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Evaluation of the fifth selfing generation of Madura Local Maize, Indonesia

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Abstract

The assembly of hybrid maize varieties with high production and early maturity is the right step to increase maize production on Madura Island, Indonesia. Assessment of the fifth generation selfing maize genotype aims to obtain potential parents that can be used in assembling hybrid maize varieties. This study aimed to evaluate the fifth selfing generation of Madura local maize, Indonesia. The study used a randomized complete block design with ten genotypes as treatment and repeated three times, so there were ten experimental units. The ten genotypes were G_1= Tb-1-10-5, G_2 = Tb-2-21-5, G_3 = EL-1-26-5, G_4 = EL-3-2-5, G_5 = DL-2-11-5, G_6 = DK-1-5-5, G_7 = CTK-1-4-5, G_8 = DBR-1-12-5, G_9 = KRA-1-2-5, dan G_{10} = GL-1-6-5. Characters observed in this study were plant height, days of 50% tasseling, days of silking, harvest age, ear length, ear diameter, 100-kernel weight, and production per hectare. The eight characters observed in ten fifth-generation selfing maize had a low coefficient of variance (0.16-6.62%), indicating that the variation within the genotype was small. The genotypic coefficient of variation (GCV) is greater than the phenotypic coefficient of variation (PCV) in all observed characters. The heritability value in the broad sense of all observed characters is 0.81-0.99 (high). Production per hectare has a significant positive correlation with plant height, days to 50% tasseling, days to 50% silking, harvest age, ear length. G_1, G_2, and G_5 were potential genotypes that could be used as parents in the assembly of high-production and early-maturity maize varieties.

Keywords: Maize evaluation; GCV; PCV; Heritability; Correlation between characters

1. Introduction

Maize is one of Indonesia's prospective commodities as the second staple food after rice [1]. Indonesia is the country that has the highest maize production in Southeast Asia with a production of 30.69 million tons per year in 2019 [2]. Madura Island is an area in Indonesia with 360,000 hectares of maize but low production of 2112 kg per hectare [3]. Maize productivity on Madura Island is very low compared to Indonesia's national maize productivity of 5474 kg per hectare [4]. The low productivity of maize on Madura Island is due to the lack of water availability due to low rainfall (1346.89 mm/year) [5] and a short rainy season (3-5 months) [6].

One strategy for overcoming the problem of low maize production on Madura Island is to assemble hybrid maize varieties with high production and early maturity. Early maturing hybrid maize is very suitable to be developed in Madura Island with short rainfall, so early maturing maize planting will increase the frequency of maize planting on Madura Island. Hybrid maize varieties with high production and early maturity are produced from crosses between inbred lines from populations with different heterotic [7,8]. According to [9] that inbred lines resulted from selfing and selecting the desired character for eight to ten generations. Selfing aims to obtain genetic purity in plant populations [10]. Genetic purity will be shown by uniformity of quantitative and qualitative characters of plants.

Selfing causes segregation and decreased vigour in plants [11,12]. A decrease in vigour occurs in each generation of selfing until a homozygous line is formed [13]. Each generation of selfing in maize plants will experience a decrease in vigour by half compared to the previous generation [10]. In addition, selfing in plants will cause inbreeding depression,

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namely a decrease in quantitative characteristics such as plant height and production. Quantitative character assessment in selfing maize plants was carried out to determine the plant's genetic potential and the level of plant uniformity.

Calculating the genotypic and phenotypic coefficient of variation, heritability and correlation between characters on quantitative characters is needed to support the formation of the desired hybrid maize variety [14,15]. Information about the performance of fifth-generation selfing maize is very useful for (1) Knowing the uniformity of maize from the fifth-generation selfing, (2) Knowing the genetic potential of maize of fifth-generation selfing, and (3) Selection of parents to be used to assemble hybrid maize varieties. This study aimed to evaluate the fifth selfing generation of Madura local maize, Indonesia.

2. Material and methods

2.1. Genetic Materials and Experimental Site

The planting material used in this study were ten genotypes from the selfing of the fifth generation of Madura local maize. The ten genotypes were G_1= Tb-1-10-5, G_2 = Tb-2-21-5, G_3 = EL-1-26-5, G_4 = EL-3-2-5, G_5 = DL-2-11-5, G_6 = DK-1-5-5, G_7 = CTK-1-4-5, G_8 = DBR-1-12-5, G_9 = KRA-1-2-5, dan G_{10} = GL-1-6-5. The study was conducted from January to April 2022. The study was conducted at the Experimental Garden of the Agriculture Faculty, University of Trunojoyo Madura, Indonesia. The research location was at a latitude of 7° 07 S, the longitude of 112°44E, and an altitude of 5 m asl, with a mean annual rainfall of 269 mm, a temperature of 28–32°C, Grumosol soil type, and a pH of 6.9.

2.2. Experimental Design, Management, and Data Collected

The research used a randomized complete block design with ten genotypes as treatment and repeated three times, so there were ten experimental units. Each genotype was planted in 2 x 5m plots with a spacing of 70 x 20 cm. Each experimental unit consisted of 100 plants. Maize seeds are planted at a depth of 3-5 cm with one seed per hole. Fertilization is carried out in three stages, i.e.: (1) The first fertilization was given when the plant was 7 DAP using 100 kg urea, 200 kg/ha Urea, and 50 kg/ha KCl, (2) The second fertilization was given when the plants were 25 DAP with 100 kg Urea and 50 kg KCl, and (3) The third fertilization when the plant was 40 DAP using 100 kg of Urea. Characters observed in this study were plant height, days of 50% tasseling, days of silking, harvest age, ear length, ear diameter, 100-kernel weight, and production per hectare.

2.3. Data Analysis

Character observation data were analyzed using the F-test. If there is a significant effect, proceed with the HSD test ($p<0.05$) using STAR software version 2.0.1. Estimates of genetic variance, environmental variance, and phenotypic variance were calculated based on the mean square value of each character [10]. The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated using the formula [16] :

$$GCV = \frac{\sigma_g^2}{\sqrt{\bar{x}}}\ x\ 100$$

$$PCV = \frac{\sigma_p^2}{\sqrt{\bar{x}}}\ x\ 100$$

Where $\bar{x}$ is the mean of the genotype or phenotype and σ^2_g and σ^2_p are the phenotypic and genotypic variance, respectively.

Estimation of heritability value in a broad sense (h^2_{bs}) is carried out using the formula [17] :

$$h_{bs}^2 = \frac{\sigma_g^2}{\sigma_p^2}$$

Pearson correlation coefficient analysis based on the formula [18] :

$$r = \frac{n\sum XY - (\sum X)(\sum Y)}{\sqrt{(n\sum x^2 - (\sum x)^2)\left(n\sum y^2 - (\sum y)^2\right)}}$$

Where n is the number of data pairs x and y, ∑x is the total number of variables x, ∑y ∑x is the total number of variables y, $\sum x^2$ is the square of the total number of variables x, $\sum y^2$ is the square of the total number of variables y, and ∑xy is the total multiplication of variable x and variabley.

3. Results and discussion

The results of the analysis of variance of ten fifth-generation Madura maize selfing on eight quantitative characters were observed to be significantly different at the 1% level (Table 1). This study's coefficient of variance (CV) is between 0.16% - 6.62% or is in a low category [19]. The low value of the coefficient of variance indicates the variation in the genotype is small, so it can be assumed that the fifth generation of selfing Madura maize already has high uniformity.

Table 1 Analysis of variance of the eight observed characters

Character	F value	CV (%)
Plant height	373.13**	1.17
Days to 50% tasseling	110.14**	1.52
Days to 50% silking	111.51**	1.44
Harvest age	857.85**	0.54
Ear length	328.05**	0.93
Ear diameter	40.08**	0.16
100-kernel weight	18.15**	6.62
Production per hectare	321.92**	2.52

Note: ** = significant at 5%; CV = Coefficient of variance

3.1. Plant height, Days to 50% tasseling, Days to 50% silking, and Harvest age

Table 2 Characteristics of plant height, days to 50% tasseling, days to 50% silking, and harvest age of ten maize genotypes

Genotype	Plant height (cm)	Days to 50% tasseling (days)	Days to 50% silking (days)	Harvest age (days)
G_1 = Tb-1-10-5	150.43 a	38.68 a	41.00 a	75.36 b
G_2 = Tb-2-21-5	148.64 ab	39.00 a	41.00 a	76.00 ab
G_3 = EL-1-26-5	150.67 a	33.34 de	35.33 de	65.68 e
G_4 = EL-3-2-5	149.38 a	34.00 d	36.36 d	66.68 e
G_5 = DL-2-11-5	147.43 abc	37.60 ab	39.65 ab	73.00 c
G_6 = DK-1-5-5	144.38 bc	36.00 c	38.00 c	71.00 d
G_7 = CTK-1-4-5	112.38 d	32.00 e	34.00 e	64.00 f
G_8 = DBR-1-12-5	143.33 c	38.67 a	40.68 a	77.00 a
G_9 = KRA-1-2-5	98.68 e	29.35 f	31.35 f	57.00 3
G_{10} = GL-1-6-5	144.37 bc	37.00 bc	39.00 bc	73.68 c

Note: The numbers followed by the same letter in the same column are not significantly different according to the 5% HSD test

Observation of plant height was carried out when the plant entered the generative phase which was marked by the appearance of the tassel on maize plants. Plant height can be used as an indicator of plant uniformity. The plant height of ten fifth-generation selfing maize ranged from 98.67 to 150.67 cm (Table 2). G_9 is the genotype with the shortest maize plant height among the other maize tested, while G_3 has the highest plant height compared to other maize plants tested.

Days to 50% tasseling, days to 50% silking, and harvest age are indicators to determine the age category of maize plants. G_9 has the lowest character values of days to 50% tasseling, days to 50% silking, and harvest age compared to other maize, which are 29.35 days, 31.35 days, and 57.00 days, respectively. G_2 has the highest values of days to 50% tasseling, days to 50% silking, and harvest age compared to other maize, which are 39.00 days, 41.00 days, and 76.00 days, respectively. According to [20], the harvest age of the fifth generation Madura selfing local maize is in the early maturity category because it has an age of under 95 days.

3.2. Ear length, ear diameter, 100-kernel weight, and production per hectare

The ear length on ten fifth-generation selfing maize plants ranged from 7.87-11.03 cm (Table 3). G9 had the shortest ear (7.87 cm) compared to other maize plants, while G_1 had the longest ear (11.03 cm) compared to other maize plants. Characters of ear diameter on ten fifth-generation selfing maize plants ranged from 2.90 to 3.60 cm. G6 has the smallest ear diameter (2.90 cm) compared to other maize plants while G_2 has the largest cob diameter (3.60 cm) compared to other maize plants.

100-kernel weight on ten fifth-generation selfing maize plants tested ranged from 14.33 to 24,933 g. G6 had the smallest 100-kernel weight (14.33 g) compared to other maize plants, while G_5 had the largest 100-kernel weight (24.93 g) compared to other maize plants. The character of production per hectare is important in this study because this character has economic value and is a goal character in the assembly of high-production maize varieties. The character of production per hectare on ten fifth-generation selfing maize plants ranged from 1405.04 to 2396.43 kg. G_7 had the lowest production per hectare (1405.04 kg) compared to other maize crops tested while G_5 had the highest production per hectare (2396.43 kg) compared to other maize crops tested. This study aims to obtain high-production and early-maturity genotypes to be used as parents in the assembly of high-production and early-maturity maize varieties. The results showed that G_1, G_2, and G_5 were potential genotypes that could be used as parents in the assembly of high-production and early-maturity maize varieties.

Table 3 Characteristics of ear length, ear diameter, 100-kernel weight, and production per hectare of ten maize genotypes

Genotype	Ear length (cm)	Ear diameter (cm)	100-kernel weight (g)	Production per hectare (kg)
G_1 = Tb-1-10-5	11.03 a	3.57 a	19.13 b	2353.05 a
G_2 = Tb-2-21-5	10.90 a	3.60 a	18.87 b	2353.34 a
G_3 = EL-1-26-5	10.40 bc	3.17 cd	20.53 b	1994.35 b
G_4 = EL-3-2-5	10.27 c	3.13 d	20.23 b	1950.10 b
G_5 = DL-2-11-5	10.87 a	3.47 ab	24.93 a	2396.43 a
G_6 = DK-1-5-5	8.93 d	2.90 e	14.23 c	1219.50 d
G_7 = CTK-1-4-5	10.27 c	3.53 a	21.17 b	1405.04 c
G_8 = DBR-1-12-5	10.43 bc	3.43 ab	14.33 c	1951.10 b
G_9 = KRA-1-2-5	7.87 e	3.17 cd	19.40 b	1027.66 e
G_{10} = GL-1-6-5	10.57 b	3.33 bc	19.20 b	1958.35 b

Note: The numbers followed by the same letter in the same column are not significantly different according to the 5% HSD test

3.3. Genetic Parameter

The genotypic coefficient of variation (GCV) is greater than the phenotypic coefficient of variation (PCV) in all observed characters (Table 4). GCV value greater than PCV indicates that selection can be made based on the appearance of these characters [21]. According to [22], the PCV value which is almost the same as GCV shows that environmental factors have very little effect on the appearance of plant characters [23,24]. Characters with almost the same PCV and GCV values are plant height, days to 50% tasseling, days to 50% silking, ear length, ear diameter, production per hectare.

The heritability of a character is the proportion of the amount of genetic variation to the total amount of genetic variation plus environmental variance [25]. Heritability describes whether a character is influenced by genetic or environmental factors (non-genetic) [26]. Heritability values in the broad sense of fifth-generation selfing maize for all evaluated characters ranged from 0.81-0.99. Based on the heritability criteria, all the fifth-generation selfing maize characters tested had high criteria. Characters with high heritability estimates indicate that genetic factors play a more important role in determining plant characters than environmental factors [27,28]. The selection of characters with high heritability values has a high chance of genetic advance because genetic factors control the observed characters so they will be passed on to their offspring [29,30], and selection of these characters can be done in the early generations [31].

Table 4 Values of environmental variance, genetic variance, phenotypic variance, heritability, GCV, and PCV of ten maize genotypes

Character	σ^2e	σ^2g	σ^2p	GCV	PCV	h^2_{bs}
Plant height	2.63	326.65	329.28	2770.57	2792.88	0.99
Days to 50% tasseling	0.29	10.54	10.87	176.85	182.38	0.97
Days to 50% silking	0.29	10.78	11.07	175.86	180.59	0.97
Harvest age	0.14	41.26	41.40	493.51	495.22	0.99
Ear length	0.01	0.99	0.99	31.03	31.03	0.99
Ear diameter	0.01	0.05	0.06	2.75	3.30	0.93
100-kernel weight	1.62	8.73	10.84	199.31	247.49	0.81
Production per hectare	2204.33	235804.61	238008.94	559574.30	564805.27	0.99

Note: σ^2e: environmental variance, σ^2g: genetic variance, σ^2p: phenotypic variance, GCV: genotypic coefficient of variation, PCV: phenotypic coefficient of variation, h^2_{bs}: heritability in the broad sense. Heritability criteria: high ($h^2_{bs} \geq 0,5$), moderate ($0,2<h^2_{bs}<0.5$), low ($h^2_{bs}\leq 0.2$)

3.4. Correlation between characters

Production per hectare is an important character of maize that has economic value. Plant breeding methods often use indirect selection methods to improve the character of production per hectare for time, effort, and cost efficiency in assembling plant varieties. Assessment of correlation coefficients on several plant characters on production per hectare is very useful for indirectly improving the character of production per hectare [32]. Production per hectare is significantly positive with plant height, days to tasseling, days to silking, harvest age, ear length (Table 5). The character production per hectare and harvest age are the main characters because the breeding program in this study is directed at assembling high-production and early-maturity varieties. The results of the study show that the two characters have a very significant positive correlation. This study's results align with the research [33,34], where there is a significant positive correlation between production per hectare and harvest age. A significantly positive correlation between characters indicates that an increase in one character will be followed by an increase in the value of another character.

Table 5 The linear correlation coefficient between characters in the maize lines tested

	PH	DT	DS	HA	EL	ED	100KW	PPH
PH	1.00							
DT	0.77**	1.00						
DS	0.77**	0.99**	1.00					
HA	0.76**	0.98**	0.98**	1.00				
EL	0.69**	0.70**	0.70**	0.71	1.00			
ED	0.04	0.43*	0.43*	0.43*	0.67**	1.00		
100KW	-0.06	-0.19	-0.19	-0.25	0.29	0.36	1.00	
PPH	0.76**	0.74**	0.75**	0.71**	0.90	0.58**	0.32	1.00

Note: PH: plant height, DT: days to 50% tasseling, DS: Days to 50% silking, HA: harvest age, EL: ear length, ED: ear diameter, 100KW: 100-kernel weight, PPH: production per hectare. *,**significant at 5% and 1% level of probability, respectively

4. Conclusion

The eight characters observed in ten fifth-generation selfing maize had a low coefficient of variance (0.16-6.62%), indicating that the variation within the genotype was small or the degree of uniformity within the genotype was high. The genotypic coefficient of variation (GCV) is greater than the phenotypic coefficient of variation (PCV) in all observed characters. The heritability value in the broad sense of all observed characters is 0.81-0.99 (high). Production per hectare has a significant positive correlation with plant height, days to 50% tasseling, days to 50% silking, harvest age, ear length. G_1, G_2, and G_5 were potential genotypes that could be used as parents in the assembly of high-production and early-maturity maize varieties.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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