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Diversity in Tuber Characteristics of Local Cultivars of Yam Bean (*Pachyrhizus erosus*) in Indonesia

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Abstract

Yam bean is legume with tuberous root originated from the semiarid tropics of Central America, and has been widely spread in several regions in Indonesia. Research on characterization of tuber yam bean was conducted in Kendalpayak Research Station (Malang, Indonesia) from May to October 2016. A total of 73 local yam bean cultivars originated from eight provinces were characterized based on their tuber characteristics. The sensory evaluation was also conducted to evaluate the tuber sweetness, fiber intensity, and texture crunchiness. The average tuber weight was 455.2 g/plant, with the average tuber length and width were 10.78 cm and 8.17 cm, respectively. The ratio of tuber length and width was 1.42, indicates that yam bean tuber in Indonesia tend to be in spherical shape. The average tuber water content was 83.87% (wet basis), showed that the water content was quite high. Based on cluster analysis, 74 local cultivars of yam bean were grouped into five clusters. The tuber weight varied among cultivars and become the distinguishing factor between local cultivars. Local variety of yam beans in Indonesia tend to have sweet taste and crunchy texture. So far, the study on characterization of tuber diversity in Indonesian local cultivar of yam bean is still limited. Thus, these results provide important information to optimize the tuber yam utilization as industrial raw materials.

How to Cite

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INTRODUCTION

In Indonesia, yam bean (*Pachyrhizus erosus*) has a high economic value. Even in some production centers, it gives a higher profit than rice production. Yam bean can be planted in wet land or dry land, and the planting is on the beginning of the rainy season. The production centers of yam bean are spreading in West Sumatra, West Java, Central Java, and East Java province. There are two functions of yam bean tubers that are used as the raw material of cosmetics industry and also consumed as a fresh fruit.

Genus of Pachyrhizus have three cultivated species: *P. erosus*, from the semiarid tropics of Central America; *P. tuberosus* from the tropical lowlands of both slopes of the Andean mountain range (Sørensen, 1996) and *P. ahipa* from Andean highland (Sorensen *et al.*, 1997; Zanklan 2013). *P. erosus* is cultivated in many South East Asian countries, including Indonesia. Adewale and Dumet (2011) have arranged the descriptors for African yam bean (*Sphenostylis stenocarpa*). Those descriptors are used to compose various accession characters in order to differentiate an accession of yam bean to other accessions.

Many studies about grouping and identifying the genetic diversity of yam bean have been done by using different distinguishing characters. Adewale *et al.,* (2010) characterized African yam bean and the result showed that the main differentiator was the character of the seed coat colors. Osuagwu *et al.,* (2014) characterized the accession of yam bean based on the pod character, then observed its relationship with the seed yield. The result of that study stated that the number of seeds per pod and pod length had significant positive association with seed weight per pod. Pod width also correlated positively with seed weight in some accessions. Popoola *et al.,* (2011) had successfully grouped the morphological characteristics of the yam bean into six different groups and obtain the character of the pod and seed as the differentiators. Ikhajiagbe and Mensah (2012) studied the effect of the seed colors (black, brown, and light grey) on the tubers production, and the result showed that the tuber production of the yam bean originated from black seed was higher than those of brown or light grey seed. By using different characters, Karuniawan and Wicaksana (2006) analyzed the genetics relationship of yam bean *P. erosus* based on the flowers and leaves characteristics. As the result, they concluded that population of yam bean in Indonesia were similar to the ancestor species from Mexico and Guatemala.

The main value of yam bean is on the tubers production. Adewale and Dumet (2011) observed the characters of yam bean tubers in terms of production, population, shape, skin color and tuber branching. Furthermore, Adewale (2011) added the tubers characteristics that are the tuber length, the tuber width and the ratio of the tuber's length and width. A study by Aremu and Ibirinde (2012) revealed that the characteristics of vine length, branching pattern, pod and peduncle number, pod length, seed number, and seed yield determined the tubers production. In yam bean, the tubers production and the seed are inversely related, hence the pruning process is performed to increase the tubers production. Zanklan (2003) stated that there was a strong competition between shoot growth, flowering, pod formation, and tuber growth in yam bean. In addition, yam bean with pruning can produce up to 44.62 t/ha than without pruning which only produce as much as 23.35 t/ha fresh tuber. Nusifera and Karuniawan (2009) who studied 27 genotypes of yam bean from Indonesia and America, concluded that pruning of reproductive sink can increase the tubers production up to 85.94%.

The knowledge of genetic diversity of yam bean is essential to observe the genetic variability and determine the potential parental plant to improve the genetic of yam bean (Aremu *et al.*, 2007; Khodadad et. al., 2011). Research in other countries has been carried out concerning on morphological characteristics of the crop (Popoola *et al.*, 2011; Osuagwu *et al.,* 2014), genetic variability on seed quality (Olasoji *et al.*, 2011), as well asnutritive and antinutritive factors (Uguru and Madukaife, 2001; Ajibade *et al.*, 2005). So far, the study on characterization of tuber diversity of Indonesian local cultivar of yam bean is still limited. The results from this research will provide a new finding on the characteristics of yam bean tuber which can be further utilized to improve the use of yam bean as industrial raw materials. The aim of the research was to identify the genetic diversity and grouping the genetic diversity of yam bean based on the tuber characteristics.

METHOD

Research material

The research materials were obtained from the exploration of local variety of yam bean since from February to May 2016. The exploration area consisted of Sumatera (North Sumatera, South Sumatera, West Sumatera, Bengkulu), Java (West Java, Central Java, East Java), and Sulawesi Islands (Gorontalo). The yam bean was obtained

from cropping area of seller, and farmer who has the seeds or yam bean pods. Each accession was given a label of the origin, such as Dukuh (sub-village), Desa (village), Kecamatan (district) and Kabupaten (regency). The accessions of local varieties were obtained in the form of seeds and pods. The pods were dried under the sunshine, and after dried then continued with seed processing. The seeds were saved in glass bottle and stored in the cold storage.

Field experiment

The total of 73 local varieties of yam beans were planted in the Kendalpayak Research Station, Malang, Indonesia from May to October 2016. The field used in this research was paddy field, and the previous crop was sweet potato. The soil tillage was performed optimally by making a ridge in 0.6m width, 50cm height, with the distance between ridge was 0.5 m. Seed was planted on ridge with 15 cm spacing, and 1 seed per hole. After planting, the hole was covered with manure. The fertilization dose consisted of 250 kg Phonska/ha and 100 kg SP 36, they all were given in the beginning of the planting process. The plant maintenance consisted of weeding, irrigation, and optimal control of the pests and diseases. The reproductive pruning treatment was performed in each 10 days up to 4 months old plant. Harvesting the tubers was done when the leaves were turned to yellow and being hard.

The collection of tuber data

The observation on characteristics of yam bean tuber was done by randomly taking three plants in each local accession. The data collection of this study were the number of tuber/plant, tuber's length, width, ratio of length and width, tuber water content (wet basis), shape, color and sweetness as well as fiber intensity, and texture crunchiness. The tuber sweetness, fiber intensity, and texture crunchiness were observed by organoleptic testing.

The criteria of tuber sweetness consisted of:
1= less sweet
2= medium sweet
3= sweet

The criteria of fiber intensity consisted of:
1 = less fibrous
2 = medium
3 = fibrous

The criteria of texture crunchiness consisted of:
1 = less crunchy
2 = medium
3 = crunchy

Data analysis

Data were analyzed using a randomized block analysis of variance (ANOVA). Descriptive data consisted of mean, range, standard deviation, and skewness for each observation data. The yam bean accession was grouping by using cluster analysis of average linkage method (McKenzie & Goldman 2005).

RESULT AND DISCUSSION

Yam bean (*Pachyrhizus erosus* (L) Urban) is a legume root crops and potential commodity in Indonesia due to its valuable profit and income for the farmers. Historical evidences explained that yam bean was belonging to the Leguminosae family that originated from Mexico and north of Central America. Then, yam bean was introduced to Philippine by Spain and spreading to many countries in South-East Asia including Indonesia (Sorensen,1996; Grüneberg *et al.*, 1999). Nowadays, the production centers of yam bean in Indonesia are spreading in some areas (Karuniawan, 2004; Damayanti, 2010).

(a) (b)

Figure 1. (a) Yam bean harvest in farmers' field; (b) Yam bean tuber in collecting trader

Analysis of variance

The analysis of variance on eleven characters of tuber from 73 local accession of yam beans from Indonesia elucidated a significant variation in all observed tuber characters, except for tuber shape and texture crunchiness (Table 1). The coefficient of variation varied from 2.18% to 31.45%. The significant value of accession showed the existence of genotypic variability between 73 local yam beans accession.

The variability of tuber characters

So far, the yam bean farmers in Indonesia only cultivated their local variety. To optimize the genetic potential, especially the potential production of tuber, it is need an understanding regarding characteristic that has economic value. The economic value of yam bean is on its tuber. However, there is a limited information on the tuber

characterization, especially in Indonesian local yam bean.

Table 1. Analysis of variance of tuber yield of 73 yam bean accessions planted at Kendalpayak Research Station, Malang, (Indonesia) in 2016.

Parameter	Mean Square		CV (%)
	Replication	Accession	
Number of tuber per plant	2.28045726**	0.47880509*	22.56
Tuber weight (g)	1485821.93**	253441.69**	37.18
Tuber length (cm) / L	27.040434ns	109.778359**	23.25
Tuber width (cm) / W	166.734083**	29.067344**	21.52
Ratio of L/W	0.3079341ns	1.7603053**	25.64
Water content (wet basis %)	2.643373ns	29.841249**	2.18
Tuber shape	0.04123858ns	0.21302770ns	31.45
Tuber colour	2.68036530*	1.18788844**	13.89
Tuber sweetness	0.85744863ns	0.99213729*	11.88
Fiber intensity	2.21771943ns	0.80478571*	13.72
Texture crunchiness	0.04263382ns	0.40568231ns	12.17

CV = coefficient of variation, * = significant at 5% probability level ($p < 0.05$), ** = significant at 1 % probability level ($p < 0.01$), ns = not significant.

In this study, characterization of 73 Indonesian local yam beans showed some variations between accessions. The variations of tubers character of yam bean were measured by the descriptive data of each character, as shown in Table 2. The number of tubers ranged from 1-3 tubers/plant with ratio 1.20 tubers/plant. The variability of number of tubers in each accession is quite tight, shown by the standard deviation value of 0.37. However, the weight of tuber showed a wide diversity, ranged from 35-1360 g/plant with the highest standard deviation value among all tuber characteristics up to 289.60. Naskar (2016) reported that the average tuber weight in India was ranged from 600 – 700 g, had sweet taste and smooth surface. A study by Silva *et al.,* (2016) obtained the weight of tuber yield per plant was 2700 g, with 2.46 tubers per plant.

Table 2. The mean and range value of morphological characters of 73 yam bean accessions planted at Kendalpayak Research Station, Malang, (Indonesia) in 2016.

Parameter	Mean	Range	Standard Deviation	Skewness
Number of tuber per plant	1.20	1.00-3.00	0.37	1.48
Tuber weight (g)	455.20	35.00-1360.00	289.60	0.98
Tuber length (cm) / L	10.78	2.00-53.33	6.05	4.84
Tuber width (cm) / W	8.17	1.00-17.57	3.12	0.07
Ratio of L/W	1.42	0.40-4.57	0.68	2.41
Water content (% wet basis)	83.87	74.31-89.29	3.15	-0.84
Tuber shape	1.84	1.00-4.00	1.03	0.85
Tuber colour	1.00	1.00-1.00	0.00	0.00
Sweetness intensity	2.19	1.00-3.00	0.57	-0.55
Fiber intensity	2.14	1.00-3.33	0.51	-0.13
Crunchy level	2.28	1.33-3.00	0.36	-0.12

The variability of tuber length and width from 73 accessions showed that the tuber length was more variable than the width. It can be seen from the range of the values including the standard deviation. The variations of both the length and the width was likely affect the ratio of length

and width by the range of 0.4 up to 4.57 and the standard deviation value was 0.68.

In Indonesia, yam bean is also used as a food that can be eaten directly without any cooking process, therefore the water content of yam bean being one important character. From the total of 73 accessions, the average of tuber water content was 83.87% by the range of 74.31 up to 89.29%, and the standard deviation was 3.15. The high water content of yam bean *P. erosus* (78%-94%) also found in other study (Sorensen 1996).

The economic value of yam bean is determined by the tuber production capacity per unit area, and also by some supporting characters such as water content, tuber sweetness, fiber content, and texture crunchiness. However, on some cases, it also required certain tuber character, i.e. round tubers. The tuber which is used as a raw material of cosmetics industry also requires tuber (starch) with certain nutritional requirements (Rizky *et al.,* 2013; Nursandi *et al.,* 2017).

In the current study, the tuber characters diversity also observed based on tuber shape and tuber color. The additional characters which was also observed in this research were the tuber sweetness, fiber intensity, and texture crunchiness. Most of the 73 local accessions were have round and oval shapes, and all the tubers skin color were cream. The average of the tuber sweetness was 2.19 and it showed that mostly the tuber sweetness was in the medium level. The fiber intensity was also in the middle level. The observation of texture crunchiness showed that generally all of them were quite crunchy.

The skewness value of eleven tuber characters showed that the tuber color value was zero. The characteristics of the number of tuber in each plant, tuber weight, length, width, ratio of L/W, and shape was positive. The skewness in positive value explains that the data was at the left and the right tail was longer, whereas the skewness in negative value showed that the data was at the right and the left tail was longer. The rest of tuber characters which including water content, sweetness intensity, fiber intensity, and texture crunchiness were negative. It means that of 73 yam bean accessions, most of them have a high water content, sweet taste, and crunchy texture which fulfill the yam bean consumers need in Indonesia. The zero skewness indicated a symmetrical distribution, which was shown by the tuber color which had only one color.

The grouping of accession

The 73 local varieties of yam bean were grouped by using cluster analysis. Based on the tuber weight, it was successfully obtained five clusters (Table 3, Figure 3). Cluster I included 18 accessions of tubers with quite low tuber weight (420-583.33 g/plant). Cluster II consisted of 14 accessions of tubers with medium tuber weight (640-793.33 g/plant). Then, cluster III was consisted of four accessions with quite heavy tuber weight (860-1003.33 g/plant). Cluster IV was a group with the most number of members, i.e. 34 accessions. Cluster IV was characterized by low tuber weight (35-365 g/plant). The last cluster which consisted of three accessions was characterized by very heavy tuber weight (1223.33-1360 g/plant).

Figure 2. Variability on tuber shape of yam bean accessions

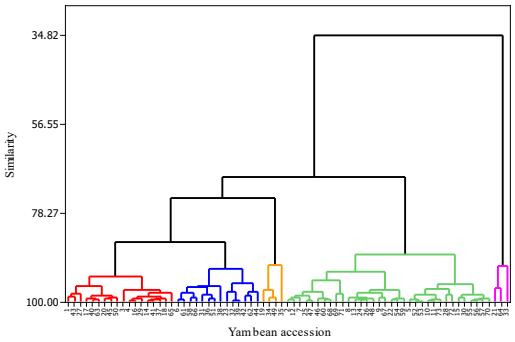

Figure 3. Groups of 73 local varieties of yam bean

Among those five clusters with the tuber weight as main distinguished character, each group shows different tuber characters. For example, cluster V with the highest tuber weight (1223.33 – 1360 g/plant) consisted of three accessions, one accession had a heavy weight tuber and also had a high water content, sweet, and the shape of the tuber tend to be round. The other accession had round shape of and crunchy texture, while another one had oval tuber shape. The pattern of tuber variability was also found in group III, whereas one accession had crunchy texture, one accession had a relatively high of fiber intensity, and the rest (two accessions) tended to be sweet.

The use of cluster analysis to assess the diversity of yam bean have been conducted by

Table 3. Groups of 73 yam bean accessions planted at Kendalpayak Research Station, Malang, (Indonesia) in 2016 based on morphological characteristics

Parameter	Cluster				
	I	II	III	IV	V
Number of cluster member	18	14	4	34	3
Number of tuber per plant	0.67 – 1.67	1.00 – 3.00	0.67 – 1.67	0.33 – 1.67	1.00 – 1.67
Tuber weight (g)	420.00 – 583.33	640.00 – 793.33	860.00 – 1003.33	35.00 – 365.00	1223.33 – 1360.00
Tuber length (cm) / L	6.00 – 16.50	7.00 – 53.33	4.33 – 16.17	2.50 – 17.67	7.00 – 14.33
Tuber width (cm) / W	7.17 – 11.67	6.00 – 11.83	3.00 – 12.00	1.00 – 8.50	10.33 – 17.57
Ratio of L/W	0.70 – 1.98	0.78 – 4.57	0.91 – 1.44	0.67 – 4.00	0.40 – 1.39
Water content (wet basis %)	80.80 – 87.84	82.97 – 88.42	85.04 – 87.59	74.31 – 89.01	86.39 – 89.29
Tuber shape	1 – 4	1 – 4	1 – 4	1 – 4	1 – 3
Tuber color	1 – 1	1 – 1	1 – 1	1 – 1	1 – 1
Sweetness intensity	1 – 2.67	2 – 3	1.33 – 2.67	1 – 3	1.33 – 3.00
Fiber intensity	1.33 – 3.00	1.33 – 2.67	1.00 – 2.67	1.33 – 3.00	1.67 – 2.00
Crunchy texture	1.67 – 3.00	1.67 – 2.67	2.33 – 3.00	1.67 – 3.00	2.00 – 2.67
The main distinguished character (tuber weight/plant)	quite small	medium	quite large	small	large

many researchers. Zanklan (2003) used 71 morpho-agronomic characters to assess the genetic diversity in the yam bean germplasm. Aremu and Ibirinde (2012) evaluate 50 accessions of African yam bean from diverse eco-geographic origins of Nigeria. Moreover, Silva *et al.,* (2016) grouped 64 yam bean accessions based on tuber yield potential using cluster analysis and successfully obtained 15 major groups. Until now, the morphological-based identification is still widely applied (Cahyanto *et al.*, 2017).

Information on the variability of tuber characteristics among accessions is important in the terms of crop genetic improvement and industrial purposes. In Indonesia, yam bean have been widely studied for food industry (Dewi *et al.,* 2012; Hermianti *et al.,* 2016) and cosmetic industry (Warnida 2015; Masluhiya *et al.,* 2016). In this study, a total of 73 yam bean accessions have been collected, and the variability was found on the tuber characteristics. The characterization on yam bean tuber in Indonesia is still limited. This research provides new findings on the characteristics of yam bean tuber which is potential for further utilization for food and cosmetic industry as well as for geneticists.

The accessions with high tuber production found in this study can be used as parental on the genetic improvement program, or potential to be released as new varieties of yam bean. Rizky *et al.,* (2013) suggested a hibridization between *P. erosus* (high tuber production) with *P. ahipa* (smaller tuber but higher in dry matter and starch content) to gain the new genotype in high tuber production with better quality especially starch content. Furthermore, the tuber starch can be extracted to be used as raw material for traditional and modern cosmetics. The accessions with certain characteristics found in this study, for example, have high water content, crunchy, and sweet, can be consumed raw. The yam bean also contains amounts of essential proteins and micronutrients, therefore it can be further developed as an alternative food source to provide food security, especially in Indonesia.

CONCLUSION

The accession of local varieties of yam bean in Indonesia has a variety of tuber production, with tuber shape vary from oval to round. Most of them are characterized by relatively high tuber water content, sweet taste, crunchy texture, and also have a relatively high water content. Based on the cluster analysis, it was obtained three accessions that have a production of tubers/plant between 1223.33 - 1360 g. Those three accessions have different characteristic, i.e. an accession have high moisture content and round tuber shapes; another one have a crunchy texture and round tuber shape; and the remaining accession have the shape of tubers that tend to be oval. All three accessions with high tuber production are compatible with consumer preferences and may be considered as a source of gene in the terms of

yam bean genetic improvement in Indonesia.

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