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Analysis of Variance, Heritability, Correlation and Selection Character of M_1V_3 Generation Cassava (*Manihot esculenta* Crantz) Mutants

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ABSTRACT

Information about genetic variability and correlation between qualitative character and yield are important to support a selection program. The objective of this research was to determine genetic variability, heritability, and path analysis of M_1V_3 cassava mutants' characters. This research was conducted at Bogor Agricultural University Experimental Field Research from May 2014 to May 2015. This research used 32 mutants from five cassava parent lines which were Malang-4 and Adira-4 (national varieties), UJ-5 (Introduction variety from Thailand), and two local genotypes from Halmahera which were Jame-jame and Ratim. The results showed that gamma ray irradiation increased variability from five cassava genotypes. Characters that had high heritability were length of leaf lobe, lengthof petiole, stem diameter, and the height of plant. The path correlation analysis showed that number of tubers, number of economic tuber (> 20 cm), height to first branchingand stem diameter had direct correlation with tuber mass per plant. The characters can be used for the selection of M_1V_4 generation.

INTRODUCTION

Cassava is the third local carbohydrate sources in Indonesia after rice and maize. This plant is planted because it has high yield and starch content. Cassava in Indonesia is used as food, raw material for bioethanol industry (fuel) and feed. Indonesia is the third biggest cassava producer in the world (24.6 millions t) after Nigeria (56.41 million t) and Thailand (28.276 million t) (FAO, 2013). Based on Statistics Indonesia (2016) the productivity of cassava in Indonesia had increased from 2011 (20.30 t ha^{-1}) to 2015 (23.37 t ha^{-1}). Cassava production also increased from 2011 (24,044,025 t) to 2014 (26,421,770 t). Even though cassava production in Indonesia has increased, in 2013 Indonesia still imported cassava. One of the reasons was the low cassava productivity due to the limited use of superior high yielding variety.

Cassava is usually propagated vegetatively because this plant only produces flower on 800 m above sea level. This is caused by the low genetic variance of cassava, so it is important to increase the genetic variance. Genetic variance can be produced by gen recombination, hybridization, or genetic manipulation, mutation induction or polyploidy (Syukur, Sujiprihati, & Yunianti, 2012). Ceballos, Kawuki, Gracen, Yencho, & Hershey (2015) conducted breeding efforts on cassava with quantitative genetic to choose genomic cassava using heterocyst concept and affinity. The method that commonly used by breeder to increase genetic variance of vegetatively propagated plant is mutation induction using gamma ray irradiation. Breeding with mutation induction technique on cassava has been commonly used to build new superior variety.

Genetic variance significantly affects the success of selection process on breeding program (Poehlman & Sleper, 1995). Genetic variance estimation, heritability, correlation analysis, and path analysis among several characters against yield are used to determine the selection criteria. The objectives of this research were to estimate genetic variance on cassava potential mutant generation M_1V_3, and to determine selection criteria based on the information of genetic variance, heritability, and path analysis among several characters of cassava generation M_1V_3.

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MATERIALS AND METHODS

This research was conducted in May 2014 to May 2015, at Bogor Agricultural University Experimental Field Research. The plant materials were M_1V_3 generation from five parent genotypes namely Jame-jame and Ratim (local genotypes from Halmahera), UJ-5 (introduction variety from Thailand), Malang-4 and Adira-4 (national varieties). The observations were done on vegetative stage and harvest. Cutting was planted with 1 m x 1 m (population of 10,000 per ha). The observed characters at vegetative stage were length of leaf lobe, width of leaf lobe, length petiole, stem diameter, the height of plant, and height of plant to first branching. Meanwhile the observed characters at harvest were number of fresh root (tuber) per plant, number of economic fresh root (> 20 cm), and tuber weight per plant. Characterization of fresh root (tuber) was based on descriptor developed by International Institute of Tropical Agriculture (Fukuda, Guevara, Kawuki, & Ferguson, 2010).

Experimental design was used environmental completely randomized design group with one factor the cassava genotype. The factor consisted of five genotypes of origin and 32 mutants resulting from gamma ray irradiation. Each treatment was replicated three times and a trial unit consisted of three plants. Number of plants used on this research was 288 plants which came from 32 high yielding putative mutants (Maharani, Khumaida, Syukur, & Ardie, 2015). Analysis of variance (F-test) was done using SAS. Heritability estimation was ratio between genotype variance and phenotype variance. Heritability from 32 mutant genotypes was using ANOVA formula below (Burton & DeVane, 1953):

$$(h^2_{bs}) = \frac{\sigma^2 c}{\sigma^2 c + \sigma^2 e} \times 100\%$$

Where: (h^2_{bs}) = broad sense heritability, σ_c^2 = clone variance, σ_e^2 = environmental variance. When broad sense heritability value 0 % - 20 % classified as low, 20 % - 50 % classified as medium, and more than 50 % classified as high.

Genetic correlation analysis was conducted to know the relationship between some characters with the yield. Direct and indirect effect of yield parameter and yield of M_1V_3 generation cassava mutants was counted using path coefficient analysis by matrix methods according to Singh & Chaudhary (1979).

RESULTS AND DISCUSSION

Analysis of variance results of vegetative and harvest character on M_1V_3 generation cassava mutants showed a significant difference on observed genotypes. This showed that there were differences on length of leaf lobe, width of leaf lobe, length petiole, stem diameter, the height of plant, height of plant to first branching, number of fresh root (tuber), number of economic fresh root, and fresh root (tuber) weight per plant. Observed character showed significantly different condition where mutant genotype affected each variable. Analysis of variance is shown on Table 1.

Analysis of variance results showed that there was a variation on observed genotypes. Variance can be separated into phenotype variance, environment variance, and genotype variance. Thus, there was an information about contribution genetic variance to total observed variance. The information about high variance was needed in selection (Sungkono et al., 2009).

Table 1. Analysis of variance character mutant cassava generation M_1V_3

Character quantitative	Mean square genotype	Mean square error	F-Test
Growth			
Length of leaf lobe (cm)	9.69	1.99	4.87**
Width of leaf lobe (cm)	0.54	0.22	2.46**
Length of petiole (cm)	57.53	8.3	6.93**
Stem diameter (mm)	180.7	35.59	5.08**
The height of plant (mm)	7278.95	1798.15	4.05**
Height of plant to first branching (cm)	3646.58	983.78	3.71**
Harvest			
Number of fresh roots per plant	21.48	5.49	3.91**
Number of economic fresh roost per plant	14.5	5.2	2.79**
Fresh root weight per plant (kg)	20.03	5.56	3.61**

Remarks: ** = highly significant at 1 % level

Selection of character is really important in plant breeding. Before doing the selection, it is necessary to know how big is the genetic diversity of the character observed, and also that it is important to know the heritability of characters as the target selection. Heritability is a percentage of ratios between genetic variance and phenotype variance. Heritability estimation is used to measure genetic factor and environmental factor on phenotype. Parameter with a high broad sense of heritability means that genetic gives more effect than environmental factor and selection can be done based on that parameter. High value of heritability used for increasing selection affectivity on plant breeding (Syukur, Sujiprihati, & Yunianti, 2012).

Phenotype variance, environmental variance and genetic variance estimation results showed that on width of leaf lobe, height of plant to first branching, number of fresh roots, number of economic fresh root, and fresh root weight per plant character, environmental effect were still high. On the other hand, on length of leaf lobe, length of petiole, stem diameter and the height of plant, genetic factor was dominant on controlling those characters, which shown by high value of broad sense heritability (Asante & Dixon, 2002) (Table 2). Heritability of M_1V_3 generation cassava mutant was around 32.65 % - 66.41 %. This result was similar with Khumaida, Ardie, Dianasari, & Syukur (2015), who stated that heritability value of M_1V_1 generation cassava mutants was high in the height of plant, height of plant to first branching, number of fresh root (tuber) per plant, and number of economic fresh root. These characters were still used on M_1V_3 generation cassava mutants' selection. According to Khumaida, Ardie, Dianasari, & Syukur (2015) M_1V_2 generation cassava mutants character that had high heritability on Ratim genotype (G2) was height of plant to first branching, number of fresh roots, number of economic fresh root. Malang-4 genotype (G4) had higher broad heritability in number of fresh roots and number of economic fresh root.

Besides the heritability of characters that is used in selection, other information that is necessary to find out its correlation coefficient and path analysis among the characters which is affect to yield. Correlation coefficient between observed characters was shown at Table 3. On agricultural research, usually, correlation coefficient is used to measure the degree of linier relationship between two characters with unclear cause and effect explanation (Gomez & Gomez, 1984/2007). High correlation coefficient meant that parameter had effect on yield improvement. Based on correlation analysis, there were positive correlations between tuber weight per plant and length of petiole, stem diameter, the height of plant, height to first branching, number of tubers, and number of economic fresh root (> 20 cm).

Length of petiole had positive correlation with length of leaf lobe, width of leaf lobe, the height of plant, number of fresh roots, number of economic fresh root, and fresh root weight per plant. Furthermore, the plant stem diameter had positive correlation with the height of plant, height of plant to first branching, number of economic fresh roots, and fresh rootweight per plant. According Khumaida, Maharani, & Ardie (2015) length of petiole character's had significantly positive correlation with number of economic fresh root and number of fresh roots. The plant stem diameter was positively correlated with fresh rootweight per plant where the increase in plant stem diameter will increase the fresh root weight per plant.

Table 2. Criteria and Estimation Value of Broad sense heritability (h^2_{bs}) on the mutant of cassava generation M_1V_3

Character quantitative	σ_g^2	σ_p^2	σ_e^2	h^2_{bs}(%)	Criteria
Growth					
Length of leaf lobe (cm)	2.57	4.56	1.99	56.32	High
Width of leaf lobe (cm)	0.12	0.33	0.22	32.65	Medium
Length of petiole (cm)	16.41	24.71	8.3	66.41	High
Stem diameter (mm)	48.37	83.96	35.59	57.61	High
The height of plant (mm)	1826.93	3625.08	1798.15	50.39	High
Height of plant to first branching (cm)	887.6	1871.38	983.78	47.43	Medium
Harvest					
Number of fresh roots per plant	5.33	10.82	5.49	49.26	Medium
Number of economic fresh roots per plant	3.1	8.3	5.2	37.34	Medium
Fresh root weight per plant (kg)	4.82	10.38	5.56	46.45	Medium

Remarks: σ_g^2 = genotype variance; σ_p^2 = phenotype variance;σ_e^2 = environment variance; h^2_{bs} = heritability broad sense

Table 3. The score of correlation between several quantitative characters on several cassava mutants generation M_1V_3

Character	LoLL	WoLL	LoP	PSD	HoP	HoPFB	NoFR	NoEFR	FRW
LoLL	1	0.47**	0.48**	0.25	0.46**	0.30	0.60**	0.56**	0.41*
WoLL		1	0.67**	0.02	0.20	-0.20	0.14	0.09	-0.07
LoP			1	-0.23	0.09	0.01	0.09	0.10	-0.06
PSD				1	0.38**	0.46**	0.34	0.37*	0.40*
HoP					1	0.67**	0.64**	0.54**	0.56**
HoPFB						1	0.57**	0.55**	0.61**
NoFR							1	0.87**	0.87**
NoEFR								1	0.87**
FRW									1

Remarks: ** = highly significant at 1 % level; * = significant at 5 % level; LoLL =Length of leaf lobe (cm); WoLL = Width of leaf lobe; LoP = Length of petiole; PSD = Plant Stem diameter; HoP = Height of plant; HoPFB = Height of Plant to first branching; NoFR = Number of fresh roots; NoEFR = Number of economic fresh roots; FRW = Fresh root weight per plant (kg)

Table 4. Direct and indirect effect between agronomy character and tuber weight per plant of cassava M_1V_3

Character	DI	Indirect Effect							
		LoLL	PSD	HoP	HoPFB	NoFR	NoEFR	Total	Difference
LoLL	-0.2		0.015	-0.014	0.033	0.318	0.251	0.408	0.6
PSD	0.06	-0.05		-0.011	0.051	0.182	0.168	0.402	0.34
HoP	-0.03	-0.092	0.023		0.074	0.338	0.245	0.557	0.59
HoPFB	0.11	-0.059	0.028	-0.02		0.304	0.247	0.609	0.5
NoFR	0.53	-0.12	0.021	-0.019	0.063		0.391	0.866	0.34
NoEFR	0.45	-0.112	0.022	-0.016	0.06	0.46		0.865	0.41
Effect of the rest = C2s=0.39 or 39 %									

Remarks: DI = Direct influence; LoLL = Length of leaf lobe; PSD = Plant Stem diameter; HoP = height of plant; HoPFB = Height of plant to first branching; NoFR = Number of fresh roots; NoEFR = Number of economic fresh root

The height of plant character was positively significantly correlated with height of plant to first branching, which means that increasing the plant height will increase the height of first branching and fresh root weight per plant, this also reported by Zuraida (2010). Other similar correlation happened on number of fresh root per plant and number of economic fresh root which had positive correlation with fresh root weight per plant. According to Sundari, Noerwijati, & Mejaya (2010) cassava tuber yield was positively correlated with agronomic characters, (ie. plant stem diameter), and yield characters including number of fresh roots, and number of economic fresh roots per plant.

The selection activity on breeding program also needed information about the relative contribution of each agronomy characters or component of the result, either direct or indirect. Correlation analysis method generally only explain relationship between characters observed phenotypically without considering how far the character gives effect on other character. Thus, path analysis method can show direct and indirect effect between agronomy character and the tuber mass of cassava M_1V_3. The value of path coefficient of direct and indirect effect from vegetative and harvest parameter, cassava tuber mass is presented on Table 4.

Path analysis showed the character that had high total effect were number of fresh root (0.53), number of economic fresh root (0.45), height of plant to first branching (0.11) and stem diameter (0.06). The character that gave quite high direct effect was number of fresh roots (0.53), the higher number of fresh roots would affect the increase of fresh root weight per plant of cassava. So, the number of fresh root character, number of economic fresh root, height of plant to first branching and plant stem diameter that effected fresh root weight per plant could be as selection criteria. Besides, indirect effect on tuber weight per plant still needed to be determined.

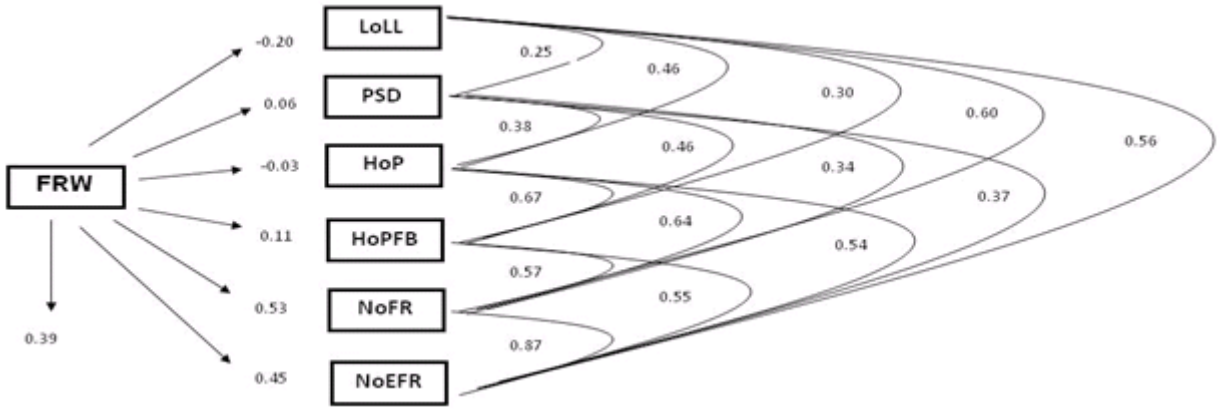

Fig. 1. Path analysis diagram cassava M_1V_3 generation to FRW (fresh root weight per plant), LoLL (Length of leaf lobe), PSD (Plant stem diameter), HoP (Height of plant), HoPFB (Height of plant to first branching), NoFR (Number of fresh roots) and NoEFR (Number of economic fresh root)

Based on Table 4, geometrically data is used to build path diagram (Fig. 1) to explain the causal relationship between independent variable and response variable. Fig. 1 shows that path analysis is able to explain the total variance from response variable of tuber weight per plant, 61 % is explained by 6 variables, and the rest 39 % is affected by other factors.

Based on the correlation analysis and path analysis that has been done in this research, the relationship pattern of nine agronomy characters with tuber weight per plant character were determined. Those relationship patterns became the basic on composting the selection criteria for M_1V_3 generation cassava mutants. The characters could be used to compost the selection criteria which had to have several conditions, (1) strongly correlated to target character, (2) has high heritability, (3) easy to be observed visually (Roy, 2000). The character that positivelycorrelated but had low direct effect on tuber weight per plant could still be considered as character for selection with condition of high heritability. Based on that, stem diameter and the height of plant could be the selection criteria for next generation selection.

CONCLUSION AND SUGGESTION

Cassava genotype characters that had high heritability were length of leaf lobe, length of petiole, plant stem diameter, and the height of plant. Path correlation analysis showed that number of fresh root (tuber) per plant, number of economic fresh root, height of plant to first branchingand plant stem diameter had direct correlation with fresh rootweight per plant. They are recommended to be us as character for the selection of individual mutant cassava in the next generation gamma irradiation (M_1V_4) population.

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