Differences in morphology and sugar content of purple sweet potato (*Ipomoea batatas* L.) with potassium treatment at several altitudes

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Abstract. This research was conducted at three locations in low, medium and high plains. This study was aimed to determine the morphological changes and sugar content of sweet potato caused by potassium dose treatment and climate change. Data was analyzed by factorial randomized block design in time series with two factors. The first factor was Altitude: A₁ (50 meter above sea level (MASL)), A₂ (750 MASL) and A₃ (1450 MASL). The second factor was Potassium: K₀ (0 kg/ha), K₁ (50 kg/ha), K₂ (100 kg/ha) and K₃ (150 kg/ha). The data of plant morphology change and sugar content was descriptively analyzed, while agronomic and harvest component data analysis by F test and continued with Duncan Multiple Range Test. The results of morphological observations showed different types of plant growth, which in the lowlands and medium plant growth types spread, twisted, more branches, wider leaf area. However, the plateau of plant growth was relatively dwarf, erect, no twist, huddled and short rods and small leaf area. The tuber weight per plant, number of tuber yield and tuber weight per plot in high altitude were significantly higher than lowland and medium. Similarly, increased altitude will be increased the sugar content significantly.

1. Introduction
Sweet potato as a crop of carbohydrate producing tubers is needed to support sustainability of food security as a complementary of rice. Indonesia needs rice up to 31 million tons annually. Meanwhile, the national rice production per year is only 30 million tons, therefore we must import about 500 thousand to 1 million tons of rice. Opportunities to develop tubers as alternative food are still open widely especially sweet potatoes. Similarly, utilization of purple sweet potatoes as functional food ingredients is increasing with public awareness in efforts to maintain natural health and potential sources of food coloring [1] and as high quality natural food dye [2].

Sweet potatoes are unique as vegetables [3,4], it has high nutrients and their physiological activities serve as treatments such as reducing risk of death of ischemic heart attack, stroke, anticancer, antidiabetic, antiinflammatory, antimicrobial, antioxidant [5] and as basic ingredients of the food industry.
Determination of suitable location needs to get maximum tuber production considering sweet potato crops adaptation widely. It can be planted from altitude 0-3,000 meters above sea level (MASL). Tuber is formed maximally at 25°C at night [6], therefore the effects of latitude, altitude and environmental factors such as light and temperature are important to consider.

Nitrogen, phosphorus and potassium is an essential nutrient, especially potassium that affects most of the biochemical and physiological processes in plant growth and metabolism, primarily contribute to accelerate photosynthesis process [7]. The ability of tuber production is closely related to availability of N, P and especially K elements to help tubers formation and sugar levels, where the starch synthase enzyme is activated by K [8], to form tuber flesh sweeter.

2. Materials and Methods
The research was conducted using top shoot cuttings of local variety, potassium chloride, urea, TSP, sweet potato flesh, ethanol, alcohol, 25% HCl and 45% NaOH, aquadest, phenolphthalein, KI 30%, Sodium Thiosulfate 0.1 N and starch indicator. Tools used were hoes, machete tripe, string, label, plastic, pipette, Erlenmeyer, filter paper and volumetric flask.

The research was conducted in 3 locations by Completely Randomized Block Design with Time Series Design for multi-site combined analysis [9]. The first factor was Altitude (A): A₁ = 50 MASL (Medan Johor). A₂ = 750 MASL (Sibolangit). A₃ = 1,450 MASL (Dolat Rakyat). The second factor was Potassium (P): P₀ = 0 kg K₂O/ha, P₁ = 50 kg K₂O/ha, P₂ = 100 kg K₂O/ha and P₃ = 150 kg K₂O/ha [10].

The parameters were primary stem length, vein internode, number of branch, leaf area, tuber weight/plant, number of tubers/plant, tuber weight/ha, total sugar content (%) and sugar/ha production. Data of observation result were analyzed by F test, while in statistical data test obtained significant result furthermore test continued by DMRT test (Duncan’s Multiples Range Test). The data was descriptively analyzed for data obtained based on visual observation.

3. Results and Discussion
3.1. Differences of plant morphology
On the basis of visual observation, there was a difference of plant morphology at three locations tested. These differences include growth type, main stem length, length of internode, number of branches and leaf area (Table 1). Plant growth type spread with main stem and vein internode longer in the lowlands than highlands where type of plant growth was tend to be erect without twining and branch shape of huddled. This condition was due to considerable temperature difference where in the lowlands average temperature of the day was 30°C and 28°C at night, whereas on the plateau average temperature of the day was 23°C and 17°C at night [11]. According to Ravi et al. [12] and Gajanayake et al. [13], both of air and soil temperatures control the development of canopies and roots of sweet potato storage. Increased air temperature plays an important role in stem extension and canopy development as well as biomass accumulation [14]. The optimum temperature for stem extension and leaf area expansion was approximately 29-30°C.

Table 1 shows the different length of main stem, length of internode, number of branches and leaf area sweet potato at different altitudes above sea level. The length of main stem spread longer and very twining in the lowlands such as Medan Johor at altitude 50 MASL than type of plant in Sibolangit. In highland plant was shorter, huddled without twisted in Dolat Rakyat. Length of internode was not significantly different in Medan Johor with Sibolangit, but it was shorter significantly in Dolat Rakyat. Numbers of branch in Sibolangit was significantly less than Medan Johor and Dolat Rakyat. The leaf area showed no difference in three areas studied. The shape of tubers in lowlands tend to be round up to ovate, in medium plains tend to obovate and long oblong to long irregular in highland.
Table 1. Differences of morphology sweet potato at several altitude.

| Treatment       | length of main stem (cm) | length of internode (cm) | number of branches (pieces) | Leaf Area (cm²) |
|-----------------|--------------------------|--------------------------|-----------------------------|-----------------|
| 1. A₁ (50 MASL) | 129.71a                  | 3.20a                    | 11.46a                      | 42.68a          |
| 2. A₂ (750 MASL)| 96.13b                   | 3.01a                    | 9.04b                       | 40.26a          |
| 3. A₃ (1450 MASL)| 51.25c                   | 2.57b                    | 10.54a                      | 37.49a          |

Note: The numbers followed different letter in the same column is significantly difference at α = 5% by Duncan's Multiple Range Test.

Difference of temperature, visually show prominently influence growth type and tuber shape compared to length of internode, number of branches and leaf area. In the summer, due to high temperatures around roots, high temperatures in air and both of its combination encourages canopy growth. Under temperature stress conditions will cause delays in initiation and tuber formation [15,16]. Beside temperature difference, possibility of different intensities of solar irradiance and air humidity causes of different types of growth. Reduction of radiation intensity will promote branch growth and reduce tuber weight [17].

3.2. Harvesting Components

Based on data analysis of crop yield component, there are difference in number of tuber per plant, tuber weight per plant and tuber weight per hectare due to difference of altitude of plant growth, which can be seen in Table 2.

Table 2. Differences of numbers and weight of tuber in various altitudes.

| Treatment       | Amount of tuber/ Plant (pieces) | Weight of Tuber/ Plant (g) | Weight of Tuber/ ha (ton) |
|-----------------|---------------------------------|-----------------------------|----------------------------|
| 1. A₁ (50 masl)| 3.75a                           | 352.46b                     | 22.09b                     |
| 2. A₂ (750 masl)| 2.42c                           | 268.15c                     | 13.73c                     |
| 3. A₃ (1450 masl)| 2.88b                           | 593.02a                     | 30.67a                     |

Note: The numbers followed different letter in the same column is significantly difference at α = 5% by Duncan's Multiple Range Test.

The number of tubers per plant is significantly different in each area where the most number of tubers in lowland (Medan-Johor) followed by Dolat Rakyat and Sibolangit. The maximum number of storage roots will increase quadratically as temperature rises to 25°C and decrease as temperature increases [18].

Tuber weight per plant and tuber weight per hectar were significantly heavier at Dolat Rakyat, followed by Medan-Johor and Sibolangit. In high altitude, intensity of solar irradiance is reduced, whereas high air humidity leads to reduced evaporation so the photosynthetic activity is more widely used for tuber formation than shoot growth. According to Haynes [17] the duration of irradiation of 56 cal/m² /day will encourage formation of tubers and the decrease of radiation intensity will reduce weight of tubers. Temperatures around the roots are critical for root and tuber initiation, canopy and plant growth [15].

Combination of treatments between potassium and altitude caused a significantly difference in response due to the interaction both of them, where amount of tuber was in Medan-Johor with K₂O 50 kg/ha treatment and the lowest amount of tuber in Sibolangit with K₂O 50 kg/ha treatment. However in same location with different levels of potassium treatment did not show difference amount of tubers.
per plant. The function of potassium [18] will increase production and yield quality as well as increase the translocation of sugar and starch required in large quantities for the process of plant growth.

The result of combination treatment between potassium and altitude caused differences in the number of tubers per plant are listed in Table 3.

### Table 3. Differences of amount of tuber per plant caused by interaction altitudes and Potassium.

| Treatment  | Number of tuber/plant (pieces) |
|------------|--------------------------------|
| A₃P₀       | 3.33abc                        |
| A₃P₁       | 4.33a                          |
| A₃P₂       | 3.92ab                         |
| A₃P₃       | 3.42abc                        |
| A₄P₀       | 3.08bcd                        |
| A₄P₁       | 2.08e                          |
| A₄P₂       | 2.25de                         |
| A₄P₃       | 2.25de                         |
| A₅P₀       | 2.50cde                        |
| A₅P₁       | 2.83cde                        |
| A₅P₂       | 3.17bcd                        |
| A₅P₃       | 3.00bcd                        |

Note: The numbers followed different letter in the same column is significantly difference at α = 5% by Duncan's Multiple Range Test.

Role of single potassium was not significant for each level treatment at certain same location, but after get interaction with environment it causes significant differences in number of tubers. The genotype and environmental interactions significantly affect to growth and production of sweet potatoes [8].

3.3. Components of Biochemical Test

Test of total sugar content and sugar production per hectare at three different locations based on altitude can be seen in Table 4.

### Table 4. Differences of total sugar content (%) and sugar production/ha at various altitudes

| Treatments      | Total sugar content (%) | Sugar production/ha (ton) |
|-----------------|-------------------------|---------------------------|
| 1. A₁ (50 MASL) | 5.21b                   | 1.13b                     |
| 2. A₂ (750 MASL)| 7.14b                   | 0.99b                     |
| 3. A₃ (1450 MASL)| 10.57a                  | 3.24a                     |

Note: The numbers followed different letter in the same column is significantly difference at α = 5% by Duncan's Multiple Range Test.

Based on statistical analysis of sugar content and sugar production per hectare was higher significantly in the highlands, whereas in low and medium plains did not show any significant difference. Although sugar content was higher in medium plains than lowland, but sugar production was low because tuber production per hectare in medium plains was lower than lowland but not significant. The environment will affect to formation of sugar, where the altitude increases, the
temperature decreases, it will increase sugar content. This is consistent with the research that differences in the amount of sugar content feasible to occur due to differences in varieties, endogenous amylase activity and environmental conditions [20].

4. Conclusions
The highest production of tubers and sugar content were found in the highlands at Dolat Rakyat District (an average of 30.67 tons/ha tuber production) and sugar production (3.24 tons/ha). The dosage of fertilization did not effect in each region, whereas altitude caused different production of tubers and sugar significantly in all areas studied. Combination of altitude treatment and potassium doses caused significant tuber numbers and resulted the largest number of tubers was A1P1 with an average tuber of 4.33 pieces/plant.

It is suggested to cultivate local genotypes in highlands to obtain tuber yields and the highest sugar production even without potassium fertilization.

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