Identification of the genetic diversity of sweet potato germplasm based on quantitative morphological characters

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Abstract. Sweet potato is one of the prospective food crops to be used as an export commodity. Information on genetic diversity of sweet potato is needed as a consideration for the improvement of superior sweet potato varieties that have export quality. The research was conducted in Wringin Songo village, Tumpang, Malang Regency. The materials used were 150 sweetpotato accessions in total that consisting of: 19 superior varieties, 38 local clones, 1 introduced variety and 92 promising clones. This experiment was arranged in randomized block design (RBD) with two replications. The quantitative morphological variables such as: potential yield, tuber weight, dry matter, stover weight, harvest index and number of tubers plot⁻¹ were observed. The results showed that the genetic diversity was quite high in the sweet potato germplasm, there were 41 clones that had yield potential (≥ 30 t ha⁻¹). Some of these clones were prospective to be used as parents for crossing due to their ability to flower. Two sweet potato clones (MSU 10001-18 and MSU 07030-64) with dark purple flesh colour, Kidal variety with yellow flesh color and above 30% tuber dry matter have the criteria required for export market.

1. Introduction

Sweet potato commodity plays a very important role in increasing food diversification, especially to reduce the consumption of rice and wheat. Non-rice food such as tuber crops need to be socialized to the public, and hence it is expected to reduce domestic rice consumption. High nutritional content also plays a physiological role for the health of the human body. The yield potential of sweet potato is high, easy to cultivate and indispensable as an industrial raw material, so the government has set sweet potato as one of the targets for increasing export commodities with a threefold movement of exports program.

Sweet potato is a commodity that has chemical advantages as an alternative food, including high dietary fiber content, low starch digestibility, starch structure including RS-2, and low glycemic index. All those advantages will prevent digestive tract such as cancer, diverticulosis, ulcers, hemorrhoids, and diabetes through controlling blood glucose levels remain low [1]. The main nutritional component of Sweet potato is carbohydrates that function as energy, besides that Sweet potatoes are rich in vitamins, minerals and fibers [2].
Breeding of high-yielding sweet potato varieties is currently prioritized not only to meet food needs but also to meet industrial needs. The released varieties also have criteria in accordance with the domestic market and export market. The criteria of sweet potato tuber for export market are flesh color (yellow, purple, and orange) and tuber dry matter above 30%. Identification of potential germplasm continues to be carried out in order to obtain characters and have good and prospective genetic potential to be developed and meet consumer tastes. Breeding of high-yielding varieties requires high genetic diversity, so the opportunity to obtain new genotypes that are superior to their parents is greater. The objective of the study was to obtain the information on the genetic diversity of Sweetpotatoes in which required as a consideration for the formation of high-yielding Sweetpotato varieties which meets export quality.

2. Materials and Method

The experiment was conducted at one location in Wringinsongo village, Tumpang sub-district, Malang district, East Java province, Indonesia. The material used were 150 sweet potato clones consisted of: 19 superior varieties, 38 local clones, one introduced variety and 92 promising clones. This experiment was designed as a randomized block design consisting of 150 clones as a treatment with two replications in which the analysis of variance was carried out according to [3]. The genetic diversity of Sweet potato germplasm can be known from the Coefficient of Genetic Diversity (CGD) and the Coefficient of Phenotypic Diversity (CPD), according to [4]. To determine the value of the high and low diversity of traits, the standard value of the relative criteria according to [5] is low (0% - 25%), rather low (25 - 50%), moderately high (50% - 75%) and high (75% - 100%). Observations were recorded for yield potential, dry matter content, stover weight plant, harvest index, number of tuber plot, flowering ability, skin and flesh color.

3. Results and Discussion

3.1. Genetic diversity based on quantitative morphological characteristics

The type of clone affected the yield potential, tuber weight plant\(^{-1}\), dry matter content, stover weight, harvest index, number of tubers plot\(^{-1}\). The diversity of phenotypic, genetic and environmental mean values, broad heritability and coefficients of phenotypic and genetic diversity are shown in Table 1.

| Variable                        | Mean  | Min. | Max.  | \(\sigma^2_p\) | \(\sigma^2_g\) | \(\sigma^2_e\) | \(h^2\)  | CPD* | CGD* |
|---------------------------------|-------|------|-------|----------------|----------------|----------------|---------|------|------|
| Yield potential (t ha\(^{-1}\)) | 25.5  | 4.4  | 53.9  | 116.6         | 50.9           | 65.7           | 0.44    | 42.30| 27.90|
| Tuber weight g plant\(^{-1}\)  | 640.5 | 115.0| 1350.0| 69788.0       | 28698.4        | 41089.6        | 0.41    | 41.20| 26.50|
| Dry matter content (%)          | 30.8  | 22.2 | 43.3  | 20.9          | 17.6           | 3.3            | 0.84    | 14.85| 13.62|
| Stover weight kg plant\(^{-1}\) | 6.5   | 2.3  | 12.0  | 4.9           | 2.5            | 2.5            | 0.50    | 34.29| 24.32|
| Harvest index (%)               | 46.0  | 10.6 | 72.7  | 186.6         | 108.2          | 78.4           | 0.58    | 29.69| 22.61|
| Number of tubers plot\(^{-1}\) | 22.7  | 7.5  | 56.5  | 124.9         | 66.5           | 58.4           | 0.53    | 49.22| 35.93|

* CPD = coefficient of phenotypic diversity (0.0 – 15.0% = narrow, 15.0 - 30.0% = slightly narrow, 30.0 – 45.0% = slightly broad, and 45.0 - 60.0% = broad);
* CGD = coefficient of genetic diversity (0.0 – 10.0% = narrow, 10.0 – 20.0% = slightly narrow, 20.0 – 30.0% = slightly broad, and 30.0 – 40.0% = broad).
The expressed phenotype is the sum of genetic influences and deviations caused by the environment, where the distribution of genotypes in the environment is random, the phenotype variety is as follows [3]:

$$\sigma_p^2 = \sigma_g^2 + \sigma_e^2 \text{ (in one environment)}$$

where $\sigma_p^2$ is the phenotypic variance, $\sigma_g^2$ is the genetic influence variance and $\sigma_e^2$ is the environmental variance. The coefficient of genetic diversity was expressed in the phenotypic as seen in the coefficient of phenotypic diversity. In general, a high coefficient of genetic diversity is followed by a high coefficient of phenotypic diversity [6]. Heritability values describe the genetic diversity of characters that are influenced by the environment, heritability values for tuber yields range from low to high for several experiments conducted. Meanwhile, [7] obtained an average tuber yield heritability value of 0.41 (ranging from 0.21 to 0.6) from the parents and their F1 at 3 locations for two years. Mariscal (1983) in [8] stated that the low heritability value was due to the influence of non-additive genes. The results of this study showed that the heritability values of various characters were observed for yield potential of 0.44, tuber weight 0.41, dry matter 0.84, stover weight 0.5 and number of tubers plot -1 0.53. Genetic diversity of each character can be described as follows:

The potential yield of Sweetpotato germplasm is average 25.5 t.ha -1, the highest MSU 07015-92 clone is 53.9 t.ha -1 and MSU 07009-12 has the lowest weight (4.4 t ha -1). The yield potential has a moderate heritability with a value of 0.44, which indicates the level of genetic diversity due to genetic and environmental factors giving the same large role to the phenotype. This can also be seen from the fairly broad coefficient of genetic diversity and phenotype. Sweetpotatoes are very sensitive to environmental changes, [9] observed yield variations and stability at many locations and different genotypes, the results showed that there was a significant interaction between environmental genotypes and tuber yield characters. Plant growth and yield is an interaction between genotype and environment. Information on the interaction of genotypes and the environment is needed to determine whether the genotype has broad or specific (narrow) adaptation. Genotypes that provide a good phenotype indicate that the genotype is able to adapt to the environment. Other tuber characteristics such as tuber weight, number of tubers, and dry matter can be used as good indicators of yield. Moreover, it can be used as a criterion for the evaluation and selection of high yielding clones [8].

The average tuber weight was 640.5 g plant -1, the diversity of tuber weight plant -1 showed variations between clones. The rate of photosynthesis will affect the tuber development process, each genotype has a different response. Similar result was observed in an earlier work by [10] stated that there was a fairly high variation in tuber weight plant -1. The heritability value of tuber weight plant -1 was included in the medium category (0.42). This suggested that genetic and environmental influences each has the same effect. Meanwhile, the coefficient of phenotypic and genetic diversity shows a rather broad category, as shown in Table 1.

The average dry matter of tubers was 30.8% with the lowest range of 22% (MSU clone 07030-118) and clone MSU 07024-123 had the highest dry matter content (43.3%). The genetic diversity of dry matter content in Sweetpotato germplasm was high, this can be seen from the high broad sense heritability value of 0.84%. This illustrated the high genetic diversity in the Sweetpotato germplasm. Meanwhile the coefficient of phenotypic and genetic diversity was slightly narrow, which shows a fairly uniform value (Table 1).

### 3.2. Correlation between harvest index (%) with tuber weight (kg), stover weight (kg) and whole plant weight

The average stover weight was 6.47 kg plot -1 with a range of 2.3 to 12.0 kg plot -1, the Papua solossa variety was able to produce the highest stover weight, while the lowest was MSU clone 07035-118. The broad meaning heritability value indicates the medium category which shows the genetic diversity of the stover weight is quite high, the diversity based on the CPD value is 34.29% which indicates the area, and this illustrates the phenotype of the stover weight having high variation. Meanwhile, based on the CGD value, it has a value of 24.32 or is quite broad, which means it is still quite genetically uniform.
The average harvest index was 46%, the range of harvest indexes showed differences, the diversity of HI values ranged from 12% - 56% [11] and 37% - 81% [12]. Bulb yields were affected by HI, which showed a positive correlation between the two, as well as HI and biomass positively correlated with tuber dry matter, indicating that increasing HI and biomass also played an important role in increasing tuber yields [10]. These results are similar to those observed by [13], tuber yields were positively correlated with HI, whole plant weight and number of tubers per plant. A high HI value indicates a greater distribution of assimilate to tubers, while a low harvest index indicates a greater distribution of assimilate to the top of the plant than to tubers, resulting in low tuber weight.

The heritability value of 0.58 which is classified as moderate, this shows the harvest index has a fairly high genetic diversity. Meanwhile, based on the CPD and CGD, it illustrates that these characters have a rather broad value, which can be interpreted as having a fairly high genetic diversity. Harvest index was related to the variables of stover weight, tuber weight and whole plant weight. The relationship between the three variables can be described in Table 2 as below.

| Category       | Correlation values between harvest index (%) with tuber weight (kg), stover weight (kg) and whole plant weight (kg). |
|----------------|----------------------------------------------------------------------------------------------------------------|
| Tuber weight   | 0.76**                                                                                                           |
| Stover weight  | -0.60**                                                                                                          |
| Whole plant    | 0.14                                                                                                              |

** and ns = significance value at 0.01 and no significance value at 0.05 significance level, respectively, based on Pearson correlation.

Harvest index and tuber weight in sweetpotato germplasm have a positive correlation and have a high category of 0.76, which means that a high HI value means a high tuber weight. On the other hand, the relationship between the harvest index and the weight of the stovetop shows a negative correlation, which means that if the harvest index value is high, the weight of the stovetop will be low. Meanwhile, the relationship between the harvest index and the weight of all plants showed no correlation between the two. According to [10], HI and biomass are positively correlated with tuber dry matter, this relationship indicates that increasing HI and biomass will increase yield. Harvest index values can be used for indirect selection in improving tuber yields [14].

The average number of tubers per plot is 22.7, the heritability value is 0.53 which indicates the medium category. The number of tubers per plot had genetic diversity based on the broad CPD and CGD values (Table 1).

### 3.3. Selection of sweetpotato germplasm for determining the parents of the crosses

Determination of the crossbreeding parents with selection criteria based on high yield potential (30 t ha⁻¹), the result of germplasm selection was that 41 clones had yield potential of 30 t ha⁻¹ which were then used as female parents. The character of the ability to flower is also a very important character as a consideration in determining the parentage of the cross. Most of the selected clones had the high ability to flower (17 clones), moderate ability (13 clones), very high ability (1 clone), low ability (7 clones) and very low to flower (1 clone). The large number of clones that high and very high ability to flower showed a large potential to be used as cross parents considering the specific characters of sweetpotato crosses were self- and cross-incompatibility and sterility. Cross-pollination in sweetpotato produced 10% normal seedling, incompatibility causes the low percentage of fruitset and seed produced, not all the formed seed are filled with an embryo [15]. The level of compatibility of each crosses combination showed differences, each parent showed its suitability as male parent and female parent [16].

| Table 3. High yielding potential of Sweetpotato clones (≥ 30 t ha⁻¹). |
| No. | Clone no. | Clone name       | Yield potential (ton ha\(^{-1}\)) | Dry matter (%) | Flowering ability | Color | Skin | Flesh* |
|-----|-----------|------------------|-----------------------------------|----------------|-------------------|-------|------|--------|
| 1.  | 150       | MSU 07015-92     | 53.9                              | 24.03          | Moderate          | R4    | Y3   |        |
| 2.  | 139       | MSU 07023-86     | 50.83                             | 23.32          | High              | R5    | O4   |        |
| 3.  | 53        | UJ-35 Batatas Merah | 48.85                            | 25.41          | Moderate          | Y5    | Y4O1 |        |
| 4.  | 103       | MSU 07035-118    | 48.08                             | 23.70          | Low               | R4    | Y3   |        |
| 5.  | 89        | MSU 07031-28     | 45.11                             | 24.08          | Very low          | R2    | O3   |        |
| 6.  | 145       | MSU 07022-15     | 42.92                             | 26.65          | Moderate          | Y3    | Y3   |        |
| 7.  | 110       | MSU 10001-18     | 42.63                             | 32.27          | High              | P6    | P6   |        |
| 8.  | 38        | UJ-15 Tinta      | 40.53                             | 26.84          | High              | Y2    | Y3   |        |
| 9.  | 62        | MSU 10039-03     | 39.96                             | 31.07          | High              | Y2    | Y1   |        |
| 10. | 142       | MSU 07009-90     | 39.03                             | 27.72          | High              | R3    | Y3   |        |
| 11. | 127       | RIS 10068-02     | 38.86                             | 31.12          | Moderate          | Y5    | Y3O3 |        |
| 12. | 149       | MSU 07025-50     | 38.69                             | 29.12          | Low               | Y5    | Y2   |        |
| 13. | 24        | Senduro          | 38.48                             | 27.04          | High              | R4    | W    |        |
| 14. | 90        | MSU 09008-92     | 37.54                             | 29.77          | Very high         | R6    | P5   |        |
| 15. | 128       | MSU 07030-54     | 37.11                             | 34.47          | Moderate          | Y5    | Y4O1 |        |
| 16. | 125       | MSU 07022-12     | 37.02                             | 30.34          | High              | Y2    | Y2   |        |
| 17. | 11        | Beta-2           | 36.81                             | 23.70          | High              | R6    | O3   |        |
| 18. | 77        | MSU 07031-82     | 36.48                             | 23.62          | Moderate          | R5    | O2   |        |
| 19. | 28        | UJ-2 Ningkey 2   | 36.38                             | 24.14          | High              | R5    | O4   |        |
| 20. | 39        | UJ-16 Slape      | 36.34                             | 25.79          | Moderate          | O1    | O4   |        |
| 21. | 131       | MSU 07012-06     | 36.29                             | 25.38          | Moderate          | R4    | O3   |        |
| 22. | 87        | MSU 07030-88     | 35.8                              | 23.28          | Low               | R2    | Y3   |        |
| 23. | 129       | MSU 07022-13     | 34.95                             | 34.77          | Low               | R3    | Y4   |        |
| 24. | 50        | UJ-32            | 34.04                             | 28.62          | High              | R3    | W    |        |
| 25. | 41        | UJ-19 Malagurom  | 33.92                             | 22.50          | Moderate          | R5    | O6   |        |
| 26. | 16        | IR Melati        | 33.80                             | 24.90          | Moderate          | R4    | Y1   |        |
| 27. | 84        | MSU 07023-58     | 33.71                             | 26.40          | Moderate          | R6    | O3U3 |        |
| 28. | 37        | UJ-13 Yoka 5     | 33.51                             | 29.63          | High              | Y4    | Y3   |        |
| 29. | 65        | MSU 10048-09     | 33.17                             | 26.81          | High              | Y2    | W    |        |
| 30. | 67        | MSU 10054-19     | 33.11                             | 30.58          | Moderate          | R2    | Y3   |        |
| 31. | 66        | MSU 10051-02     | 32.72                             | 29.77          | Low               | Y3    | O3   |        |
| 32. | 117       | RIS 10062-01     | 32.45                             | 29.70          | Moderate          | P5    | P5   |        |
| 33. | 123       | MSU 07009-75     | 32.18                             | 32.98          | High              | R4    | Y2   |        |
| 34. | 7         | Papua Solossa    | 31.94                             | 34.25          | High              | Y3    | Y3   |        |
| 35. | 4         | Kidal            | 31.58                             | 35.02          | High              | R4    | Y4   |        |
| 36. | 97        | MU 07023-63      | 31.42                             | 29.45          | Moderate          | P5    | P4   |        |
| 37. | 68        | MSU 10054-40     | 30.82                             | 33.25          | Low               | R2    | Y3   |        |
| 38. | 26        | Cilembu-1        | 30.64                             | 30.38          | Moderate          | Y4    | Y3O3 |        |
| 39. | 89        | MSU 07030-64     | 30.34                             | 33.06          | Low               | P6    | P6   |        |
| 40. | 29        | UJ-3 Ningkey 3   | 30.16                             | 27.63          | High              | R1    | O4   |        |
| 41. | 141       | MSU 07015-54     | 30.03                             | 33.90          | Very high         | R4    | W    |        |

*The color of the skin and flesh of the tuber includes red (M), white (W), yellow (Y), orange (O) and purple (P). Color intensity: 7=very dark, 6=dark, 5=slightly dark, 4=light, 3=pale, 2=slightly pale and 1=very pale (Rasco, 1994).

Characteristics of skin color and flesh of tubers showed mostly red skin and yellow flesh as shown in Table 3. Based on the criteria of sweetpotato tuber for export market which are flesh color (yellow, purple, and orange) and tuber dry matter above 30%, there are two clones (MSU 10001-18 and MSU...
07030-64) have dark purple (code P6) flesh color and Kidal variety, the clones have above 30% of tuber dry matter. The darker the flash color, the higher the antioxidant concentration of the tuber, therefore it is better for functional food. Purple sweet potato has higher antioxidant activity than yellow sweet potato and white sweet potato [17].

4. Conclusion
There is a fairly high genetic diversity of the morphological characters of Sweetpotato germplasm. Out of 150 clones of sweetpotato germplasm evaluated, 41 clones were identified as having high yield potential (≥ 30 t/ha t). Most of the selected clones had the ability to flower. The ability to flower is also a very important character as a consideration in determining the parentage of the crosses. The potential heritability of the selected clones is in the medium category, indicated that the genetic diversity of the two characters is quite high. Genetic and environmental factors show an equally large role in the appearance of the two characters. Two sweetpotato clones (MSU 10001-18 and MSU 07030-64) with dark purple flesh color and Kidal variety have above 30% tuber dry matter have the criteria required for export market.

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