The yield potential and chemical analysis of some introduction sweet cultivars in the Papua highlands

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Abstract. The research aims to identify the adaptability some Cilembu sweet potato clones in the highland region of Papua and to determine consumer responses to sweet potato clones Cilembu. The activities carried out in Jayawijaya and Yahukimo. The experiment were 10 cultivars / clones of yams consisting of 6 (six) clones Cilembu and four (4) local sweet potato clones of each: UP-UM 1 (V1), UP-UM 4 (V2), UP-UM 5 (V3), UP-UM 6 (V4), UP-UM 9 (V5), Rancung (V6), Papua Salosa (V7), Helaleke (V8), Cangkuang (V9), and Weayuken (V10). The experiment were conducted on two districts with a height above sea level (asl) different namely Jayawijaya (1550 m asl) and Yakuhimo (2000 m). Assessment was laid out using a randomized block design (RBD) with three replications. The assessment results in districts Jayawijaya shows that, clones Cilembu UP -UM1, UP -UM 5, UP -UM 6, UP -UM 9, and Rancung, as well as varieties lonkal Papua Salosa compounds containing β-carotene / Antocianin shown from yellow / orange / purple. In the district of Jayawijaya, average tuber longest and largest bulb diameter produced by local variety Cangkuang. But the number of tubers were generated by clones Cilembu UP-UM 5. Productivity and highs of 10 varieties / clones were studied both in Jayawiya and Yakohimo is Cangkuang (23.59 t / ha), while the highest dry matter content produced by clone up- UM 4. Production of dry matter produced by the highest Weayuken varieties. The results of the chemical analysis of the highest protein content produced by clone UP-6 and UP-UM UM 9; The highest content of starch and amylose varieties produced by Cangkuang; The highest content of reducing sugar produced by clone UP-6 and UP-UM UM 9; The highest content of β-carotene produced by UP-6 and UP-UM UM 9; and the highest content of vitamin C is produced by UP-UM 6.

1. Introduction
Sweet potato (Ipomoea batatas. Poir) is a staple food for people in Papua and West Papua. This food commodity is the staple food for the tribes living in areas with very few alternative food sources. People in marginal areas generally overcome food scarcity by utilizing tubers, including sweet potatoes, as a source of protein. Therefore, efforts to increase the productivity and quality of tubers will greatly help overcome food problems in the region [1].

In some locations, the position of sweet potatoes is very strategic, both from the ecological aspect and from the economic aspect. Opportunities to get sweet potato substitute commodities as food ingredients are relatively small. An ecological aspect, it is very rare for low-risk food crops other than sweet potato to be able to adapt and produce well with simple technology. The economic aspect,
supplying sweet potatoes from other districts to certain very isolated locations is a less economical alternative due to the difficulty of transportation and logistics [2].

Residents of rural areas who use sweet potatoes as a staple food often experience difficulties, because crops fail to produce as a result of extreme natural influences (floods and droughts) or pest/disease attacks. Thus alternative technologies to overcome these problems must be available. Politically, maintaining sweet potato as a staple food encourages the realization of national food diversification [3]. Almost all parts of sweet potato can be used, namely a) Leaves: vegetables, animal feed, b) Stems: planting material, animal feed, c) Potato skins: animal feed, d) Sweet potato flour: food, e) Sweet potato starch: fermentation, animal feed, citric acid, f) Fresh sweet potato: food, even according to [4], sweet potato has the potential as a raw material for modern industry (adhesives, textiles, pharmaceuticals, and cosmetics).

In Indonesia, especially in Papua, there are many varieties of sweet potato that have been identified, both local and introduced varieties. Each variety has its own advantages. This is a genetic property that must be developed. Introduced sweet potato varieties that have advantages that are expected to be developed in Papua are several varieties/clones of sweet potato originating from Cilembu, West Java, known as Cilembu variety.

The Cilembu variety is one of the superior agricultural products that has the advantage of being able to be stored for more than 10 days, cooked in an oven for 30-90 minutes (depending on the size), the center of the tuber will produce a very sweet liquid like honey. The sweetness of the cilembu variety is due to the sugar content of cilembu sweet potatoes which is higher than other sweet potatoes, namely raw sweet potatoes reaching 11-13% and cooked sweet potatoes 19-23%, so it is very popular with consumers. The skin of the Cilembu variety is yellowish white (ivory) with an elongated, round tuber shape. This sweet potato has another uniqueness, which is that it does not cause stomach upset even though it is eaten before breakfast.

The Baliem Valley in Papua has a wider genetic diversity than areas outside the valley. The results of the identification of plant characteristics in Jayawijaya district found several cultivars that have special morphotypes such as round leaves with shallow grooves and curling upwards, leaf surfaces that are shiny like oil. In terms of usability, there are also cultivars that are used as treats in rituals and customs, forage for pigs and ingredients for their traditional medicines. In connection with the increasing number of local species and short-lived superior varieties used by the community, deep-aged species tend to disappear [5]. This has prompted the Papuan government to explore the wealth of sweet potato germplasm in Papua province, especially in highland areas.

This research aims to determine the adaptability of several clones/varieties originating from Cilembu in the highlands of Papua. It is hoped that later this variety can develop well in Papua as an alternative food ingredient for the community.

2. Materials and Methods

The activity was carried out in the highlands of Papua, namely in the districts of Jayawijaya (1,550 m asl) and Yahukimo (2,000 m asl). This research was conducted from January to December 2015. The research treatments were 10 sweet potato cultivars/clones consisting of six of Cilembu sweet potato clones; UP-UM 1 (V1), UP-UM 4 (V2), UP-UM 5 (V3), UP-UM 6 (V4), UP-UM 9 (V5), Rancung (V6), and 4 local sweet potato clones: Papua Salosa (V7), Helaleke (V8), Cangkuang (V9), and Weayuken (V10). The study used a Randomized Block Design (RBD) with three replications. The cultivation technique used is the kuming system with a spacing of 100 cm x 70 cm one cutting/hole, plot size 4 m x 5 m. Plant maintenance includes weeding, stem reversal and control of major pests/diseases carried out as needed. Harvest the tubers at the age of 6-7 months after planting. An inventory of the origin and morphological characters of each cultivar/clone to be studied is carried out prior to the implementation of the activity.

The agronomic data observed and analyzed included: Number of tubers (measured the average number of tubers per kumming), tuber length (measured average length of tubers per yellow), tuber diameter (measured average diameter of tubers in the middle), tuber productivity (measured tuber wet
weight per hectare) and tuber dry matter was measured using the formula: tuber dry weight / wet sample weight x 100. The percentage of dry matter was determined by: a sample of 100 grams from each cultivar was dried in an oven at 70 °C for 72 hours or until the sample reached a constant dry weight, dry matter production, tubers (the result of multiplication of tuber production with dry matter presentation) as well as the morphological characters of each cultivar before the implementation of the study. Analysis of nutritional content, carried out in the chemical laboratory of the University of Muhammadiyah Malang. The contents analyzed were Protein (semi micro kjeldahl), amilum (direct acid hydrolysis), Amylose (spectrophotometry), Reducing sugar (Spectrofluorometry), Carotene (Column chromatography), and Vitamin C (Titration).

Agronomic data were statistically analyzed using ANOVA at the 5% level and significant differences were further tested with Duncan's New Multiple Range Test. Analysis of nutritional content is known through laboratory analysis and morphological characters are analyzed descriptively.

3. Results And Discussion

3.1 Morphological Character and Origin of Sweet Potato Germplasm

The inventory of the origin and morphological characters of each cultivar/clone was focused on observing the skin color of the tubers and the color of the flesh of the tubers. The results of the inventory of origin and morphological characters of each studied cultivar/clone are presented in Table 1.

Table 1. Morphological characters of sweet potatoes in adaptation tests of sweet potato clones/varieties in Papua

| No | Clones/Varieties | Collection          | Morphological Character | Tuber Skin      | Tuber Meat       |
|----|------------------|---------------------|-------------------------|-----------------|-----------------|
| 1. | UP-UM 1          | Univ. Padjadjaran   | Slightly brown          | Pale yellow     |                 |
| 2. | UP-UM 4          | Univ. Padjadjaran   | Brown                   | White           |                 |
| 3. | UP-UM 5          | Univ. Padjadjaran   | Purple                  | Purple          |                 |
| 4. | UP-UM 6          | Univ. Padjadjaran   | Pale yellow             | Orange          |                 |
| 5. | UP-UM 9          | Univ. Padjadjaran   | Light Pink              | Yellow/orange   |                 |
| 6. | RANCUNG          | Univ. Padjadjaran   | Yellow                  | Pale yellow/orange |               |
| 7. | PAPUA            | Balitkabi           | Yellow                  | Yellow/orange   |                 |
| 8. | HELALEKE         | Local Wamena        | Red                     | Pale Yellow     |                 |
| 9. | CANGKUANG        | Balitkabi           | Red                     | Light Yellow    |                 |
| 10.| WEAYUKEN         | Local Wamena        | Brown                   | Purple          |                 |

3.2 Yield Components

The results of statistical analysis of the average tuber length are presented in Table 2. The average tuber length in Jayawijaya district showed that the Cangkuang variety produced the highest tuber (23.62 cm). The results of the statistical analysis of tuber length showed that Cangkuang varieties were not significantly different from Halaleke and Weayuken varieties, but significantly different from other varieties. Klon UP-UM 9 memiliki panjang umbi terpendek. In Yahukimo, the results showed that the Cangkuang variety was able to produce the highest tuber (21.61 cm) but was not significantly different from clones UP-PM 1, UP-UM 6 and the local variety Papua Salosa.
Table 2. Production components of sweet potato adaptation study in Papua

| No | Clones/Varieties | Tuber Length (cm) | Tuber Diameter (cm) | Number of Tuber (bh) |
|----|------------------|-------------------|---------------------|---------------------|
|    |                  | J. Wijaya | Yahukimo | J. Wijaya | Yahukimo | J. Wijaya | Yahukimo |
| 1. | UP-UM 1          | 14.55      | 20.23    | 4.42      | 3.77      | 4.97      | 3.88      |
| 2. | UP-UM 4          | 13.67      | 15.49    | 4.15      | 4.23      | 4.93      | 4.26      |
| 3. | UP-UM 5          | 16.98      | 13.33    | 5.45      | 5.64      | 6.80      | 5.28      |
| 4. | UP-UM 6          | 15.37      | 18.89    | 4.29      | 3.43      | 6.07      | 3.75      |
| 5. | UP-UM 9          | 13.54      | 13.31    | 4.94      | 3.61      | 3.80      | 4.26      |
| 6. | RANCUNG          | 14.49      | 12.07    | 4.97      | 4.57      | 6.27      | 4.22      |
| 7. | PAPUA            | 19.04      | 18.17    | 5.27      | 5.26      | 4.60      | 4.84      |
| 8. | HELALEKE         | 20.43      | 15.09    | 5.87      | 4.38      | 3.13      | 4.33      |
| 9. | CANGKUANG        | 23.62      | 21.61    | 7.29      | 4.97      | 5.27      | 4.50      |
|10. | WEAYUKEN         | 20.00      | 13.89    | 6.23      | 4.94      | 7.40      | 4.80      |

The results of the tuber diameter in Jayawijaya showed that the Cangkuang variety produced tubers with the highest diameter of 7.29 cm and based on statistical analysis it was significantly different from introduced clones and other local varieties. The highest tuber diameter at the study site in Yahukimo was produced by the UP-UM 5 (5.64 cm) clone which based on statistical results was not significantly different from the local varieties Cangkuang (2.97 cm) and Weayuken (2.94 cm), but significantly different with other varieties.

In contrast to tuber length and tuber diameter, the analysis showed that the highest number of tubers was produced by the local variety Weayuken (7.40 pieces) which was significantly different from other varieties except for the introduced varieties UP-UM 5, Rancung, UP-UM 6, and the introduced varieties, local Cangkuang.

3.3 Yield and dry matter production

The tuber yield of the Cilembu sweet potato clones in the Jayawijaya and Yahukimo locations was the wet tuber production of each clone/variety. The results of the analysis of the performance of tuber production are presented in Table 3.

Table 3. Productivity and production of dry matter tubers adaptation study of sweet potato varieties

| No | Clones/ Varieties | Production of tuber wet weight (t/ha) | Production of tuber dry weight (t/ha) | Dry matter content (%) |
|----|------------------|--------------------------------------|--------------------------------------|------------------------|
|    |                  | J. Wijaya | Yahukimo | J. Wijaya | Yahukimo | J. Wijaya | Yahukimo |
| 1. | UP-UM 1          | 7.40      | 7.60     | 3.22      | 3.04     | 43.54     | 39.99     |
| 2. | UP-UM 4          | 10.67     | 8.68     | 4.65      | 3.26     | 43.62     | 37.53     |
| 3. | UP-UM 5          | 1.67      | 10.71    | 5.27      | 4.11     | 35.25     | 38.29     |
| 4. | UP-UM 6          | 13.61     | 7.43     | 4.32      | 2.08     | 31.81     | 28.09     |
| 5. | UP-UM 9          | 13.08     | 7.40     | 5.64      | 2.98     | 43.08     | 40.36     |
| 6. | Rancung          | 15.14     | 7.55     | 4.62      | 2.03     | 30.58     | 26.78     |
The average wet tuber production of each clone/variety in Jayawijaya appears to be quite varied, ranging from 7.40 – 23.59 t/ha. The results of statistical analysis showed that the local variety Cangkuang (23.59 t/ha) which gave the highest yield was significantly different from other varieties except the local variety Weayukan. In Yahukimo, the local variety Cangkuang also gave the highest yield (13.31 t/ha) but based on the results of statistical analysis it was not different from the local variety Weayukan and Klon UP-UM 5. However, in general, tuber production in Yahukimo was lower than the tuber production produced in Jayawijaya. Environmental and climatic factors of each location greatly affect the difference in tuber production. This is in line with the results of research by [6] which showed that the average tuber production of several varieties in Holima (1,700 m asl) was 25.69 t/ha, Napua (2,000 m asl) averaged 10.45 t/ha, and in Sinakma (1,850 m asl) only reached an average of 8.44 t/ha.

The highest tuber dry weight production in Jayawijaya district was produced by Cangkuang (9.19 t/ha) and Weayuken (9.28 t/ha) varieties. Statistically, the production was significantly different from the dry tuber production of the other eight varieties studied. Likewise in Yahukimo, statistical results showed that the highest tuber dry weight production was produced by the Cangkuang variety (5.07 t/ha), which was significantly different from other varieties/clones.

The results of tuber dry matter content showed that the UP-UM 9 clone in Jayawiya produced the highest tuber dry matter content of 43.08%, but based on the results of statistical analysis it was not significantly different from other clones/varieties except with UP-UM 5 and UP-Clone clones. UM 6. The same thing happened in Yahukimo, where the UP-UM 9 clone had the highest dry matter content (40.36%) with statistical analysis results that were not significantly different from other varieties except for the local Rancung variety.

The dry matter content of tubers is a very important parameter in the selection of sweet potato for consumption because it involves the production of tuber dry matter and the taste of the tubers that are eaten. The dry matter content of tubers was positively correlated with starch content, while the starch content of tubers was positively correlated with the taste of a variety, tubers containing high starch tended to give a good taste [7].

Tuber dry matter is a function of tuber dry weight and tuber dry weight production. Thus, if a clone/variety has high production and high dry weight, the dry matter also tends to be high. However, if a clone/variety has high tuber production but has a low dry weight, the dry matter tends to be low and vice versa. The pattern of dry matter production in sweet potato plants has been studied by several researchers. The maximization of total dry matter production in sweet potato plants depends on the availability of solar radiation, the photosynthetic capacity of the plant and the duration of that capacity.

Increased radiation or photosynthetic activity and maintenance for a long time will increase dry matter production [8]. The heritability value of tuber dry matter content of the 10 sweet potato clones studied was quite high, namely 61.2 + 19.5% (family) and 58.6 + 9.8% (individual plant) [9].

### 3.4 Chemical composition

Analysis of the chemical composition of sweet potato as a result of the study was carried out on the content of protein, amilum, sugar, amylose, beta carotene, and vitamin C, the results of the complete analysis are presented in Table 4.
Table 4. Chemical composition of clone/sweet potato varieties

| No  | Clones/Varieties | Protein  | Amylum  | Reducing sugar level | Amylose | Beta carotene | Vitamin C |
|-----|------------------|----------|---------|----------------------|---------|---------------|-----------|
|     |                  | g/100 g  | %       | g/100 g              | mg/100 g|               |           |
| 1   | UP.UM 1          | 3.06     | 15.42   | 8.48                 | 3.66    | 43.95         | 30.79     |
| 2   | UP.UM 4          | 2.50     | 18.86   | 6.92                 | 4.45    | 1.98          | 24.63     |
| 3   | UP.UM 5          | 3.02     | 14.17   | 8.74                 | 3.38    | 71.70         | 31.67     |
| 4   | UP.UM 6          | 3.09     | 15.81   | 9.05                 | 3.75    | 69.58         | 32.99     |
| 5   | UP.UM 9          | 3.09     | 15.55   | 9.02                 | 3.70    | 70.63         | 32.76     |
| 6   | Rancung          | 2.67     | 15.16   | 8.27                 | 3.60    | 39.86         | 30.13     |
| 7   | P. Salosa        | 3.02     | 15.76   | 8.22                 | 3.74    | 41.47         | 30.13     |
| 8   | Helaleke         | 2.39     | 18.42   | 7.09                 | 4.36    | 1.47          | 25.72     |
| 9   | Cangkuang        | 2.53     | 18.87   | 6.96                 | 4.46    | 1.85          | 25.06     |
| 10  | Weyayuken        | 2.71     | 16.38   | 7.52                 | 3.88    | 1.59          | 27.04     |

The results of the analysis showed that the protein content of all clones/varieties studied ranged from 2.39 to 3.09 g/100 g wet weight (ww). In general, it appears that the introduced varieties have a relatively higher protein content than the local varieties (Table 3). The total protein content of fresh sweet potatoes is very small, only around 4.38% - 8.98% (dwb) with a mean 6.29% in 100 lines from 7 parents in America [10], while some varieties in Papua are lower, 1.29% - 1.81% [11].

The high protein content of clones/introduced varieties is thought to be due to genetic factors of the varieties planted and the ability of introduced varieties to adapt well to environmental conditions in the Jayawijaya and Yahukimo highlands. Protein content is influenced by variety, growing environmental conditions, cultivation method, application of N fertilizer and plant age [12]. Sweet potato tubers with high protein content are reported to function as proteinase enzyme inhibitors which are thought to have anti-cancer and anti-oxidant abilities [13].

The Amylum content of clones/varieties studied varied between 14.17% - 18.87%. The data in Table 4 shows that the average starch content of local varieties is higher than that of introduced varieties. The highest Amylum content (18.87 %) was produced by Cangkuang variety, followed by UP-UM 4, Helaleke, and Weyayuken clones with Amylum content respectively: 18.86%, 18.42% and 16.38%. The lowest amyllum content was produced by clone UP-UM 5 (14.17%).

The low average amyllum content of introduced clones was mainly caused by genetic factors. The average fresh sweet potato amyllum content is 18% - 20%, but the variation is very large, mainly influenced by genetic factors [14]. Sweet potatoes collected from several countries such as the Solomon Islands have a starch content of 17.7 – 23.4%. India 11.0 – 25.5%, Taiwan 7.0 – 22.2% and Thailand 4.1 – 26.7%; The dry base starch content of clones from Brazil was 42.6 - 78.7%, and 52.8 -53.8% and 48.1 - 60.3%, respectively, from Malaysia and Indonesia ([15]; [16]).

Amylose is one of the main components of sweet potato starch. The results of laboratory analysis of the studied sweet potatoes showed variations in amylose content from 3.66 to 4.46%. As with the starch content, the highest amylose content (4.46%) was produced by variety Cangkuang. The lowest amylose content was produced by the UP-UM 5 clone at 3.38%. The difference in amylose content in various types of sweet potato is influenced by the variety, harvest age, climatic conditions, and different types of soil. The study was carried out in the same area, climatic conditions, soil type, and harvest age, so that the alleged difference in amylose levels in each variety was caused by genetic factors [17].

Sugar is one of the important compounds that affect the quality of sweet potatoes. Analysis of the nutritional content of sweet potatoes, one of which was carried out on the content of reducing sugar. The types of reducing sugars in sweet potatoes are glucose and maltose. The results of the analysis of the highest sugar content was produced by UP-UM 6 (9.05%) and the lowest sugar content was produced by UP-UM 4 (6.96 %). It also appears that the sugar content of Cilembu yam clones is higher than the local varieties.
The high sugar content in UP-UM 6 appears to be closely related to the identification of the morphological characters of each clone/variety. Where the yellow/orange yam flesh in UP-UM 6 is sweeter than UP-UM 4 and Cangkuang which has white sweet potato flesh and UP-UM 5 which has purple sweet potato flesh. This condition was caused by the high sugar content in Sweet Potato Cilembu UP-UM 6 and UP-UM 9. This condition is in accordance with the results of research on eight yellow/orange sweet potato clones showing that the reducing sugar content ranged from 3.4 to 8.2% higher than that of purple sweet potato whose reducing sugar content only reached 1.5-5.3% and white sweet potato which only reached 1.7%. Maltose content increased significantly on heating sweet potatoes as a result of starch hydrolysis by the enzyme α-amylase which is naturally found in sweet potatoes and optimum activity at a temperature of 70-750°C [18]. On steaming purple sweet potatoes occur an increase in reducing sugar content from 3.3% bk to 17.7% bk, also noted an increase in reducing sugar from 6% to 12% in baked sweet potatoes [19].

Beta-carotene content in Cilembu sweet potato clones was higher than that of local varieties. Most of the carotenoids in sweet potatoes were detected as beta-carotene (86-90%) especially in tubers with orange flesh. Some varieties with white sweet potato flesh generally do not contain beta-carotene or if present only in very small amounts [14]. Carotenoid content in tubers is strongly influenced by the type or variety [19]. In addition to varieties, the beta-carotene content of sweet potatoes is also influenced by planting time, harvest age, location and water adequacy [12]. The problems faced in the formation of sweet potato varieties with high beta carotene content are high water content and low dry matter [20].

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Vitamin C is one of the essential vitamins that need to be considered so that sweet potato consumers are healthy and productive. However, in this study, an analysis of the content of vitamin C was carried out, because it was considered that vitamin C was one of the vitamins found in sweet potatoes. The vitamin C content of the ten clones/varieties analyzed appeared to be quite varied between 24.63 mg/100 g to 32.99 mg/100 g ww. The results of laboratory analysis showed that generally Cilembu yam clones had higher vitamin C content than local varieties. The highest vitamin C content was found in the UP-UM 6 clone (32.99 mg/100 g ww).

Efforts to increase food diversification which is a priority program of the Ministry of Agriculture in accordance with PP No. 22 of 2009 concerning the Acceleration of Diversification of Food Consumption Based on Local Resources. The high level of dependence on rice and flour needs to be gradually reduced by increasing consumption and production of local food ingredients, including sweet potatoes. The ideal consumption of tubers is set at 100 g/capita/day in the Indonesian Food Harvest Scale in 2009 [21].

4. Conclusion
The inventory of morphological characters indicated that the Cilembu sweet potato clones UP-UM1, UP-UM 5, UP-UM 6, UP-UM 9, and Rancung, as well as the local variety Papua Salosa contained senyawa-Carotene/Anthocyanin compounds which were shown in yellow/orange/purple colors.

The Cakuang variety produced the highest tuber production of the 10 varieties/clones studied in both Jayawijaya and Yakohimo, but it was not significantly different from the UP-UM 5 clone. However, the highest dry matter content was produced by the UP-UM 9 clone at the two research sites.

The results of chemical analysis on the highest protein content were produced by clones UP-UM 6 and UP-UM 9, Cangkuang variety contains the highest amilum and amylose, the highest reducing sugar
content was produced by clones UP-UM 6 and UP-UM 9; The highest β carotene content was produced by UP-UM 5 and the highest Vitamin C content was produced by UP-UM 6.

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