Open Access Research Journal of
Life Sciences
Journals home page: https://oarjpublication/journals/oarjls/
ISSN: 2783-025X (Online)

OARJ OPEN ACCESS RESEARCH JOURNALS

(RESEARCH ARTICLE)

Check for updates

Increased productivity of maize (*Zea mays* L.) through ear-to-row selection

Ach. Supyanto, Suhartono and Achmad Amzeri *

Agroecotechnology Program, Faculty of Agriculture, University of Trunojoyo Madura, Indonesia.

Open Access Research Journal of Life Sciences, 2023, 06(01), 027–033

Publication history: Received on 28 May 2023; revised on 07 July 2023; accepted on 10 July 2023

Article DOI: https://doi.org/10.53022/oarjls.2023.6.1.0049

Abstract

Assembling superior maize varieties is one of the strategies to increase maize productivity on suboptimal land on Madura Island, Indonesia. One method of assembling high-yielding maize varieties is ear-to-row selection. The research aimed to determine the genetic advances due to ear-to-row selection on the Tambin, Sukmaraga, and Srikandi Kuning varieties. The research was carried out in two stages of activity. Stage 1, carrying out ear-to-row selection for one cycle from the C0 population to form a C1 population. Ear-to-row selection was done on three varieties: the Tambin, Sukmaraga, and Srikandi Kuning. Stage II, carried out an evaluation of the C0 and C1 populations on the three varieties so that six populations were produced. Population evaluation used a completely randomized block design with three replications, resulting in 18 experimental units. Observational variables include ear length, ear diameter, seeds number per row, weight of 100 seeds, seed weight per ear, and production per hectare. The results showed that ear-to-row selection on maize varieties Tambin, Sukmaraga, and Srikandi Kuning showed significantly different selection progress based on the t-test at 5% on maize production per hectare. Heritability values in a broad sense for all characters observed in the moderate to high categories of the three varieties (Tambin, Sukmaraga, and Srikandi Kuning).

Keywords: Ear-to-row selection; C0 population; C1 Population; Heritability; Maize plant

1 Introduction

Maize is one of the main food commodities after rice, which is important in Indonesia's agricultural and economic development [1]. The demand for maize in Indonesia continues to increase along with using maize not only as food but also as an ingredient in animal feed and raw materials in industry [2]. For this reason, Indonesia continues to increase maize production every year. The average production of maize in Indonesia in 2017-2021 was 24,704,990 tons, and Indonesia is the largest country in Southeast Asia [3]. Maize production in Indonesia can be continuously increased if Indonesia can utilize sub-optimal land, which covers approximately 80% of the maize planting area [4]. Madura Island is an island that has a maize planting area of approximately 360,000 hectares but low productivity [5]. One of the strategies to increase maize productivity on Madura Island is to assemble superior maize varieties with high production using the selection method. The variety assembly program uses a highly efficient selection method to select the best genotypes [6].

There are three methods of assembling varieties in plant breeding programs: selection, hybridization, and hybridization followed by selection [7]. Cross-pollinated plant selection has two objectives: selecting genotypes to be used as parents in forming the basic population and selecting individual plants or lines for increasing population traits or assembling new varieties. One of the selection methods used to increase maize productivity is ear-to-row selection. Ear-to-row selection is a modification of mass selection which is one of the selection methods for cross-pollinated plants to increase the quantitative character of a population [8]. Ear-to-row selection in several selection generation cycles will produce a new population with the expected character traits based on the expected selection target.

The method of assembling varieties through selection will quickly yield results if the characters are improved with high heritability values [9]. This high heritability value indicates that the character's appearance is more influenced by

* Corresponding author: Achmad Amzeri

genetic factors than environmental influences, so these genetic factors will be passed on continuously to their offspring. High genetic diversity in the population also affects the success of the selection that is applied, where high genetic diversity in certain characters will provide great opportunities for improving these characters [10].

Improving character through ear-to-row selection of maize varieties cultivated by farmers is expected to improve these maize characters. Gene and genotype frequency changes caused the increase in these characters due to selection [11]. Changes in gene frequency and genotypic mean can be used to estimate genetic advances due to selection [12]. The research aimed to determine the genetic advances due to ear-to-row selection on the Tambin, Sukmaraga, and Srikandi Kuning varieties.

2 Material and methods

2.1 Genetic Materials, Experimental Site, Experimental Design, and Data Collected

The research was conducted at the Agroecotechnology Experimental Garden, Faculty of Agriculture, University of Trunojoyo, Madura. This research was conducted from August 2022 to March 2023. The research was carried out in two stages of activity. Stage 1, carrying out ear-to-row selection for one cycle from the C0 population to form a C1 population. Ear-to-row selection was done on three varieties: the Tambin, Sukmaraga, and Srikandi Kuning. Stage II, carried out an evaluation of the C0 and C1 populations on the three varieties so that six populations were produced. Population evaluation used a completely randomized block design with three replications, resulting in 18 experimental units. Observational variables include ear length, ear diameter, seeds number per row, weight of 100 seeds, seed weight per ear, and production per hectare.

2.2 Data Analysis

Observational data were analyzed using t-test analysis at 5% level to determine the selection advance. Calculation of variance using the formula:

$$\sigma^2 p = \frac{\Sigma x^2 - (\Sigma x)^2/n}{n-1} \text{ .... (1)}$$

$$\sqrt{\sigma^2} p = \sigma \text{ ....(2)}$$

$$\sigma^2 e = \frac{\sigma^2 P1 + \sigma^2 P2}{2} \text{ ....(3)}$$

$$\sigma^2 g = \sigma^2 p - \sigma^2 e \text{ ....(4)}$$

$$h^2_{bs} = \frac{\sigma^2 g}{\sigma^2 p} \text{ ....(5)}$$

where : σ^2 p = phenotypic variance; x = nilai karakter kuantitatif yang diamati; n = observed quantitative character values; σ = standard deviation; σ^2e = environment variance; σ^2 P1 = parental variance P1; σ^2 P2 = parental variance P1; σ^2g = genetic variance; h_{bs} = heritability in broad sense. Heritability values are classified into three, namely low ($h^2<0.2$), moderate ($0.2<h^2<0.5$), and high ($h^2>0.5$) [13].

3 Results and discussion

3.1 Quantitative Character

Character ear length is one of the determining components of maize production. Several studies have shown a positive correlation between ear length and maize production [14; 15]. The t-test showed no significant difference between the initial population (C0) and the ear-to-row selection (C1) results on the Tambin, Sukmaraga, and Srikandi Kuning variety. The highest mean value for theear length character is the C1 population in the Srikandi Kuning variety (Table 3). Furthermore, the lowest average value is the C0 population in the Tambin variety (Table 1). High character values in a population on selection indicate the genetic advances of the selected plants [16].

Ear diameter character is one of the quantitative characters in plants that are controlled by many genes [17]. The t-test results showed no significant difference in the mean ear diameter between the two tested populations (C0 and C1) of the Tambin, Sukmaraga, and Srikandi Kuning varieties. The C1 population of the Sukmaraga variety has the highest average value (Table 2), while the lowest is on the C0 population of the Tambin variety (Table 1). The highest and lowest variant values were produced by the Srikandi Kuning variety (Table 3). Short ear tend to increase ear diameter and the number of rows per seed. Conversely, the ears that are too long cause the ear diameter to be smaller and the number of rows per seed to be fewer.

The data obtained from the average value of the variable observation number of seeds per row yielded significantly different results for the Tambin and Srikandi Kuning varieties, while there was no significant difference for the Sukmaraga variety. The highest mean value was the C1 population of Srikandi Kuning (Table 3). The number of seeds per row is closely related to ear length. The longer the ears produced, the more seeds per row in one row. The number of seeds that increases linearly will affect the ability of the variety to produce. The t-test results showed a difference between populations C0 and C1 in the number of seeds per row in the Tambin and Sukmaraga varieties, while the Srikandi Kuning variety was not significantly different between populations C0 and C1. The C0 population of the Srikandi Kuning variety produced a high average value, while the lowest score was in the C0 population of Tambin variety.

Maize seed size is an important character to show the superiority of maize varieties. In this study, seed size was indicated in terms of seed weight per plant and the weight of 100 seeds. The t-test results showed differences between the C0 and C1 populations in the seeds weight per ear in the three maize varieties. Furthermore, the weight of 100 seeds showed that there was a difference between C0 and C1 populations in the character of the number of seeds per row in the Tambin variety and Sukmaraga variety, while in the Srikandi Kuning variety there was no significant difference between the C0 and C1 populations. The t-test results showed differences between the C0 and C1 populations in the three varieties on the character of production per hectare. Srikandi Kuning variety produced the highest average value, while the lowest average yield was the Tambin maize variety.

Table 1 The mean and variance of the C0 and C1 populations of the Tambin variety

Characters	C0		C1	
	Mean	Variance	Mean	Variance
ear length	13.73 a	1.74	14.10 a	0.52
ear diameter	3.70 a	0.26	3.93 a	0.20
Seeds number per row	23.15 a	16.55	24.40 b	8.80
Seed weight per ear	71.5 a	817.00	79.55 b	372.95
Weight of 100 seeds	19.24 a	8.61	21.46 b	5.63
Production per hectare	3114.55 a	67846.95	3547.05 b	129737.00

Note: The mean value followed by the same letter in the same line is not significantly different based on the t-test at 5%

Table 2 The mean and variance of the C0 and C1 populations of the Sukmarga variety

Characters	C0		C1	
	Mean	Variance	Mean	Variance
Ear length	15.78 a	2.97	16.22 a	1.11
Ear diameter	4.07 a	0.15	4.26 a	0.37
Seeds number per row	25.45 a	16.95	26.65 a	10.55
Seed weight per ear	159.65 a	2152.55	179.40 b	456.80
Weight of 100 seeds	27.55 a	6.21	29.03 b	2.66
Production per hectare	5509.70 a	150510.20	6227.55 b	58210.95

Note: The mean value followed by the same letter in the same line is not significantly different based on the t-test at 5%.

Table 3 The mean and variance of the C0 and C1 populations of the Srikandi Kuning variety

Characters	C0		C1	
	Mean	**Variance**	**Mean**	**Variance**
Ear length	15.73 a	4.48	16.38 a	1.63
Ear diameter	4.05 a	0.09	4.19 a	0.41
Seeds number per row	25.90 a	9.80	26.85 b	12.55
Seed weight per ear	171.00 a	884.00	185.25 b	335.75
Weight of 100 seeds	28.26 a	7.37	29.12 a	6.09
Production per hectare	5657.50 a	104836.20	6365.50 b	76321.00

Note: The mean value followed by the same letter in the same line is not significantly different based on the t-test at 5%.

3.2 Heritability

Heritability is a measure to determine the appearance of a character caused by genetic or environmental factors [18]. The heritability value of a character needs to be known to predict genetic advances caused by selection [19]. According to [20], high heritability values play a very important role in increasing the effectiveness of selection. The results of ear-to-row selection for the three varieties show that the Srikandi Kuning variety has a high heritability predictive value in a broad sense for all characters observed in Table 6). The Tambin variety had a high heritability value in a broad sense for the characters of ear length, ear diameter, seeds number per row, weight of 100 seeds and production per hectare, while the character of seed weight per ear had moderate heritability (Table 4). Furthermore, the Sukmaraga variety has a high heritability value in a broad sense in terms of ear length, ear diameter, seeds number per row, seed weight per ear, and weight of 100 seeds while the production character per hectare has moderate heritability values (Table 5). Based on the heritability values of the three varieties, about 40-80% of the genotypic performance is determined by genetic factors and the rest by environmental factors. The heritability values of most of the observed characters can be used as a guideline for plant breeding programs [21].

High heritability values for most of the observed characters indicate that the role of genes in influencing phenotype is more dominant than that of the environment [22]. The influence of genes is greater than that of the environment as shown by the greater value of the genotype variance than the environmental variance (Table 4-6). High heritability values play an important role in increasing the effectiveness of selection. For characters with high heritability, selection will take place more effectively because of small environmental influences so that genetic factors are more dominant in the genetic appearance of plants. Selection of characters that have a low heritability value will be less effective because there is a possibility that these characters will change when planted in a different environment because the influence of the environment is quite large on these characters [23]. The selection of characters with high heritability values can be carried out in the early generations, while characters with low heritability values can be selected in the last generations [24].

Table 4 Phenotypic variance (σ^2p), genotypic variance (σ^2g), environmental variance (σ^2e), and heritability in a broad sense (h^2_{bs}) in Tambin variety

Characters	σ^2**p**	σ^2**g**	σ^2**e**	h^2_{bs}
Ear length	0.64	0.51	0.13	0.80 (high)
Ear diameter	0.22	0.15	0.07	0.68 (high)
Seeds number per row	7.70	6.21	1.49	0.81 (high)
Seed weight per ear	382.42	167.22	215.20	0.44 (moderate)
Weight of 100 seeds	6.21	4.21	2.00	0.68 (high)
Production per hectare	137754.00	71432.22	66321.78	0.52 (high)

Table 5 Phenotypic variance (σ^2p), genotypic variance (σ^2g), environmental variance (σ^2e), and heritability in a broad sense (h^2_{bs}) in Sukmaraga variety

Parameter	**σ^2p**	**σ^2g**	**σ^2e**	**h^2_{bs}**
Ear length	1.22	0.92	0.30	0.75 (high)
Ear diameter	0.47	0.32	0.15	0.74 (high)
Seeds number per row	9.55	7.23	2.32	0.76 (high)
Seed weight per ear	365.70	198.20	167.50	0.54 (high)
Weight of 100 seeds	2.56	1.92	0.64	0.75 (high)
Production per hectare	67210.22	23432.12	4377810	0.35 (moderate)

Table 6 Phenotypic variance (σ^2p), genotypic variance (σ^2g), environmental variance (σ^2e), and heritability in a broad sense (h^2_{bs}) in Srikandi Kuning variety

Parameter	**σ^2p**	**σ^2g**	**σ^2e**	**h^2_{bs}**
Ear length	1.55	0.86	0.69	0.55 (high)
Ear diameter	0.34	0.21	0.13	0.62 (high)
Seeds number per row	11.57	9.23	2.34	0.80 (high)
Seed weight per ear	345.62	189.20	156.42	0.55 (high)
Weight of 100 seeds	5.07	3.67	1.40	0.72 (high)
Production per hectare	62322.02	43211.77	19110.25	0.69 (high)

4 Conclusion

Ear-to-row selection on maize varieties Tambin, Sukmaraga, and Srikandi Kuning showed significantly different selection progress based on the t-test at 5% on maize production per hectare. Heritability values in a broad sense for all characters observed in the moderate to high categories of the three varieties (Tambin, Sukmaraga, and Srikandi Kuning).

Compliance with ethical standards

Acknowledgments

We thank the University of Trunojoyo Madura, Indonesia, for funding this research through the University's Independent Research Scheme in 2022 (Grant no. 236/UN46.4.1/PT.01.03/2022).

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Rahmawati, U. E.; Suryani, E.; Riski, R. System Thinking Approach to Increase Eco-Friendly Maize Production to Support Food Security. IPTEK J. Proc. Ser. 2021, 0 (6), 17. https://doi.org/10.12962/j23546026.y2020i6.8900.

[2] Magfiroh, I. S.; Zainuddin, A.; Setyawati, I. K. Maize Supply Response in Indonesia. Bul. Ilm. Litbang Perdagang. 2018, 12 (1), 47–72. https://doi.org/10.30908/bilp.v12i1.309.

[3] FAO. Value of Agricultural Production https://www.fao.org/faostat/en/#data/QV (accessed 2021 -12 -21).

[4] Mulyani, A.; Sarwani, M. The Characteristic and Potential of Sub Optimal Land for Agricultural Development in Indonesia. J. Sumberd. Lahan 2013, 7 (1), 46–57.

[5] Amzeri, A. Overview of the Development of Maize Farming in Madura and Alternative Processing into Biomaterials. Rekayasa 2018, 11 (1), 74. https://doi.org/10.21107/rekayasa.v11i1.4127.

[6] Soleimani, B.; Lehnert, H.; Keilwagen, J.; Plieske, J.; Ordon, F.; Naseri Rad, S.; Ganal, M.; Beier, S.; Perovic, D. Comparison Between Core Set Selection Methods Using Different Illumina Marker Platforms: A Case Study of Assessment of Diversity in Wheat. Front. Plant Sci. 2020, 11 (July), 1–11. https://doi.org/10.3389/fpls.2020.01040.

[7] Biotech, J. C. S.; Bertan, I.; Carvalho, F. I. F. De; Oliveira, A. C. De. Parental Selection Strategies in Plant Breeding Programs. 2005, 10 (4), 211–222.

[8] Amzeri, A. Ear to Row Selection in Maize Plant (*Zea mays* L.). Rekayasa 2019, 12 (1), 18. https://doi.org/10.21107/rekayasa.v12i1.5228.

[9] Marwan, A. P.; Munandar, A.; Anwar, A.; Syarif, A.; Dewi Hayati, P. K. Variability, Heritability, and Performance of 28 West Sumatran Upland Rice Cultivars, Indonesia. Biodiversitas 2022, 23 (2), 1058–1064. https://doi.org/10.13057/biodiv/d230249.

[10] Priyanto, S. B.; Effendi, R.; Zainuddin, B. Genetic Variability , Heritability , and Path Analysis for Agronomic Characters in Hybrid Maize. J. Kultiv. 2023, 22 (1), 26–35. https://doi.org/http://dx.doi.org/10.24198/kultivasi.v22i1.38807.

[11] Buffalo, V.; Coop, G. Estimating the Genome-Wide Contribution of Selection to Temporal Allele Frequency Change. Proc. Natl. Acad. Sci. U. S. A. 2020, 117 (34), 20672–20680. https://doi.org/10.1073/pnas.1919039117.

[12] Schmidt, P.; Hartung, J.; Bennewitz, J.; Hans-Peter, P. Heritability in Plant Breeding on a Genotype-Difference Basis. Genetics 2019, 212 (4), 991–1008. https://doi.org/10.1534/genetics.119.302134.

[13] Acquaah, G. Breeding Selected Crops; 2012. https://doi.org/10.1002/9781118313718.part9.

[14] Adhikari, B. N.; Shrestha, J.; Dhakal, B.; Joshi, B. P.; Bhatta, N. R. Agronomic Performance and Genotypic Diversity for Morphological Traits among Early Maize Genotypes. Int. J. Appl. Biol. 2018, 2 (2), 33–43. https://doi.org/10.20956/ijab.v2i2.5633.

[15] Aman, J.; Bantte, K.; Alamerew, S.; Sbhatu, D. B. Correlation and Path Coefficient Analysis of Yield and Yield Components of Quality Protein Maize (*Zea mays* L.) Hybrids at Jimma, Western Ethiopia. Int. J. Agron. 2020, 2020. https://doi.org/10.1155/2020/9651537.

[16] Magar, B. T.; Acharya, S.; Gyawali, B.; Timilsena, K.; Upadhayaya, J.; Shrestha, J. Genetic Variability and Trait Association in Maize (*Zea mays* L.) Varieties for Growth and Yield Traits. Heliyon 2021, 7 (9), e07939. https://doi.org/10.1016/j.heliyon.2021.e07939.

[17] Herlina, L. Yield Components and Diversity of Qualitative Characters of Fifty Accessions of Inbred Maize Lines. E3S Web Conf. 2021, 316. https://doi.org/10.1051/e3sconf/202131603009.

[18] Kuswantoro, H.; Adie, M. M.; Putri, P. H. Genetic Variability, Heritability, and Genotypic Correlation of Soybean Agronomic Characters. Bul. Palawija 2021, 19 (2), 117. https://doi.org/10.21082/bulpa.v19n2.2021.p117-125.

[19] Rosmaina; Syafrudin; Hasrol; Yanti, F.; Juliyanti; Zulfahmi. Estimation of Variability, Heritability and Genetic Advance among Local Chili Pepper Genotypes Cultivated in Peat Lands. Bulg. J. Agric. Sci. 2016, 22 (3), 431–436.

[20] Hakim, L.; Suyamto, S. Gene Action and Heritability Estimates of Quantitative Characters Among Lines Derived From Varietal Crosses of Soybean. Indones. J. Agric. Sci. 2017, 18 (1), 25. https://doi.org/10.21082/ijas.v18n1.2017.p25-32.

[21] Wahyu, Y.; Putri, N. E.; Trikoesoemaningtyas; Sutjahjo, S. H.; Nur, A. Short Communication: Correlation, Path Analysis, and Heritability of Phenotypic Characters of Bread Wheat F 2 Populations. Biodiversitas 2018, 19 (6), 2344–2352. https://doi.org/10.13057/biodiv/d190644.

[22] Lestari, A. P.; Suwarno; Trikoesoemaningtyas; Sopandie, D. I. D. Y.; Aswidinnoor, H. Panicle Length and Weight Performance of F3 Population from Local and Introduction Hybridization of Rice Varieties. HAYATI J. Biosci. 2015, 22 (2), 87–92. https://doi.org/10.4308/hjb.22.2.87.

[23] Ramakers, J. J. C.; Culina, A.; Visser, M. E.; Gienapp, P. Environmental Coupling of Heritability and Selection Is Rare and of Minor Evolutionary Significance in Wild Populations. Nat. Ecol. Evol. 2018, 2 (7), 1093–1103. https://doi.org/10.1038/s41559-018-0577-4.

[24] Rachman, F.; Trikoesoemaningtyas; Wirnas, D.; Reflinur. Estimation of Genetic Parameters and Heterosis through Line × Tester Crosses of National Sorghum Varieties and Local Indonesian Cultivars. Biodiversitas 2022, 23 (3), 1588–1597. https://doi.org/10.13057/biodiv/d230349.