Effectiveness of mycorrhizae on growth and production of orange sweet potato at various watering level

N Rahmawati\textsuperscript{1,2,*}, F E Sitepu\textsuperscript{1} and M F A Tarigan\textsuperscript{1}

\textsuperscript{1}Faculty of Agriculture, Universitas Sumatera Utara, Medan, Indonesia.
\textsuperscript{2}Centre for Roots and Tuber Study, Universitas Sumatera Utara, Medan, Indonesia.

E-mail: *nini@usu.ac.id

**Abstract.** Sweet potato is a food crop that is widely cultivated during the dry season in rice fields. Increasing sweet potato production can be done by inoculating mycorrhizae which play a role in increasing plant resistance to drought. This research was conducted to analyse the effectiveness of mycorrhizae to increase the growth and production of sweet potatoes cultivated in paddy fields with different levels of watering. Sweet potato planting began in April-July 2020 in rainfed paddy fields located in Tandem Hilir I Village, Deli Serdang Regency. The research design used was a randomized block design with 2 factors namely mycorrhizal inoculation (0 g/plant inoculum, 20 g/plant inoculum) and watering level (watered once in 10 days for 1 month, watered once in 10 days for 2 months, watered once in 10 days for 3 months, and watered once in 10 days for 4 months). The results showed that mycorrhizal inoculation treatment at a dose of 20 g/plant significantly affected the length increase of sweet potato plants. All parameters observed were not affected by the treatment watering level. The best interaction is the combination of treatment with 20 g of mycorrhizal inoculum/plant and watered once in 10 days for 3 months.

1. Introduction
Increase in sweet potato production can be done by expanding the planting area and applying appropriate cultivation techniques. Sweet potato planting can be done on dry or wet land. However, the planting time must be adjusted, in dry land it is usually done at the beginning of the rainy season, while in wetlands it is during the dry season. When young, the plant requires sufficiently moist soil. Therefore, for planting in the dry season there must be adequate water. In several production centers, sweet potatoes are planted in paddy fields during the dry season after the rice harvest. [1,2]. Lack of water availability in paddy fields during the dry season is an obstacle that many farmers face. This condition can cause the plant to suffer from drought in part or even during the growth phase.

Sweet potato cultivation is spread throughout the archipelago in Indonesia. Some experts suggest that sweet potatoes are classified as adaptive to drought, marginal land, and altitude. Every plant species, even every variety in one plant species, has a different critical growth phase against drought. The results of the research [3] showed that drought stress in sweet potatoes had a significant effect on reducing tuber weight and other vegetative parts.

The application of Arbuscular Mycorrhizal Fungi (AMF) is one solution that can be applied to marginal land such as dry land. This mycorrhizal association allows plants to obtain water and nutrients in dry and nutrient-poor environmental conditions. The external hyphae network of mycorrhizae will expand the water and nutrient uptake field. The size hyphae that better than the root
hair allow the hyphae to infiltrate the smallest (micro) soil pores hence the hyphae can absorb macro and micronutrient and also water at very low soil water content conditions [4,5].

Research on increasing the ability of sweet potato plants to overcome drought stress with AMF inoculation treatment has been presented [6,7] who examined the effectiveness of mycorrhizal and watering level treatment on sweet potatoes concluded that AMF inoculation could increase photosynthetic pigment, chlorophyll fluorescence and net photosynthetic rate so that plant growth was better in stressful conditions of water shortage.

2. Materials and methods
This research used a randomized block design with 2 factors. The first factor was the application of mycorrhizae, namely; without inoculum application and inoculum application as much as 20 g/plant. The second factor was watering levels, namely; watered once in 10 days for 1 month, watered once in 10 days for 2 months, watered once in 10 days for 3 months, and watered once in 10 days for 4 months, watering volume is 100 ml/plant. This research was conducted in rainfed paddy fields in Tandem Hilir 1 Village, Hamparan Perak Sub-district, Deli Serdang District and at USU - Faculty of Agriculture's Soil Biology Laboratory from April to July 2019.

The planting material used was sweet potato stem cuttings of the local genotype 'Tanah Seribu' orange tuber. The mycorrhizal inoculum was applied 2 weeks after planting. Plant maintenance includes fertilization activities, watering according to treatment using a soil hygrometer, and controlling pests and diseases.

The observed parameters were plant length, tuber length per sample, number of tubers, average tuber weight observed at the age of 16 weeks after planting (WAP) and calculation of the percentage degree of root infection using the colonized root length method. The data obtained from the research results were analyzed statistically using the Analysis of Variance (ANOVA), and if there is a significant influence it will be continued by the Duncan Multiple Range Test (DMRT) at $\alpha = 0.05$.

3. Results and discussion

3.1. Root infection degree
Mycorrhizae are fungi that are able to associate with various types of host plants. The degree of root infection is a parameter that indicates the ability of mycorrhizal propagules to infect plant roots. Infectivity is defined as the power of the fungus to infect and colonize plant roots. Effectiveness, in this case, was expressed as the proportion of infected plant roots.

| Mycorrhiza       | Watering  | 1 Month | 2 Month | 3 Month | 4 Month | Mean |
|------------------|-----------|---------|---------|---------|---------|------|
| Without mycorrhizae (M0) | 6.67 c | 0.00 c | 46.67 a | 53.33 a | 26.67   |       |
| Mycorrhizae 20 g (M1)   | 6.67 c | 3.33 c | 56.67 a | 20.00 b | 21.67   |       |
| Mean             | 6.67     | 1.67     | 51.67     | 36.67     |         |

Note: Numbers in the same row and column followed by the same lowercase letter indicated an insignificant difference at the 5% level according to the DMRT follow-up test.

The analysis results indicated that the interaction of mycorrhizal inoculum and watering levels had a significant effect on the root infection degree (Table 1). Mycorrhizal inoculum and watering for 3 months indicated the highest root infection degree. The results of this study indicate that the availability water in the growing medium affects the ability of mycorrhizae to infect sweet potato roots.
[8] stated that sufficient water that entered the soil bring AMF spores to develop well in root areas, and AMF developed well in sufficient moisture [9] also reported that the degree mycorrhizae infection in soybean roots increased in the moderate category of drought stress.

3.2. Length of sweet potato stems
Mycorrhizae inoculum application significantly increased plant length (table 2) by 36.46% compared to without mycorrhizae application. This indicated that mycorrhizal application can help provide nutrients and water for plants. Besides, hormone gibberellin can be raised by mycorrhizae, which stimulates stem elongation through increased cell division [10]. The increase in the number of cells led to faster stem growth hence the posture of the mycorrhizal inoculated plants was higher than the control treatment.

Different level did not significantly affect the increase in stem length at Watering sweet potato (table 2). Sweet potato plants that have the longest stems are watered for two month interval of 10 day. This is presumably because after the plant is 2 month, the carbohydrate produced in the photosynthesis process begin to be used for tuber formation and filling.

| Mycorrhiza          | Watering |          |          | Mean       |
|---------------------|----------|----------|----------|------------|
|                     | 1 Month  | 2 Month  | 3 Month  | 4 Month    |
| Without mycorrhizae |          |          |          |            |
| M0                  | 74.09    | 66.99    | 61.38    | 67.41      |
|                     |          |          |          | 67.47 b    |
| Mycorrhizae 20 g (M1)| 85.58   | 104.34   | 88.96    | 89.39      |
|                     |          |          |          | 92.07 a    |
| Mean                | 79.84    | 85.67    | 75.17    | 78.40      |

Note: Number same column followed by lowercase letter indicated an insignificant difference at the 5% level according DMRT follow-up test

3.3. Length of sweet potato tubers
Mycorrhizae inoculum application and watering level treatment affect tuber length not significant(table 3). Sweet potato plant with mycorrhizae inoculum application as much 20 g/plant and watering treatment four month at interval of once in 10 days tended to produce longer tubers than the other treatment.

| Mycorrhiza          | Watering |          |          | Mean       |
|---------------------|----------|----------|----------|------------|
|                     | 1 Month  | 2 Month  | 3 Month  | 4 Month    |
| Without mycorrhizae |          |          |          |            |
| M0                  | 16.22    | 16.57    | 12.27    | 19.60      |
|                     |          |          |          | 16.17      |
| Mycorrhizae 20 g (M1)| 19.18   | 15.52    | 16.53    | 20.65      |
|                     |          |          |          | 17.97      |
| Mean                | 17.70    | 16.05    | 14.40    | 20.12      |

The important factor needed for plant growth and development is water. Metabolic processes and plant life cycles will be disrupted in the absence of water [11]. Groundwater content reduction decreased the mass flow rate, and diffusion thereby decreasing the rate of nutrients transportation to the root surface [12]. The presence of hyphae in mycorrhizae is thought to affect the ability of plants to hold water. This condition allow plant with mycorrhizae more resistance to water stress than plants.
without mycorrhizae, and plants with mycorrhizae can form longer tubers than other treatment combination.

3.4. Number of sweet potato tuber
The application of mycorrhizae inoculum did not significantly affect the increase number of tuber and tuber weight, but the data in table 4 and table 5 indicated that the sweet potato plants treated with mycorrhizal produced a higher number of tubers than the control treatment. Likewise, sweet potato tuber weight with mycorrhizal inoculated increased its tuber weight by 14.36% compared to sweet potato without mycorrhizal application.

Stated that mycorrhizal fungi able to change their shape, structure, root system, space, and quantity [13]. With colonization, the root-branches become more, that is the root system is fuller and shorter, and the diameter is larger and forms a specific root length, making it easier to absorb nutrients by the roots. Stated that the absorption of macro and micro nutrients in bound or unavailable form for plants can be increased if the plant is in symbiosis with mycorrhizae [14]. Various studies have shown a very significant role of mycorrhizae in helping the availability and absorption of phosphorus in plants. The availability of nutrients and water will support the formation of a greater number of tubers and a better tuber filling process hence a higher tuber weight in mycorrhizal inoculated plants will obtain.

**Table 4.** The mean number of sweet potato tubers on mycorrhiza application at various watering level.

| Mycorrhiza          | Watering 1Month | 2Month | 3 Month | 4 Month | Mean  |
|---------------------|-----------------|--------|---------|---------|-------|
| Without mycorrhizae (M0) | 2.53            | 2.73   | 1.93    | 2.60    | 2.45  |
| Mycorrhizae 20 g (M1)   | 3.13            | 2.93   | 2.13    | 1.93    | 2.53  |
| Mean                | 2.83            | 2.83   | 2.03    | 2.27    |       |

3.5. Weight of sweet potato tuber
The data in table 4 and 5 also indicated watering treatment not significant effect on number of tuber and tuber weight. Plant watered for 1 month and 2 months after planting with an interval of once in 10 days produced a higher number of tubers than watering for 3 and 4 months. The results of this research indicated that sweet potato is a food crop that is quite tolerant to drought, especially when it is approaching harvest time. Application of sufficient water at the beginning of planting greatly affect its production.

**Table 5.** The mean weight of sweet potato tubers on mycorrhizal application at various watering level.

| Mycorrhiza          | Watering 1 Month | 2 Month | 3 Month | 4 Month | Mean    |
|---------------------|------------------|---------|---------|---------|---------|
| Without mycorrhizae (M0) | 258.14          | 125.05  | 142.65  | 237.61  | 190.87  |
| Mycorrhizae 20 g (M1)   | 206.45          | 228.29  | 244.34  | 212.40  | 222.87  |
| Mean                | 232.29          | 176.67  | 193.50  | 225.01  |         |

Stated that in general, the formation phase of sweet potato tubers ranges from the age of 30-45 days after planting [15]. In this phase, when there is drought, it will reduce shoot weight, leaf area, and
tuber yield. [16] also explained that the process of forming and developing tuber sweet potato requires dry weather, but if there is a lack of water in that phase, the tuber production will decrease.

The results in Table 5 show that mycorrhizal inoculation in sweet potato plants increased tuber weight by 16.77% compared to control treatment. Research [17] also found the same result, namely the increase in tuber weight in sweet potato mycorrhizae inoculated. [18] explained that the increase in tuber production is related to the role of mycorrhizae in increasing nutrient uptake which leads to increased photosynthetic production and biomass accumulation. The increase in photosynthetic activity is associated with increased growth in mycorrhizal inoculated plants which is directly related to N, P, and carbon uptake and will promote tuber development.

4. Conclusions

Mycorrhizal inoculation had a significant effect on the length of sweet potato stalks, while watering treatment did not significantly affect all observed parameters. The interaction of mycorrhizal inoculation and watering had a significant effect on the parameters of root infection degree with the highest value in the combination treatments of mycorrhizal inoculation (20 g/plant) and watering for 3 months after planting with an interval of once in 10 days.

References

[1] Andika MY, Rahmawati, N and Sitepu FE 2019 Respons pertumbuhan dan produksi genotipe ubi jalar (Ipomoea batatas L.) lokal pada aplikasi biochar jerami padi di sawah [Growth and production responses of local sweet potatoes (Ipomoea batatas L.) genotype on paddy straw biochar application in the paddy field] IOP Conf. Earth and Environmental Science 260 012152

[2] Aliyani A, Rohmat D and Jupri 2013 The potency of sweet potato (Ipomoea batatas L.) production development in Cilimus District, Kuningan Regency Antologi Pendidikan Geografi 2 1 pp 1–19

[3] Hapsari R and Imade 2016 Pengaruh Frekuensi Pemberian Air terhadap Pertumbuhan dan Hasil Ubi Jalar [The Effect of Frequency of Watering on the Growth and Yield of Sweet Potatoes] (Malang: Universitas Muhammadiyah Malang)

[4] Merani F 2009 Pengujian Fungi Mikoriza Arbuskular (FMA) dan Tanah Bermikoriza Terhadap Pertumbuhan Anakan Matotu Anakan Matotu (Pometia pinnata Forst.) [Test of Arbuscular Mycorrhizal Fungi (AMF) and Mycorrhizal Soil Against The Growth of Matoa Tillers] (Manokwari: Fakultas Kehutanan Universitas Negeri Papua)

[5] Bücking and Kafle A 2015 Role of arbuscular mycorrhizal fungi in the nitrogen uptake of plants: Current knowledge and research gaps Agronomy 5 pp 587-612

[6] Kurung S 2011 Pemanfaatan Fungi Mikoriza Arbuskular (FMA) Untuk Adaptasi Terhadap Cekaman Kekeringan Pada Ubi Jalar (Ipomoea batatas (L.) Lam.) [Utilization of arbuscular mycorrhizal fungi (AMF) for adaptation to drought stress in sweet potatoes (Ipomoea batatas (L.) Lam.)] (Papua: Fakultas Pertanian dan Teknologi Pertanian Universitas Negeri Papua)

[7] Yooyongwecha S, Samphumphuang T, Tisarum R, Theerawitaya C and Cha-um S 2016 Arbuscular mycorrhizal fungi (AMF) improved water deficit tolerance in two different sweet potato genotypes involves osmotic adjustments via soluble sugar and free proline Scientia Horticulturae 198 2016 pp 107–117

[8] Ratnawati L, Yusaini S, Utomo, M and Niswati A 2018 Pengaruh sistem olah tanah dan memupukan nitrogen jangka panjang terhadap jumlah spora mikoriza vesikular arbuskular dan infeksi akar tanaman padi gogo varietas inpago-8 pada musim tanam ke-46 [Effect of long-term tillage systems and nitrogen fertilization on the number of vesicular arbuscular mycorrhizal spores and root infection of inpago-8 upland rice plants in the 46th growing season] Jurnal Agrotek Tropika 4 2 pp 7-11

[9] Hapsoh, Yahya S, Oelim T M H and Saptapurwoko B 2006 Respons fisiologi beberapa genotipe kedelai yang bersimbiosis dengan mva terhadap berbagai tingkat cekaman kekeringan [The physiological response of soybean genotypes to vam inoculation on selected drought stress levels] Hayati 13 2 pp 43 – 48
[10] Gosling P, Hodge A, Goodlass G and Bending G D 2006 Arbuscular mycorrhizal fungi and organic farming *J. Agric. Ecosyst. Environ.* **113** 4 pp 17-35
[11] Devy L and Nawfetrias W 2013 Pertumbuhan, kuantitas dan kualitas rimpang jahe Zingiber officinale roscae) pada cekaman kekeringan di bawah naungan [the growth, quantity and quality of ginger rhizome under drought stress condition] *Pusat teknologi produksi pertanian* **14** 3 pp 216-20
[12] Barus HN 2003 Contribution of Arbuscular Mycorrhizal Fungi to Growth Nutrient Acquisition and Water Relations of Plants Under Drought Conditions (Grauer: Beuren)
[13] Prihastuti 2007 Isolasi dan karakterisasi mikoriza vesikular-arbuskular di lahan kering masam, Lampung Tengah [Isolation and characterization of vesicular-arbuscular mycorrhizae in acid dry land, Central Lampung] *Balai Penelitian Tanaman Kacang-kacangan dan Umbi-umbian* 12 pp 99-106
[14] Indriani N P, Mansyur, Susilawati I and Islami R Z 2011 Peningkatan produktivitas tanaman pakan melalui pemberian fungi mikoriza arbuskular (FMA) [Increasing the productivity of forage plants through the provision of arbuscular mycorrhizal fungi (AMF)] *Pastura* **1** 1 pp 27 – 30
[15] Rahayuningsih S A 2010 Deraan kekeringan pada tanaman ubi jalar [Drought abuse on sweet potato crops] *Buletin Palawija* 20 pp 84–95
[16] Widodo Y and Rahayuningsih S A 2009 Teknologi budidaya praktis ubi jalar mendukung ketahanan pangan dan usaha agroindustry [Sweet potato cultivation technology practice supports food security and agro-industrial enterprises] *Bul. Palawija* **17** 29 pp 21 – 33
[17] Sakha M A, Jefwa J and Gweyi-Onyango J P 2019 Effects of arbuscular mycorrhizal fungal inoculation on growth and yield of two sweet potato varieties *Journal of Agriculture and Ecology Research International* **18** 3 pp 1-8
[18] Begum N, Qin C, Ahanger M A, Raza S, Khan M I, Ashraf M, Ahmed N and Zhang L 2019 role of arbuscular mycorrhizal fungi in plant growth regulation: implications in abiotic stress tolerance *Front. Plant Sci.* **10**