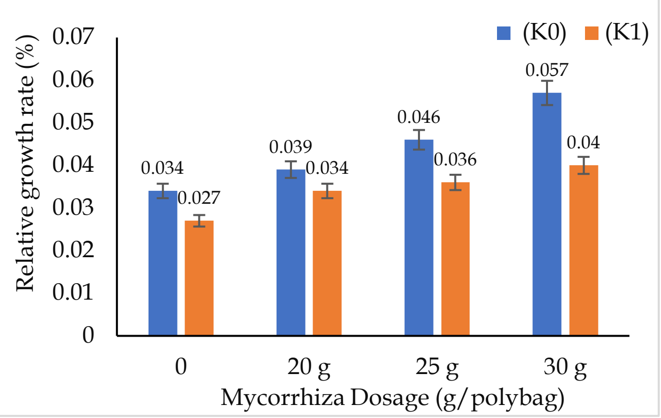

Figure 1. The Histogram of the Relative Growth Rate of Peanut Plants of the Local cultivar of Boci Sawala Pandanga with Optimal Environmental Conditions (K_0) and Condition of Drought Stress with Different Doses of Mycorrhiza

Flowering Age

The results of variance showed that the treatment of optimal environmental conditions (K0) and drought stress conditions (K1) with different doses of mycorrhiza had a significant effect on the flowering age of the local peanut cultivar Boci Sawala Pandanga, and the results can be seen in Figure 2.

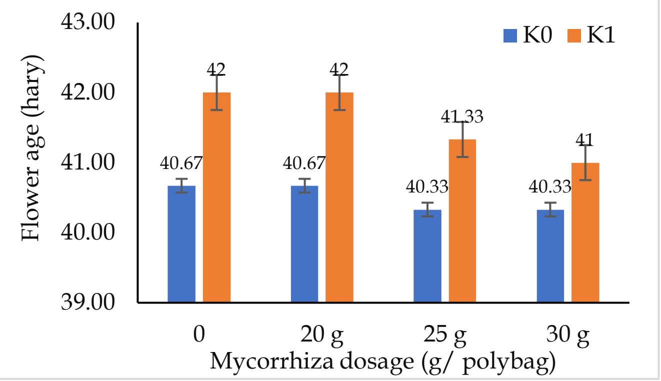

Figure 2. The Histogram of Peanut Flowering Age of Local Cultivar of Boci Sawala Pandanga with Optimal Environmental Conditions (K_0) and Drought Stress Conditions (K_1) and Different Mycorrhiza Doses

The flowering age of the local peanut cultivar of Boci Sawala Pandanga with optimal environmental conditions (K_0) and drought stress conditions (K_1) and different mycorrhizal applications showed that the time for the first flower to appear on peanut plants ranged from 40-41 days. The time for the first flower to appear under optimal conditions (K_0) was 40 days. Meanwhile, under drought stress conditions (K_1), the first flower appeared at the age of 41 days (Figure 2). This shows that drought conditions can make peanut plants flower longer so that there is an increase in the flowering age of peanut plants of approximately 1 day. Even though drought conditions occur, peanuts can still flower. Increasing the dose of mycorrhiza accelerates the flowering of peanut plants. The novelty in this study is that the application of mycorrhiza to drought stress accelerates the flowering of peanut plants.

Number of Ginophores

The results of variance showed optimal environmental conditions (K_0) and drought stress conditions (K_1) and mycorrhizal doses, interactions occurred and had a significant effect on age 56 DAP. The average number of gynophores of the local peanut variety Boci Sawala Pandanga under drought conditions and different mycorrhizal doses is presented in Figure 3.

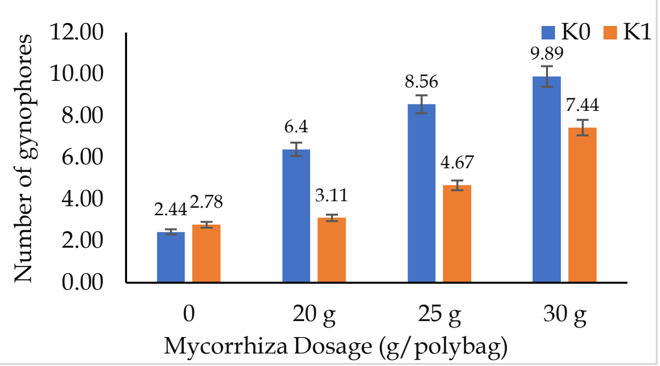

Figure 3. The Histogram of Ginophore of Peanut Plant of Local Variety Boci Sawala Pandanga at 56 DAP with Drought Conditions and Different Mycorrhiza Doses

The results of variance at 56 HST showed that the number of ginophores of peanut plants formed was greater under optimal environmental conditions (K_0) than under drought stress environmental conditions (K_1). There was an increase in the formation of the number of ginophores in peanut plants with increasing doses of mycorrhiza. In optimal conditions, there was an increase in the number of gynophores by 304.54%, while in drought conditions the number of gynophores only increased by 168%. Drought conditions can reduce the formation of gynophore in peanut plants, but the presence of mycorrhiza can make peanut plants grow well and produce gynophores.

The highest number of plant ginophores was found in the mycorrhizal dose of 30 g/polybag of 9.89 fruit, significantly different from all other treatments, but different from the mycorrhizal dose of 25 g/8.56 polybag. The lowest number of palong ginophores occurred in optimal conditions (K_0), namely without the administration of mycorrhizae of 2.44 pieces.

Number of Pods Per Plant

The results of variance of the treatment of drought conditions and mycorrhizal doses showed that there was an interaction between drought conditions and mycorrhizae which had a significant effect on the number of pods per plant. The average number of plant pods under drought conditions and different mycorrhizal doses can be presented in Figure 4.

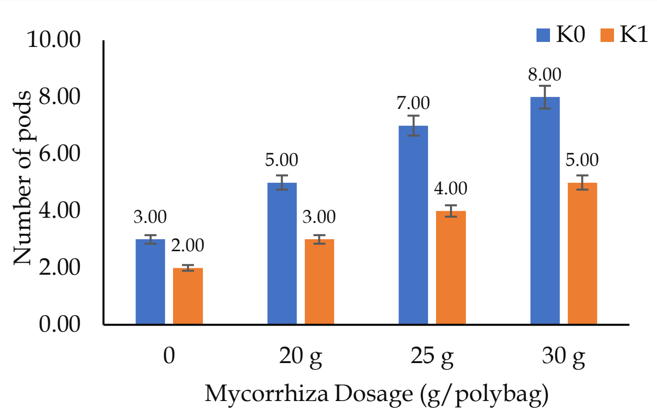

Figure 4. The Histogram of the Number of Pods Per Peanut Plant of the Local Cultivar of Boci Sawala Pandanga with Different Drought Conditions and Mycorrhizal Doses

Figure 4 shows that the number of pods per plant is higher in optimal environmental conditions (K_0) than in drought conditions (K_1). There was an increase in the formation of the number of pods per plant with increasing doses of mycorrhiza. Under optimal conditions, the increase in the number of pods per plant with mycorrhizal doses of 30 g/polybag increased by 268.47% compared to without mycorrhizal administration. Under drought stress conditions, the increase in the number of pods per plant was lower, namely 213.27%. The highest number of pods per plant was found in optimal environmental conditions (K_0) with 8 pods of mycorrhizal doses of 30 g/polybag and the lowest in environmental stress conditions (K_1) without 2 pods of mycorrhizal doses.

Percentage of Infected Roots

The results of variance showed that the treatment of drought conditions and mycorrhizal doses had a significant effect on the percentage of MVA infected roots, and there was no interaction. The average percentage of infected roots in plant roots under drought conditions and different doses of mycorrhizae can be seen in Figure 5.

Figure 5 shows that under optimal environmental conditions the percentage of infected peanut plant roots is significantly greater than under stress environmental conditions drought. The percentage of roots infected with MVA under optimal environmental conditions was 31.91%, while under stress conditions drought by 29.08%. This means with stress environmental conditions Drought can reduce the number of plant roots infected by MVA.

Figure 5 shows that increasing the dose of mycorrhizae can increase the number of infected roots. Peanut plants given mycorrhiza at a dose of 30 g/polybag had a percentage of the number of infected roots of 43.21% greater than without mycorrhizal administration and mycorrhizae at doses of 20 g/polybag and 25 g/polybag.

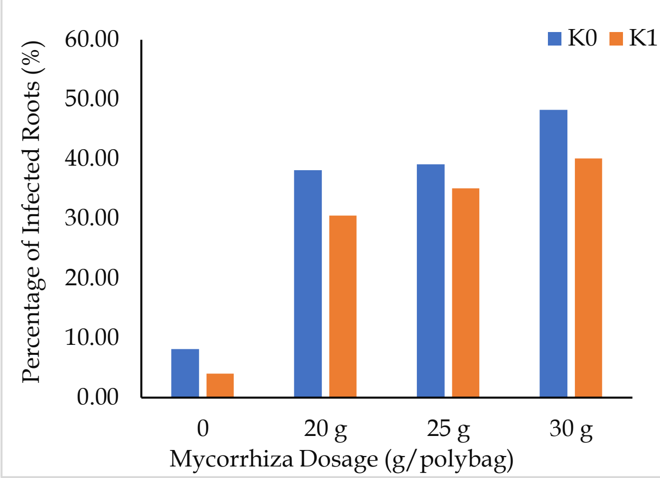

Figure 5. The Histogram of Percentage of Infected Roots of Peanut Plant of Local cultivar Boci Sawala Pandanga with Different Drought Conditions and Mycorrhiza Doses

Based on the level of root infection, it is divided into 5 classes, namely: Class 1 if root infection is 0% - 5% (very low), class 2 if root infection is 6% - 25% (low), class 3 if root infection is 26% - 50% (moderate), class 4 if the root infection is 51% - 75% (high) and class 5 if the root infection is 76% - 100% (very high). Then, the root infection rate at each level of mycorrhizal dose treatment can be seen in Table 1.

Table 1. Root Infection Rate of Peanut Plants at Each Mycorrhiza Dose

Treatment	Percentage of Root Infection (%)	Criteria
M_0 = without mycorrhiza	4.05	Very low
M_1 =20g/polybag	38.16	Fair
M_2 = 25g/polybag	36.55	Fair
M_3 = 30g/polybag	43.21	Fair

Based on the level of root infection of peanut plants, it can be seen that the application of mycorrhiza can increase the level of root infection to moderate (Table 1).

Discussion

Giving the dose of mycorrhizal increased the element of P and had an effect on increasing growth rate, number of ginophores, number of pods planted, infected roots and accelerating flowering plants (Amir et al., 2021; Indriana et al., 2021; Lala et al., 2021). In optimal environmental conditions, giving mycorrhizal inasmuch 30 g/polybag increased the relative growth rate of 67.23%, while in drought stress conditions the relative growth rate was 45.96%. Although there is a decrease in the growth rate in the presence of drought stress, the application of mycorrhiza can increase the relative growth rate of plants. Besides, it accelerated the first flowering plants in optimal environmental conditions (K_0) within 40 days. Whereas in drought stress conditions (K_1), the first flower was in 41 days (Figure 1). This shows that drought conditions can make peanut plants flower longer so that there is an increase in the flowering age of peanut plants of approximately one day. Even though drought conditions occur, peanuts can still flower. Increasing the dose of mycorrhiza accelerates the flowering of peanut plants.

The number of ginophores of peanut plants under different drought stress conditions indicated that the formation of ginophores would increase with increasing doses of mycorrhiza. Under optimal environmental conditions, the formation of plant gynophore is getting better, because it is supported by the availability of nutrients during the peanut growth phase, while under drought stress environmental conditions the formation of gynophore is inhibited. Lack of water suppresses the formation of peanut ginophores, but the presence of mycorrhiza can reduce the negative effects (Putri et al., 2019).

In optimal environmental conditions (K_0) the relative growth rate and the number of ginophores are higher than in drought stressed environmental conditions (K_1). Meanwhile, the flowering period in optimal environmental conditions (K_0) is faster than in stress conditions (K_1). This is due to drought stress the supply of water from the roots of both is reduced and the process of carbon assimilation decreases. Drought stress can reduce the rate of photosynthesis in plants and dwarf plants but does not appear to be stressed but accelerates flowering plants (Islam & Karim, 2010). According to Dong et al. (2019), drought stress photosynthetic activity, absorption of nutrients is reduced due to the fall of flowers on soybean plants.

In optimal conditions, there was an increase in the number of gynophores by 304.54%, while in drought conditions the number of gynophores only increased by 168%. Drought conditions can reduce the formation of gynophore in peanut plants, but the presence of mycorrhiza can make peanut plants grow well and produce gynophores. The highest number of plant ginophores was found in the administration of mycorrhizal doses of 30 g/polybag of 9.89 different from the others.

The development of peanut pods will increase as mycorrhiza dosage increases. In optimal environmental conditions, pod formation is increasing because it is supported by environmental conditions with sufficient water availability, whereas pod formation is slightly hindered in drought stress environmental conditions because the plants are experiencing drought stress, which disrupts metabolic processes in plants. Mycorrhizae can be used to decrease metabolic disruption in plants, with greater doses of mycorrhizae resulting in an increase in pod development even when the plants are under drought stress. This indicates that the application of mycorrhiza can mitigate the effects of a lack of water on peanut growth.

This is due to drought stress lowering the flow of water from the roots and slowing the carbon absorption process (Melina, 2022). According to Melina Siam, drought stress can inhibit plant growth, photosynthesis, and stunt plant growth. According to the findings of this study, drought stress has not yet induced a biochemical adaptation response in the local peanut plant of Boci Sawala Pandanga Morotai cultivar.

Beginning in the vegetative phase, drought stress has a deleterious impact on reproductive growth. A limited number of pods were produced by plants subjected to drought stress beginning in the vegetative phase, compared to plants grown under ideal conditions. Peanut plants experience significant growth between the ages of 15 and 30 HST, which necessitates the availability of appropriate quantities of water. The results of this study indicate that peanut yields declined during the subsequent growth phase, when water availability restored to normal, as a result of this period's reduced water availability. In the vegetative phase, drought stress affects growth, cell elongation, photosynthesis, and photosynthetic translocation (Nurhayati et al., 2020).

The maximum rate of MVA infection was seen with a dose of 30 g/polybag and an ideal degree of water dryness of 46.80%. The greater the percentage of MVA infection, the greater the phosphorus availability for plants.

Conclusion

The results of the variance of the Boci Swala Pandanga variety were tolerant to drought conditions which could be seen from the relative growth rate, number of ginophores, number of pods, infected with MVA and fastest flowering and as a novelty in this study. Peanut plants continue to grow in drought-stressed conditions when 30 g of mycorrhizal is added per polybag.

Acknowledgments

The author would like to thank his wife, children and all members of the researchers who have provided independent funding for research on legumes: with the title, "Stress Drought and Mycorrhizal Dose on The Growth Characteristics of Boci Sawala Pandanga Morotai Local Peanuts"

Author Contributions

This article was written by three people. The first, second and third authors jointly carry out each stage so that this article can be published.

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflict of interest.

References

Aggangan, N. S., Cortes, A. D., & Reaño, C. E. (2019). Growth response of cacao (Theobroma cacao L.) plant as affected by bamboo biochar and arbuscular mycorrhizal fungi in sterilized and unsterilized soil. *Biocatalysis and Agricultural Biotechnology*, *22*, 101347. https://doi.org/10.1016/j.bcab.2019.101347

Aguilera, P., Becerra, N., Alvear, M., Ortiz, N., Turrini, A., Azcón-Aguilar, C., López-Gómez, M., Romero, J. K., Massri, M., Seguel, A., & others. (2022). Arbuscular mycorrhizal fungi from acidic soils favors production of tomatoes and lycopene concentration. *Journal of the Science of Food and Agriculture*, *102*(6), 2352–2358. https://doi.org/10.1002/jsfa.11573

Amir, H., Gensous, S., Cavaloc, Y., & Wantiez, L. (2021). Phosphorus fertilization of an ultramafic soil reduced effects of arbuscular mycorrhizal fungi but not mycorrhizal colonization. *Journal of Soil Science and Plant Nutrition*, *21*, 3544–3554. https://doi.org/10.1007/s42729-021-00626-6

Basri, A. H. H. (2018). Kajian Peranan Mikoriza Dalam Bidang Pertanian. *Agrica Ekstensia*, *Vol. 12 No*(2), 74–78. Retrieved from https://www.polbangtanmedan.ac.id/upload/upload/jurnal/Vol%2012-2/11%20Arie%20Mikoriza.pdf

Baweja, P., Kumar, S., & Kumar, G. (2020). Fertilizers and pesticides: their impact on soil health and environment. *Soil Health*, 265–285. https://doi.org/10.1007/978-3-030-44364-1_15

Dass, A., Rajanna, G. A., Babu, S., Lal, S. K., Choudhary, A. K., Singh, R., Rathore, S. S., Kaur, R., Dhar, S., Singh, T., & others. (2022). Foliar application of macro-and micronutrients improves the productivity, economic returns, and resource-use efficiency of soybean in a semiarid climate. *Sustainability*, *14*(10), 5825. https://doi.org/10.3390/su14105825

Dong, S., Jiang, Y., Dong, Y., Wang, L., Wang, W., Ma, Z., Yan, C., Ma, C., & Liu, L. (2019). A study on soybean responses to drought stress and rehydration. *Saudi Journal of Biological Sciences*, *26*(8), 2006–2017. https://doi.org/10.1016/j.sjbs.2019.08.005

Hidayat, Y., & Suwitono, B. (2019). Kelayakan Usahatani Varietas Unggul Kacang Tanah Di Kabupaten Halmahera Utara. *Jurnal Pengkajian dan Pengembangan Teknologi Pertanian*, *21*(2), 127–136. Retrieved from https://repository.pertanian.go.id/items/1b8a0a98-6aca-42c1-9021-868a98cec3d0

Indriana, K. R., Suherman, C., & Rosniawaty, S. (2021). Combination of Jatropha Cultivars with the Best Dose Fungi Mycorrhizal Arbuscular and Cytokinin Concentrations for Lowland Plant. *Educational Research (IJMCER*, *3*(1), 202–208. Retrieved from https://www.ijmcer.com/wp-content/uploads/2021/02/IJMCER_AA0310202208.pdf

Islam, M., & Karim, M. (2010). Evaluation of Rice (Oryza sativa L.) Genotypes at Germination and Early Seedling Stage for Their Tolerance to Salinity. *The Agriculturists*, *8*(2), 57–65. https://doi.org/10.3329/agric.v8i2.7578

Kim, Y., Chung, Y. S., Lee, E., Tripathi, P., Heo, S., & Kim, K. H. (2020). Root response to drought stress in rice (Oryza sativa L.). *International Journal of Molecular Sciences*, *21*(4), 1513. https://doi.org/10.3390/ijms21041513

Lala, F., Jasil, Y., Habeahan, K., Bayuaji, H., & Wahab, A. (2021). The effect of arbuscular mycorrhizal fungus on morphological characters and yield of cayenne pepper (Capsicum frutescens L. *E3S Web of Conferences*, *306*, 1051. https://doi.org/10.1051/e3sconf/202130601051

Melina, S. (2022). Estimasi Karbon Tersimpan Pada Nekromassa Tumbuhan Di Rawa Lebak Kecamatan Martapura. *Bioscientiae*, *19*(1). https://doi.org/10.20527/b.v19i1.5104

Nainggolan, E. V., Bertham, Y. H., & Sudjatmiko, S. (2020). Pengaruh Pemberian Pupuk Hayati Mikoriza Dan Pupuk Kandang Ayam Terhadap Pertumbuhan Dan Hasil Tanaman Kacang Panjang (Vigna Sinensis L.) Di Ultisol. *Jurnal Ilmu-Ilmu Pertanian Indonesia*, *22*(1), 58–63. https://doi.org/10.31186/jipi.22.1.58-63

Nurhayati, Akbar, D. F., & Rahayu, M. S. (2020). *Growth and Physiology of Deli Tobacco (Nicotiana tabaacum) Varieties of Deli-4 on Drought*, 212–215. https://doi.org/10.5220/0008887602120215

Pahalvi, H. N., Rafiya, L., Rashid, S., Nisar, B., & Kamili,

A. N. (2021). Chemical fertilizers and their impact on soil health. *Microbiota and Biofertilizers, Vol 2: Ecofriendly Tools for Reclamation of Degraded Soil Environs*, 1–20. https://doi.org/10.1007/978-3-030-61010-4_1

Pasaribu, H. E. (2011). *Pengaruh Aplikasi Rhizobium terhadap Pertumbuhan dan Produksi Tiga Varietas Kacang Tanah (Arachis hypogea L.)*. Universitas Sumatera Utara. Retrieved from https://repositori.usu.ac.id/handle/123456789/58586

Perala, I., & Wulandari, A. S. (2019). Kayu Kuku (Pericopsis mooniana Thw.) seedlings growth response to tailing media added with vermicompost, rhizobium, and arbuscular Mycorrhizal fungi. *IOP Conference Series: Earth and Environmental Science*, *394*(1), 12023. https://doi.org/10.1088/1755-1315/394/1/012023

Putri, T. E., Yuliani, & Trimulyono, G. (2019). Penggunaan Mikoriza Vesikular Arbuskular (MVA) Genus Glomus untuk Meningkatkan Pertumbuhan dan Produksi Tanaman Kacang Hijau (Vigna radiata) pada Cekaman Air. *LenteraBio: Berkala Ilmiah Biologi*, *8*(2), 107–112. Retrieved from https://ejournal.unesa.ac.id/index.php/lenterabio/article/view/28622

Ramadhani, I., & Widawati, S. R. I. (2020). Synergistic Interaction of Arbuscular Mycorrhizal Fungi and Phosphate-Solubilizing Bacteria with NPK Fertilizer to Improve Sorghum bicolor (L.) Moench Growth under Saline Condition. *Microbiology Indonesia*, *14*(2), 4–4. https://doi.org/10.5454/mi.14.2.4

Shi, J., Wang, X., & Wang, E. (2023). Mycorrhizal symbiosis in plant growth and stress adaptation: From genes to ecosystems. *Annual Review of Plant Biology*, *74*, 569–607. https://doi.org/10.1146/annurev-arplant-061722-090342

Simatupang, L. (2018). Pengaruh Pemberian Mikoriza Dan Bakteri Rhizobium Terhadap Pertumbuhan Dan Produksi Kacang Tanah (Arachis Hypogaea L.). *Tapanuli Journals*, *1*(1), 123–133. https://doi.org/10.2201/unita.v1i1.157

Sosa-Hernández, M. A., Leifheit, E. F., Ingraffia, R., & Rillig, M. C. (2019). Subsoil arbuscular mycorrhizal fungi for sustainability and climate-smart agriculture: a solution right under our feet? *Frontiers in Microbiology*, *10*, 744. https://doi.org/10.3389/fmicb.2019.00744/full

Sperdouli, I., Mellidou, I., & Moustakas, M. (2021). Harnessing chlorophyll fluorescence for phenotyping analysis of wild and cultivated tomato for high photochemical efficiency under water deficit for climate change resilience. In *Climate*, *9*(11). https://doi.org/10.3390/cli9110154

Venugopal, N. V. S., & Rao, G. N. V. M. (2021). A Facile Synthesis and Characterization of new Nitrogen, Phosphorus, Potassium (NPK) Fertilizer Fortified with Tri-micronutrient Matrix and its application for Optimal Plant Augmentation. *Oriental Journal of Chemistry*, *37*(6). http://dx.doi.org/10.13005/ojc/370626

Warman, R., Santari, P. T., & Sandi, N. (2022). Performance of Shallots (Allium Ascalonicum L) in Peat Soil with Organic Fertilizer and Arbuscular Mycorrhizal Fungi (AMF. *Jurnal Penelitian Pendidikan IPA*, *8*(SpecialIssue), 58–66. https://doi.org/10.29303/jppipa.v8iSpecialIssue.2482

Yan, H., Freschet, G. T., Wang, H., Hogan, J. A., Li, S., Valverde-Barrantes, O. J., & Kou, L. (2022). Mycorrhizal symbiosis pathway and edaphic fertility frame root economics space among tree species. *New Phytologist*, *234*(5), 1639–1653. https://doi.org/10.1111/nph.18066

Yang, S., Imran, & Ortas, I. (2023). Impact of mycorrhiza on plant nutrition and food security. *Journal of Plant Nutrition*, 1–26. https://doi.org/10.1080/01904167.2023.2192780