Morphological Diversity analysis of Yam (Dioscorea alata L.) from Banggai Islands, Indonesia

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Abstract. The study aimed to determine the variation in 38 of yam accessions from Banggai Islands, Central Sulawesi. This study was conducted in August 2012 to May 2013. Morphological data were analyzed using principal component analysis (PCA). The results of ten PC analyzes of a total of 30 components were observed (Table 1) giving eigenvalues greater than 0.25 explains 77.7% of total diversity. Three of the ten PC that determine the yam variant level are PC 1 purple color character (24.3%); PC 2 which stem diameter character (13.3%); PC 3 leaf surface texture, tuber shape and maturity time (8.4%). Cluster analysis results show there are four groups formed, which are A (16 varieties); B (2 varieties); C (19 varieties); and D (1 variety).

1. Introduction

Yam (Dioscorea alata L.) is belong of the tuber type and potential as an alternative food source. Yam is a source of calory because it contains about 25% starch, 0.1-0.3% fat and 1.3-2.8% protein (Catur et al., 2010). Lebot et al. (2005) stated that D. alata contained carbohydrates (73.1%), glucose (1.85%), starch (17.2%), minerals (3.3%), fat (0.3%) and protein (11.95%). Tuber can be stored to long period of time with a good quality starch. However, long stored tuber can reduced the sugar content while proteins and lipids are relatively stable (Kouakou et al., 2010). Yam production potential can reach to 60-70 ton ha⁻¹ (Sulistyono dan Marpaung (2004). Potential production of in Banggai Islands ranges from 22-24 ton ha⁻¹ or an average fo 23 ton ha⁻¹(BPS Banggai Kepulauan, 2009). Tubers of yam can be stored longer than other tubers and the quality of starch can last for a long time, sugar content can reduced, but no effect on protein and lipids that can be used as source of food in time of crisis (Kouakou et al., 2010). Yam also has the potential to prevent breast cancer and heart disease in menopause woman because it contain dioscorin and protein hydrate binding enzymes that have a role in controlling hypertension (Yi-Hwa et al., 2009).

The cultivation of yam in Indonesia is still limited in certain areas such as Banggai Island in Central Sulawesi. The limited cultivation is caused by public not having knowledge about this cultivated species, long maturity time (8-10 months), difficulty in seed production because in general yam is not produce flower that caused the plant material have to use the tuber that supposed to be consumed.
Zhou et al. (2008) stated that farmers more prefer yam that have high and stable production, good texture, have long dormant period and does not browning due to enzymatic reactions. Each region often names different varieties for the same yam which caused obstacle in management and improvement of germplasm. On the other hand traditional farmers tend to maintain high population diversity so that they play an important role to yam in situ germplasm conservation (Eduardo et al., 2011).

This study aims to determine the morphological diversity from Banggai Islands to obtain information of morphological characteristic that can be used as a basis for enhancing expansion of high quality yam germplasm.

2. Materials and Methods
A total of 38 yam varieties were obtained from Banggai Islands, Central Sulawesi as shown in Table 1. Samples were planted in Leuwikopo IPB experimental garden, Bogor, West Java in 2012 and planted in the same garden for three times until 2013. Yam seeds were cut in to small pieces (5x10 cm) or around 100, planted in 400m2 garden with spacing of 100cm x 100 cm. A total of 12 seeds are prepared for each variety. Manure fertilizer was given once a month after planting with a dose about 200g/plant, and stake was installed to adjust growth.

Table 1. Varieties of yam from Banggai Islands.

| Accession | Local Name | Shape and color of tuber | Accession | Local name | Shape and color of tuber |
|-----------|------------|--------------------------|-----------|------------|--------------------------|
| BDa-01    | Butun 1    | Cylindrical, white       | BDa-20    | Sombok     | Cylindrical, white       |
| BDa-02    | Butun 2    | Cylindrical, white       | BDa-21    | Sombok budul | White       |
| BDa-03    | Banggai    | Cylindrical, light purple| BDa-22    | Solopia    | Round, yellowish         |
| BDa-04    | Potil mela | Round, white             | BDa-23    | Solopia patek | Cylindrical, yellowish |
| BDa-05    | Potil mbol | Round, white             | BDa-24    | Koding     | Cylindrical, brownish    |
| BDa-06    | Binda      | Cylindrical, yellowish   | BDa-25    | Paupau ateno | Round, purple-red      |
| BDa-07    | Palabatu   | Round, brownish          | BDa-26    | Keat       | Round, purple-red       |
| BDa-08    | Balatan    | Cylindrical, yellowish   | BDa-27    | Liboko     | Cylindrical, white       |
| BDa-09    | Tombos     | Round, light purple      | BDa-28    | Minui      | Cylindrical, white       |
| BDa-10    | Lendut     | Cylindrical, yellowish   | BDa-29    | Ndolonut   | Round, dark purple       |
| BDa-11    | Lembet     | Cylindrical, brownish    | BDa-30    | Bunggon    | Round, light purple      |
| BDa-12    | Tau        | Round, yellowish         | BDa-31    | BDa-31     | Round, light purple      |
| BDa-13    | Boan mela  | Round, white             | BDa-32    | Pusus      | Cylindrical, white       |
| BDa-14    | Boan       | Round, white             | BDa-33    | Kiesi      | Flathback, white         |
| BDa-15    | Alai       | Bercabang, yellowish     | BDa-34    | Lindang    | Cylindrical, yellowish   |
| BDa-16    | Danggang   | bercabang, yellowish     | BDa-35    | Salabangga | branched, light          |
BDa-17  Doso  yellowish  Round, cylindrical, branched, light purple  BDa-36  Tinggoi  purple  Round, light purple
BDa-18  Mailu  Cylindrical, white  BDa-37  Maukes  Round, light purple
BDa-19  Sombok mela  Cylindrical, light purple  BDa-38  Kasiabag  Round, white

Note: Local names are come from Banggai local language. BDa-02, BDa-19, and BDa-31 are yam varieties that have not been registered as a local varieties in PVT.

Morphological characterization using modified descriptor from IBPGR (Tarqul et al., 2011) according to existing cropping (Table 2). Phenotypic characterization is carried out from the time plant started to emergence until harvest time (1-10 months). Principal component analysis (PCA) and cluster analysis were using Minitab version 14 software. The matrix used to produced morphological distance between variety was analyzed using Dice coefficient. Hierarchical dendogram is performed with UPGMA methods using NTSYSpc program (Rohlf, 2004) multivariate GLM analysis was using to analyze Quantitative data using Minitab version 14 software.

Table 2. Phenotypic character variables observed

| No. | Variable                        | Score                                      |
|-----|---------------------------------|--------------------------------------------|
|     | STEM                            |                                            |
| 1   | Stem shape                      | 1. round, 2. triangular, 3. rectangular.   |
| 2   | Spine                           | 1. absent, 2. Present                      |
| 3   | Wing                            | 1. absent, 2. narrow, 3. Broad             |
| 4   | Stem diameter                   | 1. <2 mm, 2. 2-4 mm, 3. 4-6 mm, 4. >6 mm  |
| 5   | Shoot color                     | 1. green, 2. purple 3. Brownish           |
| 6   | Stem color                      | 1. green, 2. Purple                       |
| 7   | Node color                      | 1. green, 2. Purple                       |
| 8   | Stem segment color              | 1. green, 2. Purple                       |
| 9   | Stipule color                   | 1. green, 2. Purple                       |
|     | LEAF                            |                                            |
| 10  | Leaf shape                      | 1. cordate, 2. delta, 3. Ovate             |
| 11  | Leaf margin shape               | 1. flat, 2. Wavy                          |
| 12  | Leaf apex                       | 1. acute, 2. Obtuse                       |
| 13  | Leaf base curve angle           | 1. <30°, 2. 30° – 60°, 3. 60° - 90°, 4. >90° |
| 14  | Leaf surface texture            | 1. smooth, 2. medium, 3. Rough             |
| 15  | Young leaf color                | 1. light green, 2. Purplish green, 3. Purple |
|     |                                 | 1. light green, 2. dark green, 3. Purplish green, 4. purple |
| 16  | Mature leaf color               |                                            |
| 17  | Leaf base color                 | 1. green, 2. Purple                       |
| 18  | Petiole color                   | 1. green, 2. Purple                       |
| 19  | Leaf vein color                 | 1. green, 2. Purplish green, 3. Purple     |
|     | TUBER                           |                                            |
20 Tuber shape 1. round, 2. cylindrical, 3. flat branched, 4. branched cylinder
21 Tuber base shape 1. pointed, 2. medium, 3. widened
22 Bottom part of tuber shape 1. pointed, 2. medium, 3. widened
23 Tuber skin texture 1. smooth, 2. medium, 3. Rough
1. white, 2. yellowish, 3. light purple, 4. dark purple, 5. brownish
24 Tuber flesh color 1. white, 2. yellowish, 3. light purple, 4. dark purple, 5. brownish
25 Tuber skin color (beneath the bark) 1. ivory color, 2. Purple
26 Aerial tuber 1. present, 2. Absent
27 Time of maturity 1. early (< 7 months), 2. Medium (7 months), 3. late (>7 months)
28 Number of tuber per plant 1. one, 2. low (2-5), 3. many (>5)
29 Tuber weight per plant 1. very light (<0.5 kg), 2. light (0.5-1 kg), 3. medium (1-2 kg), 4. heavy (2-3 kg), 5. very heavy (>3 kg)
30 Direction of yam growth 1. vertical, 2. Horizontal

| Table 3. a total variant of ten component analysis |
|-----------------|-----------------|-----------------|-----------------|
| Main component  | Eigen value     | Proportion (%)   | Cumulative (%)  |
| 1. color: shoot, node, young leaves, petiole, and skin color on the inside of tuber. | 2.9751 | 24.3 | 24.3 |
| 2. stem diameter | 1.6324 | 13.3 | 37.6 |
| 3. leaf surface texture, round and cylindrical tuber shape | 1.0246 | 8.4 | 46.0 |

note: % = the total percentage of characters variable contribute to phenotype diversity.

3. Results and Discussion
The results showed the shaped of stem is mainly rectangular shaped, there are two accessions that have spine at the base of the stem which is BDa-04 and BDa-5. There are two category of narrow broad wing on the stem. Diameter varies between 2.0mm-7.0 mm.

There are three variations of leaf shape which is cordate shape represent by accessions BDa-01, delta or sagittate represented by accession BDa-32, and ovate represented by access BDa-15 (Figure 1). Leaf margin are mainly flat, leaf apex is acute and obtuse, leaf surface texture is smooth to medium, colors of young leaves is divided in to green, purplish green and purple. Mature leaf color consisted of light green, dark green and purplish green.

Based on the shape, Yam is divided into three main groups namely cylindrical, ovate and irregular (branched flat and branched cylinders) Figure 2. BDa-18 is one accession that produces variety of tuber and can be included in three tuber shape group mentioned above. In general, flesh color of tuber can be grouped into 4 groups: white, yellowish, brownish and purple. Zannou (2006) stated that the
appearance of different yam morphology is the result of selection process by farmers. Genetic differences are one of the factor that cause diversity in plants.

![BDa-01](image1) ![BDa-32](image2) ![BDa-15](image3)

**Figure 1.** Three types of leaf shapes cordate (a), sagittate (b), and ovate (c).

![Round and oval shapes](image4) ![Cylindrical or elongated](image5) ![Irregular shape](image6) ![Irregular shape](image7)

**Figure 2.** Yam shapes variation: (a). Round and oval shapes; (b). Cylindrical or elongated; (c). Irregular shape; dan (d). Irregular shape

![White](image8) ![Yellowish](image9) ![Brownish](image10) ![Light purple](image11) ![Purple](image12) ![Red-purple](image13) ![Mix color purple in the center](image14) ![Mix color purple on the side](image15)

**Figure 3.** Tuber color variation: (a) White; (b) Yellowish; (c) Brownish; (d) Light purple; (e) Purple; (f) Red-purple; (g) Mix color purple in the center; and (h) Mix color purple on the side.

Yam from Banggai Islands growth is have no difference from yam description written in Prosea (1996) which is annuals, diosious, climbing, fibrous root system. Tubers are usually single, vary in size and shape, cylindrical or round, often branched like finger shaped or curved, yam skin color varies from brown to black; flesh color is white, yellow and light purple (Figure 3). Stem is twining anticlockwise (twining to the right), not spiked but sometimes rough or speckles on the bottom,
angular and have 4 wings, green to purplish. Single leaves, interspersed at the base, facing at the top like arrows or oval like spears, bright green or often purplish (Flach and Rumawas, 1996).

Principal Component Analysis based from 30 morphological character shows diversity among 38 yam accessions from Banggai Islands. Cluster analysis divide it into 4 cluster A, B, C and D (Figure 4). Group A divided into 16 accessions, group B divided into 2 accessions, group C divided into 19 accessions and group D has only one accession. Accessions BDa-01 and BDa-02 has similarity of 99.5%, while accessions that has the lowest similarity is between BDa-01 and BDa-25 of 86.5%. Overall group A is consisting of yam that has white flesh color from 16 accessions.

Group B is only consist of two accessions namely BDa-04 and BDa-05 with coefficient similarity of 91%. Both of these accessions have the same specific characteristic including spines at the base of stem and tuber shape is like coconut. The difference between the two is BDa-04 have purple anthocyanin pigment whereas BDa-05 has no such pigment.

Group C consisted of accessions that have purple shoots, leaves base and spatula. In addition, the group has branched tuber and tuber color varies from white, yellowish, brown to reddish purple accessions. Accessions BDa-30 and BDa-31 has similarity level of 96.0%. Accessions that have the lowest similarity level is BDa-31 and BDa-33 of 89.0%.

Group D has only consists of one accessions BDa-17 which has very specific characteristic such as purple plant stems and leaf spines, dark green leaves color, stem shape is cylinder and have very narrow wing and sometimes has no wings, tuber shapes varies from ovate shape, cylindrical and branching so that it forms its own group in the cluster. However, based on molecular analysis, doso yam BDa-17 joins the other purple yam.

Principal Component Analysis I (PCA-I) shows 24.3% of the total variations are related to color of shoots, node, young leaves, petiole and skin color of the inside of the tuber. Principal Component Analysis II (PCA-II) describes 13.3% the total variation related to stem diameter character. Principal Component Analysis III (PCA-III) shows 8.4% of the total variation related to leaf surface texture, round and cylindrical tuber, and early maturity time characteristic.

Figure 4. Average dendogram shows the relationship between groups.
Note: BDa01-BDa38 yam accessions. A, B, C, and D as a different group.
4. Conclusion
Cluster analysis dividing yam from Banggai Islands into 4 groups which is A, B, C and D. Group A composed of 16 accessions, group B composed of 2 accessions, group C composed of 19 accessions, group D composed of 1 accession. Morphological character that determine the grouping of yam based on Principal Component Analysis are shoot color, node color, young leaves color, petiole color and skin color on the inside of tuber contribute 24.4% of the total variations.

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