Yield and tuber quality of orange-fleshed sweet potato cultivars under drought stress in greenhouse

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Abstract. Water shortage is an environmental stress that affects the growth, quantity and quality of sweet potato production. The study objective was to analyse the effect of drought stress on the quantity and quality of orange-fleshed sweet potato. Field research has been carried out in April to July 2019 in the greenhouse. This research used a randomized block design with two factors, the first factor was sweet potato cultivars (Beta-1 variety, Perbaungan cultivar, Cengkeh Turi cultivar and Tanah Seribu cultivar) and the second factor was drought stress with different watering level namely severe drought (watered until 1 month and until 2 months with 10 days interval, respectively) and control (watered until 4 months with 10 days interval). The results showed that the orange-fleshed sweet potato cultivars produced significantly different average tuber weights, the number of tubers, beta carotene content, starch content and tuber moisture content were not significantly different. Drought stress influences the yield and quality of tubers which causes a very significant decrease in the parameters of number of tuber, tuber weight, beta carotene content, starch content and tuber water content. The higher the level of drought will cause a decrease in the quantity and quality of sweet potato production.

1. Introduction

At this time the community has recognized the importance of the role of sweet potatoes as functional foods that contain a variety of important nutrients. Sweet potatoes contain carbohydrates in an amount comparable to rice, corn and sorghum. Besides sweet potatoes also contain macro and micro nutrients, vitamin C content, vitamin B complex, vitamin E and folic acid [1] [2] [3].

Sweet potato is one of the tubers that have good adaptability in marginal land [4]. Sweet potato productivity is limited by biotic and abiotic constraints. Growth and crop production often decreases due to environmental stress, one of which is water stress. When harvesting, plant water stress can be a cause of lower yields and the possibility of crop failure [5] [6]. Drought stress can reduce crop production and each plant has a different response. Sweet potato canopy is the only source of biomass that will be distributed to tubers in sweet potato plants. If biomass production is limited due to limited photosynthetic material, tuber production will decrease [7].

The availability of water in the rhizosphere greatly affects plant roots. Root conditions in plants are closely related to physiological and biochemical reactions in the stem, the rate of photosynthesis, respiration and nutrient metabolism in plants [8] [7]. The quantity and quality of tubers is strongly...
influenced by the availability of water during the sweet potato growth period [9] [10]. It's just that research on the effect of drought on tuber quality has not been done much, as stated by George et al [11] that there is very little information about the effect of drought on the content of beta carotene in orange sweet potatoes. To get more information about the effect of drought stress on sweet potatoes, the purpose of this study was to analyse the effect of drought stress on the quantity and quality of orange-fleshed sweet potato.

2. Material and method
Field research and tuber quality analysis have been carried out in April to July 2019 in the greenhouse, Tissue Culture Laboratory and Food Technology Laboratory of the Faculty of Agriculture, Universitas Sumatera Utara. This research used a randomized block design with two factors, the first factor was sweet potato cultivars (Beta-1 variety, Perbaungan cultivar, Cengkeh Turi cultivar and Tanah Seribu cultivar) and the second factor was drought stress with different watering (watered until 1 month with 10 days interval), (watered until 2 months with 10 days interval) and control (watered until 4 months with 10 days interval).

The study began with the preparation of planting material in the form of stem cuttings, planting in a styrofoam box using topsoil as a planting medium, watering according to treatment, plant maintenance, harvesting and analysis of tuber nutrition. The parameters observed were the number of tubers, the average tuber weight, beta carotene content of tubers, tuber starch content and tuber water content. Data observed in this study were tested by F test, then continued using Duncan Multiple Range Test (DMRT) at α level of 5%.

3. Results and discussion
Tubers are a component of production in sweet potato plants. The process of sweet potato tuber formation has started since the age of two weeks after planting (WAP) and stopped at eight WAP. After eight weeks there was no tuber formation. In early-age genotypes, the tuber formation phase is earlier and ends faster than deep-aged genotypes. Differences in harvest age result in a critical phase for the drought flare will be different [12]. Each sweet potato cultivar has a different genetic potential to form tubers. The number of tubers formed is also influenced by the environment and technical culture of sweet potato cultivation. The results of the study (Table 1) showed that the number of tubers produced by the four sweet potato cultivars was not significantly different. Planting using Styrofoam box causes a limited rooting environment so that the number of tubers formed is less than planting in the field.

| Treatment                      | Number of tuber | Description: The numbers followed by the different letters in the rows in each average show significantly different based on DMRT at the level of α = 5% |
|--------------------------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------|
| Cultivars                      | ……tuber……     |                                                                                                                                 |
| Beta – 1                       | 1.08            |                                                                                                                                 |
| Perbaungan                     | 1.83            |                                                                                                                                 |
| Cengkeh Turi                   | 1.89            |                                                                                                                                 |
| Tanah Seribu                   | 1.75            |                                                                                                                                 |
| Drought stress                 |                 |                                                                                                                                 |
| Severe drought stress          | 1.21 b          |                                                                                                                                 |
| Moderate drought stress        | 1.58 ab         |                                                                                                                                 |
| Control                        | 2.13 a          |                                                                                                                                 |

Table 1. Number of tubers of orange-fleshed sweet potato cultivars under varying degrees of drought stress
Table 1 shows that drought stress treatment significantly decreases amount of tuber. The number of tubers under severe drought grip conditions decreased by 76.03% compared to the optimum conditions. The research of Hapsari et al [13] also showed that very limited water supply reduced the number of tubers formed in several sweet potato clones.

Table 2 shows the average tuber weights produced by the four orange sweet potato cultivars were significantly different. Local sweet potato cultivars have higher tuber yields than superior varieties. This is thought to be related to the ability to adapt local cultivars better than superior varieties. Fitter and Hay [14] stated that the high production of a variety is because the variety is able to adapt to the environment. The genetic potential of a variety is very supportive in the success of farming.

| Treatment                      | Average tuber weight |   |
|--------------------------------|----------------------|---|
| Cultivars:                      |                      |   |
| Beta – 1                        | 27.32 c              |   |
| Perbaungan                      | 87.85 a              |   |
| Cengkeh Turi                    | 45.73 bc             |   |
| Tanah Seribu                    | 81.11 ab             |   |
| Drought stress:                 |                      |   |
| Severe drought stress           | 37.26 b              |   |
| Moderate drought stress         | 64.52 ab             |   |
| Control                         | 79.73 a              |   |

Description: The numbers followed by the different letters in the rows in each average show significantly different based DMRT at the level of α = 5%.

In accordance with the decrease in the number of tubers due to drought stress, the average tuber bobo also decreased. The average tuber in plants experiencing severe drought stress decreased 113.98% (Table 2). Sarawa [15] states that in the process of plant growth, water is needed, both for the need to maintain cell turgidity and to carry out metabolism, especially for photosynthesis. The process of photosynthesis requires water as a raw material in the formation of photosynthates, water is mainly needed in the light phase as an electron source to form chemical energy in the form of NADPH₂ and ATP. Rahayuningsih [16] states that the critical phase of sweetpotato plants against the drought is at the beginning of growth at the age of 1-60 days after planting (DAP). In this phase, if there is a drought stress will reduce the weight of the shoor, leaf area, and tuber.

The specialty of sweet potatoes compared to other food plants is due to the higher beta carotene content. Data in Table 3 shows beta carotene in the four orange sweet potato cultivars is not significantly different. The presence of beta carotene compounds in tubers can be seen from the color of the tubers, where sweet potatoes with reddish orange and yellow tubers have higher beta carotene content compared to white and purple tubers. Kammona et al [17] and Alam et al [18] stated that tubers which are bright orange to yellow are sweet potatoes which have high beta carotene content. The content of beta carotene is influenced by genetic and environmental factors.

Data in Table 3 shows that drought stress significantly affects the beta carotene content. Beta carotene content increases with increasing drought stress. Increased beta carotene content reached 25.95% in sweet potato plants that experienced severe drought stress compared to optimal conditions. The results of Laurie et al [19] research also showed that beta carotene content in sweet potatoes treated with limited watering treatment was higher than the moderate and optimal watering level. Motsa et al [20] explained that sweet potato plants experiencing drought stress formed more beta carotene in leaves and tubers which function as antioxidants as protectors from oxidative stress.
Table 3. Beta carotene in tubers of orange-fleshed sweet potato cultivars under varying degrees of drought stress

| Treatment          | Beta carotene (mg/g) |
|--------------------|----------------------|
| Cultivars:         |                      |
| Beta – 1           | 5.85                 |
| Perbaungan         | 6.84                 |
| Cengkeh Turi       | 6.85                 |
| Tanah Seribu       | 6.39                 |
| Drought stress:    |                      |
| Severe drought stress | 7.28 b              |
| Moderate drought stress | 6.38 ab            |
| Control            | 5.78 a               |

Description: The numbers followed by the different letters in the rows in each average show significantly different based on DMRT at the level of α = 5%.

Sweet potato tubers are formed due to the process of root differentiation as a result of the accumulation of assimilates from the leaves that form tubers. The chemical composition of sweet potatoes is influenced by variety, location, and growing season. Carbohydrates are the main content of sweet potatoes. Most of the carbohydrates in sweet potato starch are in the form of starch. The results in Table 4 show the starch content of the four orange sweet potato cultivars was not significantly different. Beta 1 variety has the highest starch content compared to other cultivars. Beta 1 variety is a national superior variety that has been through the stages of selection as a high-source carbohydrate food crop. Rahman et al [21] explained that the main components of carbohydrates in sweet potatoes are starch and food fibre. The high carbohydrate content shows that orange sweet potato can act as a source of carbohydrates.

Table 4. Starch in tuber of orange-fleshed sweet potato

| Treatment          | Starch in tuber (%) |
|--------------------|---------------------|
| Cultivars:         |                     |
| Beta – 1           | 27.20               |
| Perbaungan         | 26.68               |
| Cengkeh Turi       | 26.78               |
| Tanah Seribu       | 27.02               |
| Drought stress:    |                     |
| Severe drought stress | 23.14 c             |
| Moderate drought stress | 26.58 b            |
| Control            | 31.05 a             |

Description: The numbers followed by the different letters in the rows in each average show significantly different based on DMRT at the level of α = 5%.
Starch is a product of the process of photosynthesis. Drought stress is very disturbing the continuity of photosynthesis. The results showed starch content in tubers decreased with increasing drought stress significantly. Nayyar and Gupta [22] stated that drought had a direct influence on the process of photosynthesis. The occurrence of drought causes the rate of transpiration to decrease, stomata closed, the entry of CO₂ is inhibited so that the availability of CO₂ in the leaves decreases which ultimately decrease beta carotene and starch content, tuber characteristics that determine tuber quality are water content. Tuber moisture content is influenced by sweet potato varieties. According to Antarlina and Utomo [23] sweet potato has a high water content if the value is more than 73.5% and is classified as low if the value is less than 65.5%. Based on these criteria, the orange-fleshed sweet potato cultivar includes high water content, and yellow-fleshed sweet potato cultivar including low water content. Ginting et al [24] stated that sweet potatoes which have low water content will have high levels of dry matter. According to the National Standardization Agency (SNI 01-4493: 1998), the requirement for the quality of sweet potato water quality I (tuber weight > 200 gr) is 60%. The results of the study in Table 5 show the tuber moisture content of the four cultivars of orange sweet potato that were studied had met the requirements to become a food.

| Treatment                  | Tuber water content | Description                                                                 |
|---------------------------|---------------------|-----------------------------------------------------------------------------|
| Cultivars                 |                     |                                                                             |
| Beta – 1                  | 61.07               |                                                                             |
| Perbaungan                | 62.48               |                                                                             |
| Cengkeh Turi              | 61.66               |                                                                             |
| Tanah Seribu              | 61.26               |                                                                             |
| Drought stress            |                     |                                                                             |
| Severe drought stress     | 51.28 c             | The numbers followed by the different letters in the rows in each average show significantly different based on DMRT at the level of α = 5%. |
| Moderate drought stress   | 63.98 b             |                                                                             |
| Control                   | 69.59 a             |                                                                             |

Water often limits the growth and development of cultivated plants. The response of plants to lack of water can be seen in its metabolic activity, morphology, growth rate, or productivity. The results of the study in Table 5 show that tuber water content decreases with increasing drought stress significantly. At the level of severe drought, tuber water content decreased 35.71% compared to optimal conditions. Tuber moisture content is strongly influenced by the availability of water that can be absorbed by the roots to meet plant needs. Lahai and Ekanayake [25] state that, drought stress reduces the allocation of dry matter and water to the tuber.

4. Conclusion
The orange-fleshed sweet potato cultivars significantly different in tuber weights, while the number of tubers, beta carotene content, starch content and tuber moisture content were not significantly different. The character of number of tubers, the average tuber weight, beta carotene content, starch content and tuber water content significantly effect to drought stress. The higher the level of drought stress, the quantity and quality of orange sweet potato decreases.
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Acknowledgement
The author would like to thank the Universitas Sumatera Utara for the financial support and facilities for conducting this research through Penelitian TALENTA USU 2019 with contract number 4167/UNS.1.R/PPM/2019 01 April 2019.