Qualitative Characteristics and Genetic Parameters of F3 Purple Corn Lines from Open Pollination Hybridization

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ABSTRACT

Purple corn is a cereal plant that has health benefits. Purple corn contains anthocyanins, which are useful as anticancer and antioxidants, and has high nutritional value. Improving the quality of corn production can be done through plant breeding. This study aimed to determine the value of variability, heritability and expected genetic advance of F_3 purple corn from open-pollinated hybridization. The research was conducted from December 2020 to April 2021 at Universitas Bangka Belitung. The study used a single plant design experimental method. The selection used was ear to row. The results showed that the color of the seeds of the F3 line was dominated by orange. The lines have different quantitative characters. The lines that have the most purple color were F3-PXU-11-25, F3-PXU-6-16, and F3-PXU-11-20. The value of phenotypic variability and genotypic variability of the broad criteria was found in the weight of corn cob with husk and without husk. The broad heritability was high on the weight corn cob with and without husk. The value of the expected genetic advance progress of the high criteria was on the characters of cob length, the weight of 100 seeds, the weight of corn cob with husk, and the weight of corn cob without husk.

Keywords: Expected genetic advance; Heritability; Purple corn; Qualitative; Variability

ABSTRAK

Jagung ungu merupakan tanaman yang memiliki manfaat bagi kesehatan. Jagung ungu memiliki kandungan antosianin yang bermanfaat sebagai anti kanker, antioksidan dan memiliki nilai gizi yang tinggi. Peningkatan kualitas produksi jagung dapat dilakukan melalui pemuliaan tanaman. Tujuan penelitian adalah mengetahui nilai variabilitas, heritabilitas dan keragaman genetik harapan jagung ungu pada generasi F_3 hasil persilangan bersari bebas. Penelitian dilaksanakan pada bulan Desember 2020 sampai dengan April 2021 di Universitas Bangka Belitung. Penelitian menggunakan metode eksperimen rancangan tanpa ulangan. Seleksi yang digunakan yaitu tongkol kebaris. Hasil penelitian didapatkan warna biji galur F3 didominasi warna orange. Galur memiliki perbedaan karakter kuantitatif. Galur yang memiliki warna ungu terbanyak yaitu F_3-PXU11-25, F_3-PXU6-16, F_3-PXU11-20. Nilai variabilitas fenotip dan variabilitas genotip kriteria luas terdapat pada karakter bobot tongkol dengan kelobot dan tanpa kelobot. Nilai heritabilitas arti luas kriteria tinggi pada karakter bobot tongkol dengan kelobotdan bobot tongkol tanpa kelobot. Nilai kemajuan genetik harapan kriteria tinggi pada karakter panjang tongkol, bobot 100 biji, bobot tongkol dengan kelobot, dan tanpa kelobot.

Kata Kunci: *Kemajuan Genetik Harapan; Heritabilitas; Jagung Ungu; Kualitatif; Variabilitas*

INTRODUCTION

Corn plants have a relatively high genetic diversity in seeds. The color of the corn kernels is genetically controlled. The color of the corn kernels consists of purple, red, yellow, and white (Pamandungan & Ogie, 2018). Purple corn contains anthocyanins, which function as antioxidant compounds beneficial to prevent cancer, diabetes, and coronary heart disease (Tumei et al., 2018). Therefore, it is necessary to assemble purple corn, which has a high anthocyanin content.

Plant breeding aims to increase the expression of plant genetic potential (Azrai, 2016). Plant breeding can be done by crossbreeding plants to obtain the desired characteristics (Sain, 2016). Previous researchers have carried out corn plant breeding. Selected purple corn has no resistance to corn stem borer (*Ostrianiafurnacalis* G.) (Oktaviani, 2017). Improvement of resistance characters was carried out by crossing 'Marassempulu' purple corn with 'Magetan' white corn and 'Sungailiat' yellow corn

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(Yahya, 2018). F1 selection results obtained 14 lines (Safitri, 2019), and F2 selection obtained 9 corn lines (Abadi et al., 2021).

The lines produced from free-pollinated crosses had high diversity. Genetic variance and diversity of F2 corn plant populations were found (Sudika et al., 2022).The estimates of genetic effects traits were specific in eachgenotypes (Nabila et al., 2022). According to Juita et al. (2022), the F2 and F3 lines from free pollination crosses had better characters than their parents, in which 88.11% of the lines had purple seed color.

Selection is made to get superior lines. Ear-to-row selection is used to select segregated plant populations. Segregated plants have more dominant diversity between families (Hallauer et al., 1988). The selection success is determined by genetic diversity, heritability, and correlation between traits (Priyanto et al., 2017). High heritability values are important in increasing the effectiveness of selection (Lasmono et al., 2018). High genetic progress results from character improvement through selection (Wulandari et al., 2016). The lines have different quantitative characters indicate the presence of genetic diversity.

It is expected that the results of this study will produce F4 lines of purple corn that have wide variability, high hertability, and high genetic progress. The F4 lines with high anthocyanin content will continue in the next generation selection. The aim of the study was to determine the diversity of qualitative characters, the variability value, the heritability value and the genetic progress of the F3 purple corn lines as a result of open pollination.

MATERIALS AND METHOD

The research was conducted from December 2020 to April 2021. The research location was in the Research and Experimental Garden (KP2) of the Faculty of Agriculture, Fisheries and Biology, Universitas Bangka Belitung.

The research was arranged in an experimental method with a single plant design. The selection method used was ear to row. There were 9 purple cord lines used, namely F2-PxU-11-14, F2-PxU-11-20, F2-PxU-11-21, F2-PxU-11-2, F2-PxU-6-15, F2-PxU-6-16, F2-PxU-11-13, F2-PxU-11-11, and F2-PxU-11-25. The control varieties were hybrid parents (purple corn Marassempulu from South Sulawesi and white Magetan corn from East Java). This research applied distance and time isolation. The study was conducted in 4 locations with a distance of 20 m. A total of 11 maps were made. The difference in planting time was 2 weeks. Each plot was planted with 30 plants.

The stages of the research included land preparation, making plots, selecting seeds, soaking the seeds, planting, watering, fertilizing, controlling pests, and harvesting. The research map was made with a size of 3.4 x 1.5 m. Plant spacing was 75 cm x 20 cm; each planting hole was given 1 seed with a 2-3 cm planting depth. Fertilization was performed when the plants were 14 and 30 days after planting, with the NPK fertilizer dose of 450 kg/ha. Harvesting was done when the corn cob looked dry, or the color of the corn husks was brown.

The observed characters included qualitative and quantitative characters. Qualitative characters consist of leaf shape, leaf color, panicle shape, top seed surface shape, seed row shape and seed color distribution. Quantitative characters consist of plant height, age of flowering plants, weight of 100 seeds, stem diameter, weight of corncob with husks, harvest age, number of leaves per plant, corncob length, weight of corncob without husk, and number of seed rows.

Qualitative data was written descriptively. Quantitative data were used to calculate the value of variability, heritability and expected genetic progress. The value of genetic variance, environmental variance and phenotype variance are three important components in finding variability values. According to Suharsono et al. (2006), this value is obtained using the formula:

Genotype variance (σ^2_g) = $\sigma^2_{f-}\sigma^2_e$ (1)

Phenotype variance (σ^2_f) = $\frac{\sum_i^N=1\,(xi-\mu)^2}{n}$ (2)

Environment variance (σ^2_e) = $\frac{\sigma 2p1+\sigma 2p2+\cdots....+\sigma 2pn}{n}$ (3)

Formula description:
σ^2_{P1} = Variance of the female parent
σ^2_{P2} = Variance of the male parent
σ^2_g = Genotype Variance

Determining the phenotypic coefficient of diversity (PCD) and genetic coefficient of diversity (GCD):

%PCD = $\frac{\sqrt{\sigma_f^2}}{\mu}\,x\,100$ (4)

%GCD = $\frac{\sqrt{\sigma_g^2}}{\mu}\,x\,100$ (5)

Formula description:
σ^2_f = Phenotype variance
σ^2_e = Environment variance
μ = mean
n = population

According to Moedjiono and Mejaya (1994), the criteria for the PCD and GCD are divided into four criteria in percentage form, namely:
0-25% : Narrow
25-50%: Rather narrow
50-70%: Rather wide
75-100%: wide

according to Syukur et al. (2012), estimated value of broad sense heritability h^2(BS) is based on analysis of variance.

h^2(BS) = $\frac{\sigma^2 F3-\sqrt{(\sigma^2 P1)(\sigma 2P2)}}{\sigma^2 F3}\,X\,100\%$ (6)

Formula description:
h^2 (BS): Broad sense heritability
σ^2_{F3} = Variance F_3
σ^2_{P1} = Variance of the female parent
σ^2_{P2} = Variance of the male parent

The criteria for heritability values are as follows:
Low = h^2 (BS) <20%
Moderate = 20%≤h^2 (BS) ≥50%
High = h^2 (BS) >50%

Expected Genetic Advance value (EGA) can be calculated using the formula:
EGA = i.h^2 (BS).σp (7)

%EGA = $\frac{EGA}{\mu}\times 100\%$ (8)

Formula description:
EGA = Expected Genetic Advance
i = Selection intensity (10% = 1,76)
h^2(BS)= Heritability
σp = Phenotypic standard deviation
μ = Mean

The expected genetic advance criteria are as follows:
0 < KGH ≤ 3.3% = Low
3,3% < KGH ≤ 6,6% = Rather low
6,6% < KGH ≤ 10% = High enough
KGH > 10% = High

RESULTS AND DISCUSSION

The F3 generation of the purple corn lines resulted from crossing purple and white corn, with 330 plants studied. Selection was made to get the selected F4 lines. The qualitative characters observed in the F3 line of corn plants consisted of

Table 1. Qualitative characters of the F3 generation of corn lines and parents

Lines	Qualitative Characters				
	Leaf Shape	Leaf Color	Panicle shape	Top Seed Surface Shape	Seed RowShape
F3-PxU11-14	100% Spiky	100% *Moderate Olive Green*	5.6%Very Small 27.8%Small 55.5%Medium 11.1%Large	27.8%Wrinkled 38.8%Serrated 16.7%Flat 16.7%Round	22.3%Regular 33.3% Irregular 44.4%Straight
F3-PxU11-20	100% Spiky	100% *Moderate Olive Green*	3.7%Very Small 29.7%Small 33.3%Medium 33.3%Large	3.7%Wrinkled 51.8%Serrated 37.1%Flat 3.7%Round 3.8%Tapered	37.1%Regular 33.3% Irregular 25.9%Straight 3.7%Curved
F3-PxU11-21	100% Spiky	10% *Moderate Olive Green* 90% *Greyish Olive Green*	6.7%Very Small 26.7% Small 46.7% Medium 16.7% Large 3.3% Very Large	40%Serrated 40% Flat 20% Round	40%Regular 30% Irregular 30% Straight
F3-PxU11-2	88.9% Spiky 11.1% Pointed Slightly rounded	94.4% *Moderate Olive Green* 5.6% *Strong Yellow Green*	5.5% Very Small 61.1% Small 16.7% Medium 16.7% Large	11.1% Wrinkled 61.2% Serrated 11.1% Flat 16.6% Round	27.8% Regular 50% Irregular 22.2% Straight
F3-PxU6-15	100% Spiky	89.5% *Moderate Olive Green* 10.5% *Strong Yellow Green*	5.3% Very Small 10.5% Small 52.6% Medium 31.6% Large	5.3% Wrinkled 42.1% Serrated 10.5% Flat 36.8% Round 5.3% Tapered	15.8% Regular 57.9% Irregular 21.1% Straight 5.2% Curved
F3-PxU6-16	90% Spiky 10% Pointed and Slightly rounded	70% *Moderate Olive Green* 30% *Greyish Olive Green*	45% Small 30% Medium 25% Large	10% Wrinkled 25% Serrated 30% Flat 30%Round 5%Tapered	50% Regular 50% Irregular
F3-PXU11-13	100% Spiky	96.4% *Moderate Olive Green* 3.6% *Strong Yellow Green*	3.6% Very Small 28.7% Small 32.1% Medium 35.6% Large	7.1% Wrinkled 85.7% Serrated 3.6% Flat 3.6% Round	35.7% Regular 10.7% Irregular 46.4% Straight 7.2% Curved
F3-PxU11-11	100% Spiky	91.3% *Moderate Olive Green* 8.7% *Strong Yellow Green*	4.3% Very Small 26.1% Small 56.5% Medium 13.1% Large	30.4% Serrated 39.2% Flat 30.4% Round	26.1% Regular 43.5% Irregular 30.4% Straight
F3-PxU11-25	69.2% Spiky 30.8%Pointed and Slightly rounded	46.2% *Moderate Olive Green* 53.8% *Greyish Olive Green*	26.9% Small 50% Medium 23.1% Large	61.6% Serrated 34.6% Flat 3.8% Round	53.9% Regular 11.5% Irregular 34.6% Straight
Parent 'Marassempulu'	44.8% Spiky 55.2%Pointed Slightly rounded	82.8% *Moderate Olive Green* 17.2%*Strong Yellow Green*	3.4%Very Small 31.1%Small 37.9%Medium 27.6%Large	13.7%Serrated 55.2%Flat 31.1%Round	37.8% Regular 31.1% Irregular 31.1% Straight
Parent 'Magetan'	58.6% Spiky 41.4% Pointed and Slightly rounded	89.7% *Moderate Olive Green* 10.3% *Greyish Olive Green*	6.9%Very Small 31.1%Small 58.6%Medium 3.4% VeryLarge	41.4%Serrated 48.3%Flat 10.3%Round	34.5%Regular 34.5% Irregular 31% Straight

Table 2. Qualitative characters of seed color distribution in the F3 generation of corn plant lines and parent

Color Seed	Lines									Parents	
	F3-PxU11-14	F3-PxU11-20	F3-PxU11-21	F3-PxU11-2	F3-PxU6-15	F3-PxU11-16	F3-PxU11-13	F3-PxU11-11	F3-PxU11-25	'Marassempulu'	'Magetan'
Purple	5	8	0	4	4	11	7	2	14	29	0
Yellow	5	5	10	1	7	7	7	5	1	0	0
Orange	2	13	20	11	8	2	11	14	10	0	0
Red	6	1	0	2	0	0	3	2	1	0	0
White	0	0	0	0	0	0	0	0	0	0	29

Table 3. Variance Value of Phenotypes, Genotypes and Environment

Characters	Variance Value of Phenotypic	Genotypes	Environment
Plant Height	966.19	226.22	739.98
Stem Diameter	9.63	1.95	7.68
Number of Leaves per Plant	1.50	0.19	1.30
Age of Male Flowering Plants	9.65	1.95	7.70
Age of Female Flowering Plants	10.13	1.51	8.62
Harvest Age	25.57	3.24	22.32
Corncob Length	8.56	3.34	5.22
Weight of Corncob with Husk	3060.61	2282.64	777.97
Weight of Corncob without Husk	2370.67	1747.20	623.47
Weight of 100 Seeds	82.28	27.44	54.83
Number of Seed Rows	3.72	1.05	2.67

6 characters: leaf shape, leaf color, panicle shape, top seed surface shape, seed row shape and seed color distribution (Table 2). Qualitative characters are identified based on CPVO (2020).

Leaf tip shape characters are grouped into five criteria. The shape of the leaves is divided into two criteria, namely sharp and slightly rounded, and the ratio is 197:12. Leaf shape with pointed, slightly rounded criteria has more dominant results. The shape of the pointed leaves is based on the parent of white corn. Leaf color characters consist of three groups, namely moderate olive green (56), greyish olive green (47), and strong yellow-green (6). The panicle shape characters consist of five criteria, namely very small (8), small (64), medium (87), large (49), and very large (1). The characters of the seed surface shape consist of five criteria, namely wrinkled (13), serrated (104), flat (54), round (35), and tapered (3). The seed row shape characters consist of four criteria, namely regular (74), irregular (70), straight (61), and curved (4) (Table 1).

Serrated criteria dominate the shape of the top seed surface, thought to be inherited from the white parents. The shape of the seed row shape is influenced by the various characteristics of the two parents. Differences in plant characteristics are due to the maternal effect. According to Pamandungan & Ogie (2018), the maternal effect occurs when the female parent's nuclear genotype determines the offspring's phenotype.

The F3 generation of purple corn lines has various seed color distributions. The seed color obtained was grouped into purple, orange, yellow, and red. The orange color showed the highest ratio

Table 4. Phenotypic variability values, genotypic variability values, heritability values, and expected genetic advance values

Karakter	Phenotypic Variability (%)	Criteria	Genotypic Variability (%)	Criteria	Heritability Broad Sense	Criteria	Expected Genetic Advance	Criteria
Plant Height	17.45	Rather narrow	8.44	Narrow	23.41	Medium	7.19	High enough
Stem Diameter	21.39	Rather narrow	9.61	Narrow	20.20	Medium	7.60	High enough
Number of Leaves Per Plant	10.47	Narrow	3.79	Narrow	13.15	Low	2.42	Slightly Low
Age of Male Flowering Plants	6.98	Narrow	3.14	Narrow	20.24	Medium	2.49	Slightly Low
Age of Female Flowering Plants	6.61	Narrow	2.55	Narrow	14.10	Low	1.76	Low
Harvest Age	6.16	Narrow	2.21	Narrow	12.69	Low	1.38	Low
Corncob Length	21.93	Rather narrow	13.70	Rather narrow	39.04	Medium	15.07	High
Corncob Weight with Husk	48.01	Broad	41.46	Wide	74.58	High	63.02	High
Corncob Weight without Husk	49.45	Broad	42.45	Wide	73.70	High	64.14	High
Weight of 100 Seeds	36.16	Broad Enough	20.88	Rather narrow	33.35	Medium	21.22	High
Number of Seed Rows	16.47	Rather narrow	8.76	Narrow	28.32	Medium	8.21	High enough

Remarks: 1. Phenotypic variability criteria: 0-12.4 (Narrow), 12.4-24.7 (Rather narrow), 24.7-37.1(Broad Enough), 37.1-49.5(Broad). Genotypic variability criteria: 0-10.6 (Narrow), 10.6-21.2 (Rather narrow), 21.2-31.8 (Broad Enough), 31.8-42.4(Broad).
2. Criteria for heritability value: $h^2(BS)<20\%$ (Low), $20\% \leq h^2(BS) \geq 50\%$ (Medium), $h^2(BS)>50\%$(High).
3. Criteria for Expected Genetic Advance (EGA): $0 < EGA \leq 3.3\%$ (Low), $3.3\% < EGA \leq 6.6\%$ (Slightly Low), $6.6\% < EGA \leq 10\%$ (High enough) and $EGA > 10\%$ (high).

compared to the other colors. Complete variations with ratios can be seen in Table 4. The lines with the most purple color were F3-PXU11-25, F3-PXU6-16, and F3-PXU11-20. The purple color came from one of the elders. The color that appears indicates the influence of the xenia effect. According to Ishartati et al. (2020), the xenia effect shows that the pollen of the male parent has a direct and specific impact on the character of the seeds. The emergence of colors such as yellow and orange in corn is thought to be due to open pollination in the previous generation. The pollination results often get the same color in one corncob even though the cross parents differ. According to Hariyanti et al. (2014), seed color is caused by dominance by dominant color control genes. The presence of one dominant gene can express color and dominance.

Phenotypic variability values were obtained from narrow to broad criteria. The narrow criteria were found in the number of leaves per plant, the age of male flowering plants, the age of female flowering plants, and the age of harvest. The relatively narrow criteria were found in the character of plant height, stem diameter, corncob length, and the number of seed rows. The broad enough criteria were found in the character of the weight of 100 seeds, while the broad criteria were found in the character of the weight of corncob with and without husks (Table 4).

According to Moedjiono & Mejaya (1994), the variability value is divided into 4 criteria, namely 0-25% (narrow), 25-50% (rather narrow), 50-70% (broad enough), and 75-100% (broad). The phenotypic and genotype variability value was adjusted by setting 49.45% of the largest value as 100% diversity. Therefore, the criteria for phenotypic variability are 0-12.4 (narrow), 12.4-24.7 (rather narrow), 24.7-37.1 (broad enough), and 37.1-49.5 (broad). Therefore, the criteria for genotypic variability are 0-10.6 (narrow), 10.6-21.2 (rather narrow), 21.2-31.8

(broad enough), and 31.8-42.4 (broad).

Narrow variability values indicate lines that have very little or almost uniform diversity. The broad phenotypic variability value was found in the characters of the weight of corncob with and without husks. According to Napitupulu & Damanhuri (2018), the low phenotypic variability value indicates that individuals in the population tested tend to be uniform. High phenotypic variability values indicate a high level of diversity. According to Amoros et al. (2020), a high phenotypic variability value indicates a large environmental influence on this character.

The values of the variety of genotypes and the environment influence the variety of phenotypes. Genetic variety has a negative correlation with environmental variation (Table 3). If plants have a broad genetic variability value, the environmental variability value is narrow/low. Narrow genetic variability values were found in the characters of plant height, stem diameter, number of leaves per plant, age of male flowering, age of harvest, and the number of seed rows. The value of broad genotypic variability was found in the characters of the weight of corncob with and without husks (Table 4). Broad variability values can increase the chances of obtaining plants with good properties (Joshi et al., 2018). Variability with broad criteria can increase the selection response (Effendy et al., 2018).

The low criteria of heritability values were obtained in the characters of the number of leaves per plant, the age of female flowering, and the age of harvest. Medium criteria were obtained in plant height, stem diameter, age of male flowering plants, corncob length, the weight of 100 seeds, and number of seed rows. The high criteria were obtained in the characters of the weight of the corn cob with and without husks (Table 4). Characters with high heritability values indicate that they are more influenced by genetic factors. High heritability values can be passed on to the next generation (Wulandari et al., 2016). According to Sari & Sugiharto (2018), a high heritability value will make the selection more effective. Selection is more effective because the influence of the environment is very small, so genetic factors are more dominant in the appearance of plant phenotypes.

The low criteria of the expected genetic advance values were found in the characters of the age of female flowering plants and the age of harvest. The rather low criteria were obtained in the number of leaves per plant and the age of the male flowering plants. The high enough criteria were found in the characters of plant height, stem diameter, and the number of seed rows. Meanwhile, the high was obtained in the characters of long length, the weight of the corncob with and without husks, and the weight of 100 seeds (Table 4).

Expected genetic advance value is an indicator of success in plant selection. High expected genetic advance values are directly proportional to heritability values for several plant characters. According to Ibrahim et al. (2018), a good selection of genotypes can use characters with high heritability values and genetic advance values. According to Kristamtini et al. (2016), a high value of genetic advance in a character indicates that genetic factors support the character. The value of genetic advance can be a guideline for selection in the next generation.

Variability, heritability, and expected genetic advance values guide plant breeders in selecting. Genetics influences inheritance and gene expression tends to be affected by the environment. The values of heritability and genetic advance are very useful for estimating how many stages of selection must be carried out. According to Miftahorrachman (2010), characters that have low variability values indicate genetic homogeneity. Improving character through plant breeding tends to be difficult. According to Hadiati et al. (2003), broad genetic variability will provide a higher chance of selection.

Characters with broad genetic variability and phenotypic variability will increase the value of genetic advance. Plant breeders have a high chance of obtaining the desired genotype (Sari & Susilo, 2013). According to Muin(2021), a high heritability value indicates that genetic factors have a large influence. Selection of corn plants can be stopped if they have high expected genetic advance values, broad heritability values, and narrow variability. The selected purple corn lines are expected to have characteristics that correlate well with production so that high-yielding purple corn can be obtained. Selection needs to be continued because the plants show broad criteria of variability values on characters that are correlated with production.

CONCLUSION

The results showed that the seeds of the F3 lines were dominated by orange color. The lines have different characters of leaf shape, leaf color, panicle shape, top seed surface shape, seed row shape and seed color distribution. The lines that had the most purple color were F3-PXU-11-25, F3-PXU-6-16, and F3-PXU-11-20. The weight of corncob with and without husk showed broad criteria of variability value and high criteria of broad sense heritability value. The high expected genetic advance value was found in the characters of corncob length, weight of corncob with and without husk, and weight of 100 seeds.

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