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Diversity Analysis of Several Indonesian Yam Bean (*Pachyrhizus erosus*) Accessions

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Abstract

Yam bean (*Pachyrhizus erosus*) is one of the introduced plants that thrives well in Indonesia. Yam Bean exhibits a considerable range of variability, contingent upon its cultivation region. The objective of this study is to analyze several Indonesian yam bean accessions in order to identify accessions yielding high harvest results and tuber inulin content. This research was conducted in Duku, Kasang, Batang Anai, Padang Pariaman. Observations and analyses were carried out in the Plant Physiology Laboratory, Instrumentation Laboratory, and Biology Laboratory of Andalas University, Padang, from January to December 2022. The experiment was arranged in a Completely Randomized Design, consisting of 11 yam bean genotypes from various yam bean production centers in Indonesia. The research results indicate that out of 22 observed traits, 8 traits show narrow variability, while 8 traits exhibit wide variability. One of the reasons for the narrow variability is due to yam bean flowers undergoing pollination before the blossoming of the flowers.

Keywords: accession; diversity; yam bean.

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1. Introduction

Yam bean (*Pachyrhizus erosus*) is one of the introduced plants that can thrive well in Indonesia. The tuber of yam bean is utilized as a food source and the fruit is consumed fresh. In terms of agronomy and economics, cultivating yam bean holds advantages compared to other leguminous crops, such as high yield stability, drought resistance, fewer pest and disease attacks, harvestable at 4-5 months of age, adaptability to less fertile soil, ease of cultivation, and higher protein content compared to other tuberous crops [1].

According to efficiency ratio assessment criteria, yam bean farming is classified as an efficient endeavor [2]. Several farmers from Way Kanan, Lampung state that cultivating yam bean yields twice the income compared to corn due to the relatively high market price. Yam bean still possesses a wide-open market [3].

In the era of free markets, every nation must enhance the competitiveness of its products to engage in global trade and to assert its position domestically, safeguarding domestic products from displacement by foreign goods. The favored commodities are required not only to exhibit high yield potential but also to prioritize product quality, enabling the offered products to compete in the market. This criterion holds true for agricultural products as well, necessitating that they meet consumer preferences and desires for quality. Currently, there is a discernible trend of increasing consumer preference for agricultural products. The public's inclination is towards consuming agriculturally derived products that are both wholesome and of high quality.

Jora and his colleagues assert that yam bean tubers contain inulin. Inulin is a carbohydrate imparting sweetness to the yam bean [4]. Generally, this compound serves as a prebiotic, fostering gut health by inhibiting the growth of pathogenic bacteria, enhancing immune response, promoting digestion, alleviating constipation, mitigating the risk of colon cancer, and regulating the concentrations of insulin and glucagon hormones [5].

Inulin is also employed as a sugar and fat substitute in low-calorie food products. In the pharmaceutical realm, inulin is used for kidney function tests [6]. Presently, inulin finds extensive utility as supplementary nutrition in toddler and infant formula products, owing to its capacity to stimulate bone growth and foster beneficial gut bacteria [7].

Attaining superior cultivars of yam bean with heightened production and inulin content constitutes an endeavor aimed at enhancing both productivity and the quality of yam bean products. In this context, an approach is needed to identify yam bean plants with desired morphophysiological and genetic traits. Selection is one of the crucial steps in the development of promising varieties. Information on phenotypic and genotypic traits is essential for the effective selection of desired characters and genotypes [8].

Prior research on the phenotypic diversity of yam bean, as referenced by Krisnawati and his colleagues concluded that tuber weight varies among cultivars and serves as a distinguishing factor among local cultivars [3]. Karuniawan and his colleagues cited by Ningsih and his colleagues stated that yam bean exhibits significant variability, contingent upon its cultivation region. Based on these premises, research is undertaken on several Indonesian yam bean accessions with the aim of identifying accessions that exhibit high harvest yields and inulin content in the tubers [1].

2. Methods

Table 1: How to collect data on the observed characters tested.

No.	Observation Character	The Measurement of Counting Method
1.	Germination day	days when the seeds germinate with a radicle of 0.5 cm in length
2.	Leaf corner	the angle between the 8th compound petiole and the main stem
3.	Internode length	the distance between the 7th internode and the 8th main stem
4.	Compound leaf length	starting from the base of the petiole to the tip of the terminal leaf
5.	Compound petiole length	starting from the base of the compound petiole to the lateral petiole
6.	Compound petiole diameter	measured 2 cm from the base of the terminal petiole
7.	The length of the terminal petiole	from the base of the lateral petiole to the tip of the terminal.
8.	The length of the terminal leaf	from the tip of the terminal petiole to the leaf.
9.	Terminal leaf width	From one side of the leaf to its adjacent side at the widest leaf part
10.	Terminal leaf thickness	from one side of the leaf to the other widest part
11.	Lateral petiole length	from the side of the lower leaf and the top of the termina
12.	Lateral leaf length	from the tip of a compound petiole to the base of the lateral leaves
13.	Lateral leaf width	from the tip of the lateral petiole to the tip of the leaf
14.	Thick lateral leaf	from one side of the leaf to the widest part
15.	Flowering day	the day the first flowers bloom
16.	Pod length	starting from the base to the end of the pod
17.	Pod width	measured the center of the pod
18.	Number of seeds per pod	total pithy seeds found in one pod
19.	Seed length	the distance between the left and right sides of the seed by placing the growing point at the top
20.	Seed Width	measured between the growing point and the side below it
21.	Seed thickness	measured between the face and back of the seed by placing the growing point at the top
22.	Weights 100 seeds	total weight of 100 pithy seeds
23.	Root length	measured from the neck to the tip of the root
24.	Tuber diameter	measured the largest and smallest width of the tuber divided by 2
25.	Fresh weight of tubers	weighed after the tubers are cleaned and dried
26.	Dry weight of tubers	weighed after the tubers are dried in an oven at 60ºC until their weight is constant
27.	Canopy fresh weight	All parts of the plant canopy starting from the root neck to the end of the stem are cleaned of dirt, then weighed at harvest time
28.	Canopy dry weight	All parts of the plant canopy starting from the root neck to the end of the stem are cleaned of dirt, then weighed at harvest time and dried to constant weight
29.	Harvest index	calculated by the formula: $IP = \frac{\text{tuber + canopy dry weight}}{\text{canopy dry weight}}$
30.	Tuber Inulin Level (%)	Cysteine Carbazole Method (Kierstan, 1978)

A field study was conducted in Duku, Kasang, Batang Anai, Padang Pariaman, situated at an elevation of 8 m above sea level, with daily temperatures ranging from 24-30ºC and a monthly rainfall of 382.4 mm. Observations and analyses were carried out at the Plant Physiology Laboratory, Instrumentation Laboratory, and Biology Laboratory of Andalas University, Padang, from January to December 2022. The experiment was designed using a Completely Randomized Design, comprising 11 yam bean genotypes sourced from various yam bean production centers in Indonesia, namely Kuranji, Koto Tangah, Batang Anai, Lubuk Alung, Padang Sidimpuan, Binjai, Batam, Bogor, Blitar, Jember, and Madura, with 10 replications. Observations were made on 30 traits using the following approach:

The data is processed using the Social Package for the Social Science (SPSS) program version 19 and continued with the Duncan Multiple Range Test (DMRT) at the 5% level assuming the difference is significant.

3. Result and Discussion

3.1 The analysis of 30 traits from 11 yam bean genotypes

The success of research in obtaining yam bean with high production and inulin content depends on the germplasm available. Germplasm plays a vital role as a fundamental resource for both selection and breeding processes. One of the stages in plant breeding is selection. Prior to establishing the method and timing of selection, it is necessary to ascertain the estimated values of genetic parameters. Several genetic parameters that can be considered to ensure an effective and efficient selection process include the genetic diversity and variability of the plant, supported by correlations among closely related traits relevant to the objective [9].

Table 2: Value range, mean, diversity, standard deviation and character variability of 11 yam bean accessions.

No.	**Character**	**Range**	**Mean**	**Diversity**	**SD**	**2 SD**	**Variability**
1	Germination day (hst)	6.25-6.58	6.44	0.02	0.14	0.28	Narrow
2	Leaf corner (◦)	36.00-79.00	55.36	111.87	10.58	21.15	Large
3	Internode length (cm)	8.00-16.00	12.09	4.81	2.19	4.38	Large
4	Compound leaf length (cm)	14.58-21.18	18.86	3.05	1.75	3.49	Narrow
5	Compound petiole length (cm)	5.15-8.96	7.66	1.07	1.03	2.07	Narrow
6	Compound petiole diameter (cm)	0.12-0.20	0.16	0.00	0.02	0.05	Narrow
7	Terminal petiole length (cm)	2.48-3.80	3.20	0.19	0.43	0.87	Narrow
8	Terminal leaf length (cm)	6.67-8.82	8.10	0.60	0.77	1.55	Narrow
9	Terminal leaf width (cm)	8.53-10.55	9.70	0.36	0.60	1.20	Narrow
10	Terminal leaf thickness (cm)	0.10-0.40	0.21	0.01	0.10	0.19	Narrow
11	Lateral petiole length (cm)	0.37-0.68	0.51	0.01	0.10	0.19	Narrow
12	Lateral leaf length (cm)	5.83-8.50	7.52	0.68	0.83	1.65	Narrow
13	Lateral leaf width (cm)	4.66-7.42	6.65	0.64	0.80	1.59	Narrow
14	Lateral leaf thickness (mm)	0.10-0.30	6.65	0.01	0.08	0.16	Narrow
15	Flowering Day (HST)	67.92-70.50	69.28	0.37	0.61	1.22	Narrow
16	Pod length (cm)	10.01-12.92	11.92	0.59	0.77	0.88	Large
17	pod width (cm)	1.09-1.38	12.33	0.01	0.07	0.14	Large
18	number of seeds / pods	8.50-9.80	9.01	0.14	0.38	0.75	Narrow
19	Seed length (cm)	0.82-0.99	0.87	0.00	0.05	0.09	Narrow
20	Seed width (cm)	0.68-0.78	0.73	0.00	0.02	0.05	Narrow
21	Seed thickness (cm)	0.34-0.44	0.40	0.00	0.03	0.07	Narrow
22	Weight 100 seeds (grams)	16.10-21.26	19.05	28633.00	5351.00	10.70	Large
23	Root length (cm)	20.34-20.66	20.75	0.04	0.21	0.42	Narrow
24	Tuber diameter (cm)	8.37-8.62	8.53	0.01	0.11	0.23	Narrow
25	Tuber fresh weight (grams)	205.00-371.50	260.59	2575.88	50.75	101.51	Large
26	Tuber dry weight (grams)	30.40-35.48	32.94	4.30	2.07	4.15	Large
27	Canopy fresh weight (grams)	347.15-391.07	366.89	331.43	18.21	36.41	Large
28	Crown dry weight (grams)	22.23-24.00	23.00	0.55	0.74	1.48	Narrow
29	Harvest index	0.429-0.433	0.43	0.00	0.00	0.00	Narrow
30	Tuber Inulin Level (%)	10.82-15.64	13.65	3.69	1.92	3.84	Narrow

Genetic diversity has an impact on the success of plant breeding. Within genetic diversity lies variation in genotype values among individuals within a population. The genetic improvement of yam bean necessitates the presence of germplasm with wide genetic diversity. The initial phase of a plant breeding program involves the collection of diverse accessions, which subsequently serve as sources to obtain desired genotypes. Collections can originate from local as well as introduced sources. The broader the genetic diversity of a plant, the greater the likelihood of achieving the desired genetic enhancement. Prior to commencing breeding, it is essential to ascertain the extent of genetic diversity and variation within the plant to be improved.

Table 2 reveals that yam bean possesses 22 traits with narrow variability, namely germination days, compound leaf length, compound leaf petiole length, compound leaf petiole diameter, terminal leaf petiole length, terminal leaf blade length, terminal leaf blade width, terminal leaf blade thickness, lateral leaf petiole length, lateral leaf blade length, lateral leaf blade width, lateral leaf blade thickness, flowering days, seed length, seed width, seed thickness, number of seeds per pod, root length, tuber diameter, shoot dry weight, harvest index, and tuber inulin content, all of which exhibit low variability, indicated by values less than two times the standard deviation. This signifies that each of these traits has narrow variability. In contrast, the remaining 8 traits, including leaf angle, internode length, pod length, pod width, 100-seed weight, fresh tuber weight, dry tuber weight, and fresh shoot weight, exhibit variability greater than 2 times the standard deviation, indicating broad variability.

Broad variability contributes to higher success prospects in selection. Greater individual trait diversity within a population corresponds to a higher frequency of desired genes, thereby increasing the potential for obtaining improved traits through selection. Conversely, with narrow variability, the population tends to exhibit uniformity, diminishing the effectiveness of trait improvement through selection. Values of variance and variability are generally greater when accessions are distantly related and originate from crosses of parents with distinct genetic backgrounds.

Hamrick and Godt as cited in Frianto and his colleagues state that patterns of diversity distribution can be attributed to mating systems, population history and speciation, population dispersion, geographical location, and gene flow [7]. The process of evolutionary adaptation of plant populations to specific environments in their habitats leads each population to develop distinct morphophysiological and genetic characteristics, rendering them unique from other populations.

3.2 Cleistogamy as one of the causes of the narrow variability in yam bean

In the examination of 30 tested traits, 22 traits exhibited limited variability. To ascertain the cause of this limited variability, an investigation into the yam bean's mating system was conducted. The yam bean's flowers are compound and arranged in racemes, composed of 1-103 flower buds per inflorescence. Flowers are found in the leaf axils and at the stem tip. Sorensen states that flowers of Leguminosae plants undergo pollination prior to full bloom (cleistogamy). To confirm this, observations were made on yam bean flowers that were still in bud stage (not yet fully bloomed), on the day before full blooming (marked by the corolla emerging from the calyx measuring 7 mm in length), with observations conducted between 16:00 and 24:00 WIB (Western Indonesian Time), at hourly intervals for sample collection and observation.

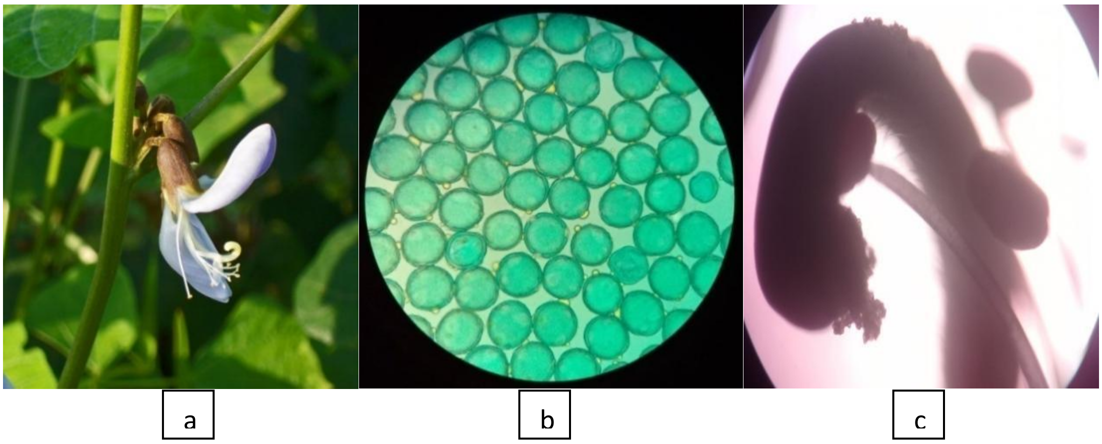

Figure 1: (a) flower buds, (b) pollen H-1 (400x magnification), (c) pistil attached by anthers (40x magnification).

To examine pollen viability, pollen released from the anthers was treated with lactophenol cotton blue and observed under a microscope. Spherical and intact pollen grains indicate viability, whereas shrunken and damaged pollen grains indicate non-viability. Subsequently, pollen grains extracted from the anthers were treated with a 5% sucrose solution + fluorescein diacetate. The resulting color was used as an indicator. If the color appeared bright (indicating a fluorochromatic reaction), it demonstrated pollen viability. From the investigation of flowers at H-2, H-1, H0, H+1, and H+2 stages, the following results were obtained:

Table 3: Pollen Viability and Pistil Receptivity of the Jicama.

Pollen viability (%)			Pistil receptivity	
Flower Age	Viable	Nonviable	Esterase's presence	Description
H-2	59.21	40.79	+	Esterase is not evenly distributed
H-1	94.18	5.82	++	Esterase is not evenly distributed
H0	42.39	80.39	+++	Esterase evenly
H+1	10.84	89.16	++	Esterase evenly
H+2	0.32	99.68	+	The pistil is drying up

Description: 2 days before flowers bloom (D-2), 1 day before flowers bloom (H-1), days when flowers bloom (H0), 1 day after flowers bloom (H + 1), 2 days after flowers bloom (H + 2). Observations were performed at 10.00 WIB

Table 3 demonstrates that yam bean flower pollen is already viable from 2 days prior to blooming (59.21%). Viability progressively increases, reaching its peak (94.18%) at H-1. At H0, the viable pollen is merely 42.39%, and it steadily decreases and nearly diminishes at H+2. The reduction in viability results from pollen desiccation. Pollen viability is contingent upon both the genetic factors of the parental plants and the environmental conditions throughout the plant's growth until flowering.

The determination of receptive stigma maturity is accomplished by applying the enzyme esterase to fresh flowers. The development of a reddish-brown color on the stigma surface signifies that the stigma is receptive (mature). In the enzyme esterase activity study of the stigma, changes were visible 2 days before flowering, though not evenly distributed; by H-1, a somewhat even distribution was noticeable. At H0 (flower blooming) and H+1, the entire stigma surface turned reddish-brown when treated with the enzyme. This color change indicates the effective receptivity of the stigma, ready to receive pollen. At H+2, the stigma still exhibited a reddish-brown color upon enzyme application, but signs of drying were also evident, rendering it unsupportive of pollen germination. If no pollination occurs, the flower will eventually abscise.

Cluster analysis based on the 30 phenotypic traits of yam bean under examination. The results of the cluster analysis on the 30 observed traits, using a dissimilarity threshold of 15%, grouped the 11 yam bean accessions into four clusters. The first cluster comprised 7 accessions: (1) Kuranji, (3) B. Anai, (4) L. Alung, (5) P. Sidimpuan, (8) Bogor, (10) Jember, and (11) Madura. The second cluster consisted of a single accession, (2) Koto Tangah. The third cluster comprised a single accession, (9) Blitar. The fourth cluster consisted of 2 accessions: (6) Binjai and (7) Batam. The dendrogram depicting the clustering results based on the 30 phenotypic traits is presented in Figure 2.

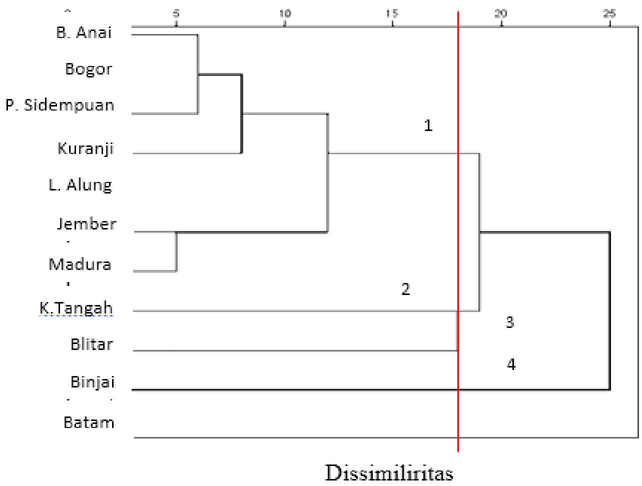

Figure 2: Yam bean Dendrogram Based on 30 Morphophysiological Characters.

4. Conclusion

Observations on 30 morphophysiological traits in the 11 tested yam bean accessions revealed that 22 traits displayed narrow variability, while 8 traits exhibited broad variability. One of the causes of the observed narrow variability is the fact that yam bean flowers undergo pollination before they fully bloom (cleistogamy).

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