Cassava genotypes selection for high yield and high starch content in advanced yield trials

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Abstract. Increasing the cassava-based industry requires a large and continuous supply of tubers. Tuber production is increased with planting high yielding varieties with high starch content. This study aimed to select cassava genotypes obtained from open pollination among parents showing high yield and starch content in the advanced yield trial (AYT) stage. The experiment was carried out at Muneng research station (Probolinggo District, East Java, Indonesia) using randomized complete block design with three replications and two planting seasons (2018 and 2019). The experiments used 24 cassava genotypes, including three varieties as a control (Adira 4, UJ 5, and Litbang UK 2). The cassava planted in 2018 was exposed to stress due to drought, while in 2019, the plants received optimal water availability. During the drought stress, the attack of red mite (Tetranycus sp) negatively correlated with tuber yield. In optimal water conditions, the symptoms of red mite attack are low. Based on the combined analysis of variance, genotype × growing season interaction affected plant height at six months, and at ten months for tuber yield, starch content, and starch yield. Among the clones tested, OMM 1207-22 produced the highest tubers yield with an average of 47.5 t·ha⁻¹ in the two growing seasons, with the starch yield, was equivalent to 8.89 t·ha⁻¹, significantly higher compared with the Litbang UK 2 variety (average tubers yield 41.5 t·ha⁻¹, starch yield 7.40 t·ha⁻¹). Also, 13 genotypes produced starch ranging from 6.49 t·ha⁻¹ to 8.33 t·ha⁻¹.

1. Introduction

Environmental factors strongly influence plant growth. Environmental factors that are less than optimal will limit plant growth. For example, plants that are well adapted to a limited amount of water can survive better in water-limited environments such as deserts. Several environmental factors that affect plant growth include light, temperature, water, humidity, and nutrients [1]. Plants require different optimal moisture conditions, varying depending on many factors, such as soil type, climatic conditions, growth rate and habits [2]. Water availability is one of the essential factors in determining plant survival, development, and productivity. The primary source of water for the plant comes from rainfall and irrigation [3]. The growth of cassava is highly influenced by environmental conditions and has a significant genotype and ecological interaction. Cassava exhibits substantial differential genotypic responses to varying environmental conditions, a phenomenon termed genotype × environment interaction (GEI) [4].
The breeding program for cassava relies on a recurrent phenotypic selection that takes advantage of the vegetative propagation of this crop. Successive stages of selection (single row trial–SRT; preliminary yield trial–PYT; advanced yield trial–AYT; and uniform yield trials UYT), gradually reduce the number of genotypes as the plot size, the number of replications and locations increases. Plots at this stage of selection are more extensive than those from previous stages with four (or five) rows and five plants per row. Three replications are used in a single location [5].

This study aimed to select the promising clones that showed high yield potential and high starch content at advanced yield trial–AYT.

2. Materials and Methods

2.1. Site description

The research was carried out at Muneng research station, Probolinggo District, East Java Province, Indonesia. The characteristics of research locations were altitude is about 10 m above sea level, the minimum temperature is 23.5 °C, and the maximum temperature is 34.0 °C, with a relative humidity of 77%. The soil type of research location is Alfisol with 22% clay fraction, 38% dust, and 42% sand [6].

2.2. Experimental design

The experiment was set using a randomized block design with three replications and conducted in two seasons (2018 and 2019). The treatments were 24 clones or varieties of cassava, consisting of 21 promising clones and three control varieties (Adira 4, UJ 5, and Litbang UK2). The control varieties are cassava varieties that have been released by the Ministry of Agriculture with the high yield potential and high starch content. Each clone was planted on a plot measuring 5 m × 4 m, spacing 1.0 m × 0.8 m (25 plants/plot). Plants are fertilized at a dose of 750 kg Phonska + 100 kg Urea/ha which is given three times. At two weeks after planting, the fertilizer given was 25% Phonska, six weeks 33% Phonska + 50% Urea, and ten weeks after planting 42% Phonska + 50% Urea. Reduction of shoots by maintaining two shoots per plant was carried out at the age of 6 weeks after planting. Weed control (weeding), repair of mounds, and drainage channels are carried out twice before fertilization is carried out, namely at the age of 1 and 3 months. Pest and disease control are carried out to control red mite pests, mealybugs, and tuber rot diseases. Irrigation is given according to plant needs. The variables observed in 6-month-old plants included plant height, symptom scores of red mites (Tetranycus sp.), and brown leaf spot disease (Cercospora sp). Observation of the symptom score of pests and diseases was carried out by giving a score of symptoms that dominated each treatment. For red mites and mealybugs, refer to the method of [7]. Red mite attack symptom score: 0 = healthy leaves (no spots), 1 = early yellowish spots (about 10%) on some lower leaves and/oridle leaves, 2 = there are quite a lot of yellowish spots (11-20%) on the leaves lower and middle, 3 = obvious damage, which is a lot of yellow spots (21-50%), leaves slightly necrotic (<20%), lower and middle leaves slightly shrunk, some leaves turn yellow and fall off, 4 = severe damage (51-75%) in the lower and middle leaves, mite populations are abundant and white threads are found such as spider webs, and 5 = total leaf loss, smaller plant shoots, more white threads, and can cause plant death. Meanwhile, the symptom score for brown leaf spot attack refers to [8]. As follows: score 1 = healthy leaves, no spots, score 2 = spot area 0.05 leaf area, score 3 = spot area> 0.05 -0.10 leaf area, score 4 = spot area> 0.10 - 0.20 leaf area, and a score of 5 = spot area> 0.20 leaf area. Harvesting is done when plants were 11 months of age. At harvest time, the observed variables included tuber yield, starch content, and starch yield.

The starch content of fresh tubers were estimated using the specific gravity (X) approach [9], namely weighing 5 kg of fresh tubers in the air (Wa), then weighing in water (Ww). Specific gravity (X) is calculated using the equation (1).
\[
X = \frac{W_a}{(W_a - W_w)}
\]  

(Wa= the weight of the tubers in the air  
(Ww= the weight of the tubers in the water  
And to measure the starch content (SC) is using the equation below:

\[
SC = ((112.1 \times X) - 106.4)
\]

2.3. Statistical analysis
The data obtained were analysed using ANOVA and continued with the LSD test 5%, and analysis of the correlation between observed parameters was carried out.

3. Results and Discussion
According to [10], to be able to produce optimally, cassava plants require rainfall of 150-200 mm at the age of 1-3 months, 250-300 mm at the age of 4-7 months, and 100-150 mm in the phase before and at harvest. Cassava requires a certain amount of water daily to meet its crop water requirements [4]. Probolinggo district has a strict dry climate. In 2018 and 2019, the rain lasted for four months after planting. However, in 2019, the amount of rainfall and rainy days were higher than in 2018 (Figure 1).

![Rainfall and number of rainfall days in 2018 and 2019 planting season, Muneng research station.](image)

The combined ANOVA on the parameters of 6-month-old plant height, tuber yield, starch content, and starch yield, showed significant differences in the genotype factor, year, and genotype × year interaction (Table 1). However, tuber and starch yields were not influenced by the year factor. The year factor contributed 97.9% to the plant height, 59.8% to tuber yield, 96.0% to starch content, and 87.1% to starch yield. Genotype and interaction factors had small contributions to all parameters. This shows that seasonal factors influence all observed parameters. A significant GEI presents challenges in the selection of superior genotypes [4].
Table 1. The combined analysis of variance.

| Source of variation | df  | Plant height (6 wap) | Tuber yield (t·ha\(^{-1}\)) | Starch content (%wb) | Starch yield (t·ha\(^{-1}\)) |
|---------------------|-----|----------------------|-------------------------------|----------------------|-------------------------------|
| Year (Y)            | 1   | 122,002.7 **         | 557.8ns                      | 254.8**              | 102.8ns                      |
| Replication/Y       | 4   | 956.7                | 505.9                        | 13.9                 | 13.4                         |
| Genotype (G)        | 23  | 1,721.2**            | 247.6**                      | 5.3**                | 9.8**                        |
| Y x G               | 23  | 636.7**              | 101.6**                      | 4.3**                | 4.4**                        |
| Error               | 92  | 229.2                | 25.1                         | 1.1                  | 1.0                          |
| Total               |     | 124,589.8            | 932.1                        | 265.5                | 118.0                        |

ns = not significant  ** = significantly different at 1%

Figure 2 shows the plant height difference in 24 clones/varieties in two years (2018 and 2019). The plant height of all clones/varieties in 2018 was lower than that of in 2019. In 2018, the average plant height was 129.1 cm, while in 2019 the average plant height reached 187.3 cm. This was due to differences in rainfall. In 2018, the plant height ranged from 107.7 cm to 183.3 cm. The shortest plants were in the OMM 1209-3 clone and the highest in the OMM 1207-01 clone. Whereas in 2019 the plant height ranges from 140.9 cm to 220.3 cm. The shortest clone in the 2019 planting season was OMM 1207-50, while the highest was the same as the highest clone in 2018, namely OMM 1207-01.

![Figure 2. Plant height of 24 clones/varieties in two planting seasons (2018 and 2019) in Muneng research station.](image-url)

The tuber yield in the two seasons was not significantly different, with an average of 36.5 t·ha\(^{-1}\) (yield ranges between 23.7 t·ha\(^{-1}\) to 47.5 t·ha\(^{-1}\)). There are 12 promising clones in which the tuber yields were above average. The three promising clones that had the highest average yield were OMM 1207-22 (47.5 t·ha\(^{-1}\)), OMM 1207-57 (45.7 t·ha\(^{-1}\)), and OMM 1206-091 (43.9 t·ha\(^{-1}\)). The three promising clones had higher tuber yields than Litbang UK 2, which had the highest yield among the control varieties used (Table 2). Reported by [11] that the follow-up yield test using 24 genotypes showed a yield range between 22.30 to 44.6 9 t·ha\(^{-1}\), lower than that achieved in this study.

Starch content measured using the specific gravity method showed that the genotype × environmental interactive was significantly different. In 2018, starch content ranged from 13.85 to 18.6% with an average of 16.6%. The highest starch content was found in the OMM 1204-36 (18.6%) which was not different from the UJ 5 as a check (18.5%), while the lowest was in the OMM 1207-50 (13.8%). In 2019, the average starch content was higher than in 2018, namely 19.2% (an increase of 15.7%). The highest starch content in 2019 reached 21.3% found in the OMM 1204-36, while the lowest was in the
OMM 1205-51 (16.5%). The same genotype achieved the genotype with the highest starch content in the two seasons, but the average tuber yield was moderate (average equivalent) (Table 3). The overall optimal plant growth in 2019 could be the cause of the increase in starch levels.

Starch yield is the result of multiplying the starch content with the tuber yield. Starch was not significantly different during the two years. In two years, an average of starch yield ranged from 4.1 t·ha⁻¹ to 9.2 t·ha⁻¹ (average 6.6 t·ha⁻¹). The lowest average of starch yield was found in the OMM 1207-01, because it had low starch content and the tuber yield was not high. The highest starch yield was obtained in the OMM 1207-22, which had the highest average tuber yield in two years, combined with a relatively high starch content (Table 2).

**Table 2.** Tuber yield, starch content, and starch yield of 24 cassava clones/varieties in two planting seasons.

| Clones/varieties | Tuber yield (t·ha⁻¹) | Starch content (%wb) | Starch yield (t·ha⁻¹) |
|------------------|---------------------|----------------------|----------------------|
|                  | 2018                | 2019 | Average | 2018 | 2019 | Average | 2018 | 2019 | Average |
| 1 OMM 1011-10    | 37.3               | 45.1 | 41.2    | 15.0 | 19.6 | 17.3    | 5.4  | 8.9  | 7.1     |
| 2 OMM 1201-63    | 37.0               | 34.0 | 35.5    | 15.8 | 19.1 | 17.5    | 5.8  | 6.5  | 6.2     |
| 3 OMM 1201-195   | 38.8               | 43.8 | 41.3    | 17.4 | 17.4 | 17.4    | 6.8  | 7.6  | 7.2     |
| 4 OMM 1204-04    | 38.2               | 37.9 | 38.1    | 15.6 | 18.6 | 17.1    | 6.0  | 7.0  | 6.5     |
| 5 OMM 1204-09    | 30.7               | 41.2 | 36.0    | 14.8 | 18.1 | 16.4    | 4.6  | 7.4  | 6.0     |
| 6 OMM 1204-36    | 29.4               | 44.6 | 37.0    | 18.6 | 21.3 | 19.9    | 5.5  | 9.5  | 7.5     |
| 7 OMM 1205-38    | 32.1               | 44.5 | 38.3    | 16.8 | 19.0 | 17.9    | 5.4  | 8.4  | 6.9     |
| 8 OMM 1205-47    | 40.0               | 38.2 | 39.1    | 16.1 | 18.6 | 17.3    | 6.5  | 7.1  | 6.8     |
| 9 OMM 1205-51    | 39.4               | 37.4 | 38.4    | 18.3 | 16.5 | 17.4    | 7.2  | 6.2  | 6.7     |
| 10 OMM 1205-57   | 22.4               | 25.0 | 23.7    | 17.7 | 18.1 | 17.9    | 4.0  | 4.5  | 4.2     |
| 11 OMM 1205-70   | 26.7               | 24.1 | 25.4    | 15.9 | 17.5 | 16.7    | 4.3  | 4.2  | 4.3     |
| 12 OMM 1206-001  | 23.7               | 30.6 | 27.1    | 16.1 | 18.6 | 17.3    | 3.9  | 5.7  | 4.8     |
| 13 OMM 1206-050  | 34.9               | 39.2 | 37.0    | 18.0 | 20.2 | 19.1    | 6.4  | 7.9  | 7.1     |
| 14 OMM 1206-091  | 40.0               | 47.8 | 43.9    | 16.9 | 19.2 | 18.1    | 6.9  | 9.2  | 8.0     |
| 15 OMM 1206-112  | 37.5               | 40.3 | 38.9    | 17.6 | 19.2 | 18.4    | 6.6  | 7.8  | 7.2     |
| 16 OMM 1207-01   | 23.2               | 24.7 | 23.9    | 15.1 | 19.5 | 17.3    | 3.5  | 4.8  | 4.1     |
| 17 OMM 1207-22   | 40.4               | 54.6 | 47.5    | 17.9 | 20.3 | 19.1    | 7.2  | 11.1 | 9.2     |
| 18 OMM 1207-48   | 45.4               | 33.6 | 39.5    | 15.8 | 18.5 | 17.1    | 7.2  | 6.2  | 6.7     |
| 19 OMM 1207-50   | 25.2               | 30.9 | 28.0    | 13.8 | 20.4 | 17.1    | 3.4  | 6.3  | 4.9     |
| 20 OMM 1207-57   | 51.5               | 40.0 | 45.7    | 16.3 | 20.6 | 18.5    | 8.4  | 8.2  | 8.3     |
| 21 OMM 1209-3     | 35.2               | 37.4 | 36.3    | 17.6 | 20.7 | 19.1    | 6.1  | 7.8  | 6.9     |
| 22 Adira 4       | 28.8               | 49.6 | 39.2    | 15.5 | 20.4 | 18.0    | 4.5  | 10.1 | 7.3     |
| 23 UJ 5          | 29.1               | 39.6 | 34.3    | 18.5 | 21.0 | 19.7    | 5.3  | 8.3  | 6.8     |
| 24 Litbang UK2    | 44.4               | 38.6 | 41.5    | 16.7 | 19.2 | 17.9    | 7.4  | 7.4  | 7.4     |
| Min              | 22.4               | 24.1 | 23.7    | 13.8 | 16.5 | 16.4    | 3.4  | 4.2  | 4.1     |
| Max              | 51.5               | 54.6 | 47.5    | 18.6 | 21.3 | 19.9    | 8.4  | 11.1 | 9.2     |
| average          | 34.6               | 38.4 | 36.5    | 16.6 | 19.2 | 17.9    | 5.8  | 7.4  | 6.6     |

LSD 5%:
- clones 5.8 1.23 1.14
- Year × clones 8.1 1.74 1.61
- CV (%) 13.72 5.97 15.01
Based on the results of the correlation analysis between the parameters observed in 2018 (Table 3), it was shown that the plant height after six months was not related to the other parameters. In 2018, due to a relatively drier season than 2019, mite infestation was quite severe thus significantly reduced tuber yields as indicated by a negative correlation value ($r = -0.340 **$) and also reduced starch yield ($r = -0.259 *$). The yield of tubers had a positive correlation with starch yield with a correlation value of $r = 0.938 **$, meaning that the higher the tuber yield, the higher the starch yield.

### Table 3. Correlation between observed parameters in 2018.

| Parameters | Plant height (6 maps) | Red mite attack | Starch content (% wb) | Tuber yield (t·ha$^{-1}$) | Starch yield (t·ha$^{-1}$) |
|------------|-----------------------|-----------------|-----------------------|---------------------------|---------------------------|
| Plant height (6 maps) | 1                     |                 |                       |                           |                           |
| Red mite attack | 0.209                 | 1               |                       |                           |                           |
| Starch content (% wb) | -0.050               | 0.155           | 1                     |                           |                           |
| Tuber yield (t·ha$^{-1}$) | -0.165               | -0.340**        | 0.093                 | 1                         |                           |
| Starch yield (t·ha$^{-1}$) | -0.157               | -0.259*         | 0.421**               | 0.938**                   | 1                         |

Correlation analysis was also carried out on the parameters observed in 2019 (Table 4). Based on the results of the correlation analysis, the height of the 6-month-old plants was also not correlated with other parameters, similar to the correlation analysis in 2018. In contrast to 2018, the conditions in 2019 were exceptionally wet so that brown leaf spot attack was more dominant than red mite attack. However, the attack of brown leaf spot did not affect tuber yield or starch yield (correlation value was not significant). Starch content had a positive correlation with tuber yield and starch yield. Tuber yield and starch yield were also had a positive correlation.

### Table 4. Correlation between observed parameters in 2019.

| Parameter | Plant height (6 maps) | Cercospora Brown spot | Starch content (% wb) | Tuber yield (t·ha$^{-1}$) | Starch yield (t·ha$^{-1}$) |
|-----------|-----------------------|-----------------------|-----------------------|---------------------------|---------------------------|
| Plant height (6 maps) | 1                     |                       |                       |                           |                           |
| Cercospora Brown spot | 0.104                 | 1                     |                       |                           |                           |
| Starch content (% wb) | 0.080                 | -0.116                | 1                     |                           |                           |
| Tuber yield (t·ha$^{-1}$) | -0.033               | 0.172                 | 0.249*                | 1                         |                           |
| Starch yield (t·ha$^{-1}$) | -0.011               | 0.111                 | 0.526**               | 0.953**                   | 1                         |

### 4. Conclusions

The results of this study showed that both the year and genotype and their interactions greatly influenced the observed parameters. Promising clones that have high tuber yield and high starch yield in the two seasons are OMM 1207-22 (47.5 t·ha$^{-1}$), OMM 1207-57 (45.7 t·ha$^{-1}$), OMM 1206-091 (43.9 t·ha$^{-1}$).

### References

[1] Van DerZanden A M 2008 Environmental factors affecting plant growth Oregon State University
[2] Singh R, Alderfer R B 1966 Effects of soil—Moisture stress at different periods of growth of some vegetable crops *Soil Science* 1 1
[3] Nagarajan R 2009 *Agriculture Drought Assessment* (Dordrecht: Springer) chapter 5 pp 121-159
[4] Tumuhimbise R, Melis R, Shanahan P, Kawuki R 2014 Genotype × environment interaction effects on early fresh storage root yield and related traits in cassava *Crop J.* 2 5 329-337
[5] Barandica A J, Pérez J C, Lenis J I, Calle F, Morante N, Pino L, Hershey C H, and Ceballos H 2016 Cassava Breeding II: Phenotypic Correlations through the Different Stages of Selection Front. Plant Sci 7 1649

[6] Balitkabi 2017 Profil kebun percobaan (Demplot profile) [In Indonesian]

[7] Bellotti A, Schoonhoven A 1978 Cassava Pests and Their Control (Colombia: Centro Internacional de Agricultura Tropical) p 71

[8] Kisirivu J B K, Esurijoso O F, Terry E R 1980 Field screening of cassava clones for resistance to Cercospora henningsii. Proc. First triennial root crops symp: Internt. Soc./Trop. Root Crops 8-12 September 1980 Nigeria p 49-57

[9] Teye E, Asare A P, Amoah R S, Tetteh JP 2011 Determination of the dry matter content of cassava (Manihot esculenta Crantz) tubers using specific gravity method ARPN Journal of Agricultural and Biological Science 6 11 ISSN 1990-6145

[10] Wargiono J, Hasanudin A, dan Suyamto 2006. Teknologi produksi ubikayu mendukung industri bioethanol (Tuber production for bioethanol industry) Puslitbang Tanaman Pangan-Bogor p 42 [In Indonesian]

[11] Kim H, Phuong N, Long H 2017 A New Future for Cassava in Asia: Its Use as Food, Feed and fuel to Benefit the Poor. Proceedings 8th Regional Workshop, held in Vientiane, Lao PDR. Oct 20-24 2008