Variation of morphological and agronomic characters of eight F1 half-sib populatıons of cassava

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Abstract. The objectives of this study were to estimate the degree of morphological and agronomic variation among plants in eight F1 half-sib population. Unreplicated experiment was conducted at Integrated Field Laboratory of University of Lampung, Bandar Lampung from April 2016 to March 2017. The degree of variation of was estimated on eight F1 half-sib populations. The color of apical leaves, abaxial petiole color, and adaxial petiole color showed mostly high degee of variation in five F1 half-sib population. The characters number of leaf lobes, length of leaf lobe, width of leaf lobe, ratio of lobe length to lobe width of central lobe, and petiol length showed high degree of variation in eight F1 population. The degree of variation of starch rendement was high in F1 population derived from BL 5-1, CMM 25-27-145, and Mulyo. Selection for starch rendement in the three population should be effective in the three population. It is suggested to estimate the variation on other economically important characters.

1. Introduction

Cassava (*Manihot esculenta* Crantz) is one of the most important crops in Lampung Province. The province contributed 35% of total cassava production of Indonesia. Cassava storage roots can be utilized for food, feed, bioplastics, and bioenergy [1][2][3][4]). Bioenergy using cassava as raw material can yield bioethanol 167 liters per ton of roots; higher than that of sweet potato and sago (125 and 90 liters respectively) [5]. In 2009-2013, the average yield of cassava in Indonesia was 20.6 t ha^{-1}, less than India 35.82 t ha^{-1} [6]. Due to the high demand, the yield of cassava must be increased, i.e., by developing high-yielding cultivars or clones.

Reviews on cassava breeding in Indonesia was reported by Poespodarsono *et al*. [7]. Comprehensive reviews of breeding to develop superior cultivars of cassava woldwide was reported by Ceballos *et al*. [08]; Ceballos *et al*. [09]; and Ceballos *et al*. [10]. The method of cultivar development of cassava is relatively simple: development and enhancement of genetic variation (i.e., through sexual hybridization resulting F1 population), selection on F1 population, and yield trials Enhancement of genetic variation or diversity of population is very important for effective selection to develop superior cultivars of cassava. Sexual hybridization among diverse parents can enhance the genetic diversity through genetic recombination and segregation. Segregation is expected on F1 population due to natural or artificial hybridization among parents that may not be homozygote. Selection is performed in F1 population followed by yield trials; inbreeding is not required because cassava plants are vegetatively propagated; genetic fixation occurs through vegetative propagation.

The progress of selection depends on the magnitude of genetic variation of characters of interest. The degree of variation can be estimated at morphological, physiological, and molecular levels. Estimating variabilty based on morphological characters can be effective and relativey simple in preliminary study to predict genetic variation of cassava and the difference among genotypes [11][12]). Silva *et al*. [13] showed variation among cassava genotypes for characters of plant shoot weight, number of roots per plant, fresh root yield, harvest index, and starch content.

Breeding program of cassava at the University of Lampung have been started in 2011. The program consists of genetic enhancement of population, selection, and yield trial, which are running simultaneously [14]. In 2011, 40 local clones/landraces from Provinces of Lampung, Central Java, and East Java were evaluated. In 2013 – 2014, botanical seeds of cassava were collected from South Lampung, Central Lampung, and West Lampung, germinated, and evaluated In 2015 - 2017, natural and artificial hybridization were started in highland of Sekincau, West Lampung. F1 seeds harvested from cross-pollinated plants has been germinated and then grown in the field in 2016 -2017. This preliminary study was the part of clonal evaluation to estimate the magnitude or degree of variation of morphological and agronomic characters. The information is important to estimate the effectiveness of selection.

The objectives of this study were to evaluate the degree of morphological and agronomic variation among plants in eight F1 half-sib population.

2. Materials and Methods

The evaluation of the degree of phenotypic variation of eight F1 half-sib populations was conducted at Integrated Field Laboratory of University of Lampung, Bandar Lampung from April 2016 to March 2017. The eight F1 half-sib populations were originated from natural sexual hybridizations using 8 female parents, i.e., BL5-1, BL8, Cimanggu, CMM 25-27-46, CMM 25-27-57, CMM 25-27-122, CMM 25-27-145, and Mulyo. Except Cimanggu and Mulyo, the six female parents are F1 clones as a part of germplasm collection of the University of Lampung. Cimanggu or Manggu is a national cultivar; Mulyo is a local clone.

The eight F1 half-sib populations were the part of big populations as the results of half-sib natural sexual hybridization of 80sparental clones conducted in highland of Sekincau (1100 above see level), West Lampung in early 2015. The parental clones consisted of national cultivars and F1 clones, i.e., Adira 4, BL 10, BL 4, BL 5, BL 5-1, BL 8, BL-1, BL-11, BL-14, BL-2, Cimanggu, CMM 25-27-103, CMM 25-27-107, CMM 25-27-109, CMM 25-27-112, CMM 25-27-127, CMM 25-27-143, CMM 25-27-145, CMM 25-27-158, CMM 25-27-167, CMM 25-27-180, CMM 25-27-33, CMM 25-27-38, CMM 25-27-41, CMM 25-27-42, CMM 25-27-43, CMM 25-27-46, CMM 25-27-57, CMM 25-27-66, CMM 25-27-67, CMM 25-27-69, CMM 92-6-1, CMM 97-6, CMM 97-6-10, CMM 97-6-2, CMM 97-6-3, Darul Hidayah, Duwet 3-1, UJ 5, Kasesart Ungu, Klenteng 37, Klenteng, Klenteng 16KS, Klenteng 6, Klenteng K7, Macan, Malang, Malang 6-48, Malang 6-18, Malang 6-31, Malang 6-41, Malang 6-6, Mesa 1, MU-53, MU-55, MU-57, Mulyo 1, Mulyo 3, Mulyo 4, T 110, T 12, T 15-4, T 19, T 80, T-12, T-142, T-143, T-353, T-73, T-93, dan UJ 3. Except UJ 3 and UJ 5, each clone was planted in one row (10 stem cutting) arranged randomly; each clone was replicated 1 – 5 times distributed randomly in seven blocks. UJ 3 and UJ 5 were replicated 21 times; three rows per block, the rows were distributed evenly across a block. Each block consisted of 20 – 25 rows. The planting distance was 100 cm between row and 50 cm within row. Botanical seeds was harvested in July – November2015; then the seeds were germinated and grown on soil media (10 kg polybag) on 12 December 2015.

Each population consisted of F1 clones derived from one female parent; the male parent was one of 80s clones grown in the surrounding female parents, or in case the F1 was the results of selfing, the male parent was the same as female. The eight female parents were BL5-1, BL8, Cimanggu, CMM 25-27-46, CMM 25-27-57, CMM 25-27-122, CMM 25-27-145, and Mulyo. The cutting of F1 plants were transplanted from polibag to the field four months after sowing. The total number of F1 clones evaluated were 134 plants; one plants was one clone.

Variables observed included qualitative and quantitative characters[15]. The qualitative characters were the color of apical leaves, the color of upper-side of petiole, and the color of bottom side of petiole. The quantitative characters consisted of the number of leaf lobes, leaf lobe length, leaf lobe width, petiole length, and starch rendement. Only 50 clones were measured for starch rendement; the rendement was measured manually, by comparing the weight of dried starch and the weight root pulp (parenchyma).

The degree of variation of qualitative characters was based on the proportion of recombinant phenotypes. The phenotypes of F1 clones different from parental were defined as recombinant phenotypes (RP); RP could be the same as the phenotypes of male parents. The degree of variation was high if RP ≥ 67%, medium if 33% ≤ RP< 67%, and low if RP< 33%.

The variation of quantitative characters was high if the total range of phenotypes was more than twice of range within Box and Whizker plots (Fig.1).

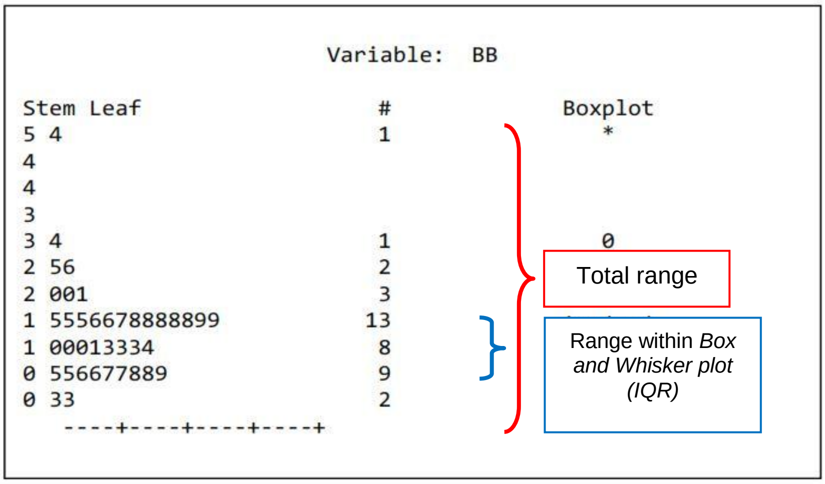

Fig. 1. Box and Whisker plot. The variation of quantitative characters was high if the total range of phenotypes of a character was more than twice of range within Box and Whizker plot (IQR)

3. Results and Discussion

Table 1 shows variation of the three qualitative characters of population derived from female parents Cimanggu, CMM 25-27-46, and CMM 25-27-57. RP of the color of apical leaves, abaxial petiole color, and adaxial petiole color of the three population were ≥ 67%, indicating high degree of variation. Table 2 shows variation of the three qualitative characters of population derived from female parents CMM 25-27-145 and Mulyo. The degree of variation of the three characters was high in population derived from CMM 25-27-145. Low variation was indicated by character of adaxial petiole color of population derived from Mulyo.

Table 1.The degree of variation of qualitative characters (the color of apical leaves, the color of abaxial petiole, and the color of adaxial petiole) ofhalf-sib populations derived from female parents Cimanggu, CMM 25-27-46 and CMM 25-27-57.

No.	**Variable**	**Cimanggu**		**CMM 25-27-46**		**CMM 25-27-57**	
		Number of genotypes	**(%)**	**Number of genotypes**	**(%)**	**Number of genotypes**	**(%)**
1	Color of apical leaves						
	Light green	7	58.3	5	62	6	50
	Dark green	1	8.3	3	38	6	50
	Purplish green	4	33.4	-	-	-	-
	Purple	-	-	-	-	-	-
	Parental phenotype	purplish green*		purplish green*		purplish green*	
	Recombinant phenotype (RP) (%)	67		100		100	
	Degree of variation	high		high		high	
2	Abaxial petiole color						
	Yellowish green	2	16.7	-	-	-	-
	Green	2	16.7	-	-	3	25
	Reddish-green	1	8.3	1	12.5	1	8.3
	Greenish-red	4	33.3	4	50.0	6	50.0
	Red	3	25.0	3	37.5	-	-
	Purple	-	-	-	-	2	16.7
	Parental phenotype	red		red		red	
	Recombinant phenotype (%)	75		100		100	
	Degree of variation	High		high		high	
3	Adaxial petiole color						
	Yellowish green	8	66.6	3	37.5	1	8.3
	Green	2	16.7	3	37.5	8	66.7
	Reddish-green	2	16.7	1	12.5	3	25
	Greenish-red	-	-	1	12.5	-	-
	Red	-	-	-	-	-	-
	Purple	-	-	-	-	-	-
	Parental phenotype	purple		reddish-green		reddish-green	
	Recombinant phenotype (%)	100		87.5		75	
	Degree of variation	High		high		high	

Table 2. The degree of variation of qualitative characters (the color of apical leaves, the color of abaxial petiole, and the color of adaxial petiole) of half-sib populations derived from female parents CMM 25-27-145 and Mulyo.

No.	Variable	CMM 25-27-145		Mulyo	
		Number of genotypes	**(%)**	**Number of genotypes**	**(%)**
1	Color of apical leaves				
	Light green	9	60	16	55,2
	Dark green	3	20	3	10,3
	Purplish green	2	13	9	31
	Purple	1	6.7	1	3,45
	Parental phenotype	Purplish green*		Light green	
	Recombinant phenotype (%)	87		44.8	
	Variation	High		Moderate	
2	Abaxial petiole color				
	Yellowish green	-	-	2	6.9
	Green	2	13.2	8	27.6
	Reddish-green	7	46.7	7	24.1
	Greenish-red	4	26.7	10	34.5
	Red	1	6.7	2	6.9
	Purple	1	6.7	-	-
	Parental phenotype	red		Green	
	Recombinant phenotype (%)	93.3		72.4	
	Degree of variation	high		High	
3	Adaxial petiole color				
	Yellowish green	3	20	8	27.6
	Green	7	46.7	21	72.4
	Reddish-green	4	26.7	-	-
	Greenish-red	3	20	-	-
	Red	-	-	-	-
	Purple	-	-	-	-
	Parental phenotype	reddish-green		green	
	Recombinant phenotype (%)	73.3		27.6	
	Degree of variation	high		low	

The degree of variation of the number of leaf lobes, length of leaf lobe, width of leaf lobe, ratio of lobe length to lobe width of central lobe, and petiol length was mostly high in eight F1 population (Table 3). The degree of variation of starch rendement was high in F1 population derived from BL 5-1, CMM 25-27-145, and Mulyo. The range of starch rendement across population was 14.5-28.2%. The results indicated that high variation that may be due to recombination occured in most populations. In this study, variation may be due to hybridization among different parents or selfing of heterozigot parents. The variation of the morphological and agronomic characters can be an indicator of the variation of other important agronomic characters. The high degree of variation in qualitative and quantitative characters supported the study reported by Silva *et al*. [13] and Avijala *et al*. [16]. The data were preliminary results; the high degree of variation enables effective selection in developing superior cultivars.

Table 3. Variation of quantitative characters of eight F1 populations of cassava in Bandar Lampung

No	Female parent /Variable	Min.	Max.	Range	Inter-quartile range	Degree of variation
1	BL5-1					
	Number of leaf lobes	5.0	9.0	4.0	0.0	High
	Length of leaf lobe	5.5	25.7	20.2	9.2	High
	Width of leaf lobe	2.0	6.6	4.6	1.8	High
	Ratio of lobe length to lobe width of central lobe	2.7	4.8	2.1	0.8	High
	Petiol length	3.2	39.0	35.8	11.5	High
	Starch rendement	15.9	24.4	8.5	3.1	High
2	BL8					
	Number of leaf lobes	5.0	7.0	2.0	0.0	High
	Length of leaf lobe	8.0	22.6	14.6	6.6	High
	Width of leaf lobe	2.9	13.7	10.8	1.1	High
	Ratio of lobe length to lobe width of central lobe	1.3	4.4	3.1	0.8	High
	Petiol length	7.3	32.4	25.1	11.1	High
	Starch rendement	18.5	20.2	1.7	1.7	Low
3	Cimanggu					
	Number of leaf lobes	5.0	7.0	2.0	0.0	High
	Length of leaf lobe	8.7	24.0	15.3	3.9	High
	Width of leaf lobe	3.1	13.6	10.5	1.0	High
	Ratio of lobe length to lobe width of central lobe	1.7	4.5	2.8	0.5	High
	Petiol length	10.7	41.7	31.0	6.7	High
	Starch rendement	16.5	19.9	3.4	3.4	Low
4	CMM 25-27-46					
	Number of leaf lobes	7.0	9.0	2.0	2.0	Low
	Length of leaf lobe	12.4	18.3	5.9	1.5	High
	Width of leaf lobe	4.1	5.4	1.3	0.7	Low
	Ratio of lobe length to lobe width of central lobe	2.9	3.6	0.7	0.4	Low
	Petiol length	3.6	33.0	29.4	5.8	High
	Starch rendement	19.8	25.4	5.6	5.6	Low
5	CMM 25-27-57					
	Number of leaf lobes	5.0	7.0	2.0	0.5	High
	Length of leaf lobe	9.3	24.5	15.2	8.2	Low
	Width of leaf lobe	3.4	6.3	2.9	1.2	High
	Ratio of lobe length to lobe width of central lobe	2.8	4.7	1.9	0.8	High
	Petiol length	10.6	38.0	27.4	12.7	High
	Starch rendement	15.5	28.2	12.7	7.2	Low

Continuation of Table 3

No	Female parent /Variable	Min.	Max.	Range	Inter-quartile range	Degree of variation
6	CMM 25-27-122					
	Number of leaf lobes	7.0	9.0	2.0	0.0	High
	Length of leaf lobe	14.3	22.5	7.0	2.0	High
	Width of leaf lobe	3.7	5.8	2.1	0.8	High
	Ratio of lobe length to lobe width of central lobe	3.0	4.7	1.7	0.8	High
	Petiol length	20.6	31.0	10.4	2.7	High
	Starch rendement	15.8	25.6	9.8	5.3	Low
7	CMM 25-27-145					
	Number of leaf lobes	5.0	9.0	4.0	0.0	High
	Length of leaf lobe	11.1	21.9	10.8	3.4	High
	Width of leaf lobe	3.4	6.0	2.6	1.0	High
	Ratio of lobe length to lobe width of central lobe	2.8	4.4	1.5	0.6	High
	Petiol length	7.8	38.5	30.7	5.5	High
	Starch rendement	14.6	27.3	12.7	3.3	High
8	Mulyo					
	Number of leaf lobes	5.0	9.0	4.0	0.0	High
	Length of leaf lobe	6.5	24.6	18.1	5.8	High
	Width of leaf lobe	2.2	6.2	4.0	1.0	High
	Ratio of lobe length to lobe width of central lobe	2.5	4.5	2.0	0.5	High
	Petiol length	8.5	33.5	25.0	9.4	High
	Starch rendement	14.5	25.8	11.4	4.7	High

4. Conclusion and Suggestion

The color of apical leaves, abaxial petiole color, and adaxial petiole color showed mostly high degee of variation in five half-sib F1 population. The quantitative characters related to leaf showed high degree of variation in eight F1 population. The degree of variation of starch rendement was high in F1 population derived from BL 5-1, CMM 25-27-145, and Mulyo. Selection for starch rendement in the three populations should be effective. Estimation of variation on other economically important characters is suggested.

Acknowledgment

This study was partially supported by National Competitive Grant "Hibah Strategis Nasional" Ministry of Research, Technology, and Higher Education, Republic of Indonesia fiscal year 2016 and 2017. Letter of Appointment from the Head of LPPM Unila # 419/UN26/8/LPPM/2016 and 585/UN 26.21/KU/2017. The financial support was highly appreciated.

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