Agrotech Journal
Url: http://usnsj.id/index.php/ATJ
Email: editor.atj@usnsj.com

Evaluation of Double Cross on Growth and Production of Cayenne Pepper (*Capsicum frutescens* L.)

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ARTICLE INFO

e-ISSN: 2548-5148
p-ISSN: 2548-5121
Vol. 8 No. 1, June 2023
URL: http://dx.doi.org/10.31327/atj.v8i1.1990

Abstract

Cayenne pepper is one of the horticultural commodities with high economic value in Indonesia. In addition, this plant also never runs out of enthusiast because almost everyone needs it. Therefore, the fulfillment of this demand must be supported by the availability of sufficient cayenne pepper in Indonesia. This research aims to obtain better diversity in the results of double cross and three way cross than their parents, to obtain characters with good genetic parameters in predicting the results of double cross and three way cross crosses, and to obtain hybrid combinations of cayenne pepper resulting from double cross and three way cross which has purple fruit properties. The results of the evaluation of crosses showed that all cross-evaluation characters had a high heritability predictive value and were followed by high genetic diversity in the characters of plant height, dichotomous height, plant habitus, flowering age, harvesting age, fruit weight, fruit length, fruit diameter, fruit stalks length, and yield.

Keywords: double cross, three-way cross, heritability, diversity

A. Introduction

Cayenne pepper (*Capsicum frutescens* L.) is one of the horticultural commodities with high economic value in Indonesia. In addition, this plant also never runs out of enthusiasts because almost everyone needs it. A sizeable population increase of around 270 million people in 2020 (BPS, 2021), means that the demand for cayenne pepper will continue to increase. Therefore, the fulfillment of this demand must be supported by the availability of sufficient cayenne pepper in Indonesia. One of the reasons is the production gap to the demand for cayenne pepper, which is less than optimal productivity. Therefore, the development of intensification such as assembling high-yielding varieties needs to be carried out.

The plant breeding program is one of the strategies to produce superior varieties with high yield potential and good quality. However, the effectiveness of the program greatly depends on the genotypic diversity of the basic population. The combination of crosses with many parents allows the formation of high diversity. This is supported by the statement of Syukur, Sujiprihati & Rahmi (2015), plant breeding is highly dependent on the existence of genetic diversity, because the higher the genetic diversity, the greater the opportunity to get superior varieties. Without genetic diversity, the efficiency and effectiveness of breeding programs is very low. Genetic diversity can be obtained from local varieties, national superior varieties, introduced lines, and breeding lines. In assembling hybrid varieties, the selection of parents and crossing methods are the first steps that must be taken (Arif, SUjiprihati, & Syukur, 2012). Genetic variation in plant populations can be due to domestication, segregation, germplasm collection, plant introduction, hybridization, mutation, polyploidy, somaclonal variation, and genetic engineering (Abrham, 2019). Genetic information is essential for more efficient and effective plant section (Amas, Musa, Farid & Anshori, 2023).

The concept of hybridization is often combined with cross-design to optimize the combined potential of different parent cultivars used (Muthoni & Hussein, 2020). The chosen parents are parents who have some specific characteristics that will be combined in their offspring. Meanwhile, the crossing method should be adjusted to the resources owned. One method that is widely used is the double cross and three way-cross. A double cross is a cross between F1 and F1 resulting from two single crosses. A cross between two parents who have superior characters and both are hybrids (F1) of a single cross. This cross will produce good F1 and if it is continued it will produce high diversity (Syukur et al., 2015). Meanwhile, a three-way cross is a cross between a single cross and one pure line, where the three pure lines are not related, so they are more genetically different and have a more diverse appearance (Pathy, Rao, & Ramesh, 2019). The genetic diversity of the three-way cross hybrid is greater than the single cross hybrid because it uses three different types of inbred lines.

High heritability values indicate that the influence of genetic factors was more significant and prevailing than environmental factors. The higher the heritability value, the more variability production traits gain influence by differences in genotypes and less by environmental variations. Traits with high heritability values will increase the effectiveness of selection because such attributes reflect the influence of genetic factors compared with environmental factors (Bdr, Nasaruddin, Iswoyo, Ridwan, & Arsyad, 2020; Afa, Mustafa, Syahri, Bulawan, & Musdalifa, 2021).

In this case the researcher will use the Double cross (DC) and Three Way Cross (TWC) methods. In this cross only involves several hybrid varieties to be crossed. The two crossing methods have significant differences, one of which is the ability to produce antioxidant content (cayenne pepper with purple young fruit characters). The researcher hopes that in carrying out crosses, the ability of the two parents to produce the character of cayenne pepper can be known. In addition, the superior traits possessed by some of the parents can be incorporated into the F1 genotype resulting from the artificial crosses that were carried out.

B. Methology

The research was conducted at the Experimental Garden of the Faculty of Agriculture, Hasanuddin University, in Tamalanrea District, Makassar City, South Sulawesi. At an altitude of 22.4 m asl with an average temperature of 24 °C in the morning and 32 °C during the day. This research was conducted from August to December 2021.

The materials used in the research were 10 genotypes resulting from crosses and 4 parental varieties of cayenne pepper seeds, namely G1 (U/B//D/K), G2 (U/D//B/U), G3 (U/D//D /K), G4 (U/K//D/B), G5 (U/D//D/B), G6 (U/B//D/U), G7 (U/B//D/B), G8 (U/D//B), G9 (U/B//D), G10 (D/U//B), G11 (Bara), G12 (Dewata 43 F1), G13 (Ungara IPB), G14 (Katokkon), soil, manure, rice husk charcoal, compost, polybags measuring 10 cm x 15 cm and 30 cm x 35 cm, furadan, patent fertilizer, AB Mix, NPK Mutiara 16-16-16, herbicide with active ingredients paraquat dichloride, insecticide with the active ingredient profenopos, fungicide with the active ingredient propineb and zinc, rapia rope, stake, plastic scrap, plastic bag and research board.

This research was arranged using a randomized block design consisting of 10 genotypes resulting from crosses and 4 parental varieties of cayenne pepper. The experiment was repeated

3 times and each experimental unit consisted of 4 plant samples, so there were 168 experimental units. Observation of cross character evaluation of cayenne pepper was carried out by measuring the observed variables for each plant sample. The diversity of plant characters that appear is determined based on the measurements that have been made. The observed variables included plant height, dichotomous height, plant habitus, stem diameter, flowering age, harvest age, fruit weight, fruit length, fruit diameter, fruit stalk length, and yield. The data obtained was analyzed for variance (Anova), cluster analysis using the STAR (Statistical Tool for Agricultural Research) program and if there is a real or very significant effect, then proceed with the BNT test (α = 0.05). Meanwhile, to see the relationship of each parameter, a correlation analysis was carried out.

C. Result

The results of the BNT test at the 0.05 level in Table 1 show that the U/B//D/B (G7) and U/D//B/U (G2) genotype treatments produced the best plant height with respective values (69.67 cm) and (69.53 cm), so that it is significantly different from all the comparison varieties. The genotype treatments U/D//D/B (G5) and U/B//D/B (G7) had the best dichotomous height (31.57 cm) and (30.92 cm) so that they were significantly different from the Bara (a) control variety, Dewata 43 F1 (b), Ungara IPB (c), and Katokkon (d). Plant habitus characters showed that the genotype treatments U/K//D/B (G4), U/D//B/U (G2), and U/D//D/B (G5) had the best plant habitus with a value respectively (79.75 cm), (78.25 cm), and (74.46 cm), so that they were significantly different from the control varieties Bara (a), Dewata 43 F1 (b), Ungara IPB (c), and Katokkon (d). The stem diameter character of the U/K//D/B (G4) genotype treatment produced the best stem diameter with a value of (11.07 cm), so it was significantly different from the reference variety Dewata 43 F1 (b). Genotype treatments U/B//D/K (G1), U/K//D/B (G4), and U/B//D/B (G7) produced the fastest flowering time with their respective values (38.83 DAP), (39.92 DAP), and (41.08 DAP), so that they were significantly different from the control varieties Bara (a), Dewata 43 F1 (b) and Katokkon (d). While the characters of harvesting age showed that genotype treatment U/B//D/K (G1) and U/K//D/B (G4) had the fastest harvesting age with respective values (70.42 DAP) and (71.42 DAP) so that significantly different from the control varieties Bara (a), Dewata 43 F1 (b), Ungara IPB (c), and Katokkon (d)

Table 1. Average plant height (cm), dichotomous height (cm), plant habitus (cm), stem diameter (mm), flowering age (DAP), and harvesting age (DAP).

Genotypes	Observation Parameters					
	Plant Height	Dichotomous Height	Plant Habitus	Stem Diameter	Flowering Age	Harvesting Age
G1 (U/B//D/K)	61.83 b	21.35 c	60.63	10.94b	**38.83abd**	**70.42 a-d**
G2 (U/D//B/U)	**69.53 a-d**	28.99 cd	**78.25 a-d**	10.89b	43.00d	73.17 ad
G3 (U/D//D/K)	60.83 b	27.31 cd	72.88 bcd	10.29b	41.58d	72.75 abd
G4 (U/K//D/B)	69.50 bcd	29.85 bcd	**79.75 a-d**	**11.07b**	**39.92abd**	**71.42 a-d**
G5 (U/D//D/B)	67.25 bcd	**31.57 a-d**	**74.46 a-d**	10.19	41.92d	73.00 ad
G6 (U/B//D/U)	63.42 b	25.53 cd	70.13 bc	10.27b	42.58d	73.42 ad
G7 (U/B//D/B)	**69.67 a-d**	**30.92 a-d**	66.49	10.48b	**41.08 abd**	73.75 ad
G8 (Bara) a	60.58	26.34	66.44	10.65	44.08	76.25
G9 (Dewata) b	51.00	25.10	62.65	9.00	43.83	75.42
G10 (Ungara) c	58.17	15.80	62.50	11.73	39.58	74.08
G11 (Katokkon) d	57.61	21.37	65.31	10.92	48.00	84.67
NP BNT 0.05 %	8.94	3.95	6.80	1.20	2.65	2.49

Note: Numbers followed by the same letters in columns (a,b,c,d) mean that they are significantly different from the genotypes for comparison G11 Bara (a), G12 Dewata 43 F1 (b), G13 Ungara IPB (c), G14 Katokkon (d), in the BNT test α = 0.05%. (B = Bara, D = Dewata, U = Ungara, K = Katokkon).

The results of the BNT test at the level of 0.05 in Table 2 show that the U/D//D/K (G3) and U/K//D/B (G4) genotype treatments had higher weight per fruit with their respective values (1.93 g) and (1.82 g) so that they were significantly different from the comparison variety Bara (a), Dewata 43 F1 (b). The U/D//B/U (G2) and U/B//D/B (G7) genotype treatments produced the highest fruit length with values (3.83 cm) and (3.61 cm), so that they were significantly different from the Bara control variety (a), Ungara IPB (c), and Katokkon (d). The fruit diameter character indicated that the genotype treatments were U/D//D/K (G3), U/B//D/U (G6), U/K//D/B (G4), and U/B//D /B (G7) has the highest fruit diameter with respective values (10.49 mm), (10.11 mm), (9.57 mm), and (8.98 mm) so that it is significantly different from the comparison varieties Bara (a) and Dewata 43 F1 (b). The character of fruit stalk length indicated that the U/B//D/B (G7) and U/D//B/U (G2) genotype treatments had the highest fruit stalk length with values of (3.16 cm) and (3.03 cm) respectively, so that it is significantly different from the control varieties Bara (a), Dewata 43 F1 (b), Ungara IPB (c), and Katokkon (d). Meanwhile, the character of crop production showed that genotype treatments U/D//B/U (G2), U/D//D/B (G5), U/B//D/U (G6) had more crop production with respective values (582.05 g), (523.06 g), and (501.08 g), so that they were significantly different from the comparison varieties Ungara IPB (c), and Katokkon (d).

Table 2. Average fruit weight (g), fruit length (cm), fruit diameter (mm), fruit stalk length (cm), yield (g)

Genotypes	Observation Parameter				
	Fruit Weight	Fruit Length	Fruit Diameter	Fruit Stalk Length	Yield
G1 (U/B//D/K)	1.22	2.57	8.37	2.68	457.75 d
G2 (U/D//B/U)	1.72 a	**3.83 acd**	8.18	**3.03 a-d**	**582.05 cd**
G3 (U/D//D/K)	**1.93 ab**	3.93 cd	**10.49 ab**	2.75 c	472.23 d
G4 (U/K//D/B)	**1.82 ab**	3.53 cd	**9.57 ab**	2.89 bcd	476.51 d
G5 (U/D//D/B)	1.41	3.00 c	8.72 a	2.86 bcd	**523.06 cd**
G6 (U/B//D/U)	1.52 a	2.71	**10.11 ab**	2.64	**501.08 cd**
G7 (U/B//D/B)	1.69 a	**3.61 acd**	**8.98 ab**	**3.16 a-d**	468.43 d
G8 (Bara) a	0.96	3.00	7.37	2.68	555.53
G9 (Dewata) b	1.27	3.82	7.70	2.52	584.83
G10 (Ungara) c	2.03	2.31	13.12	2.41	384.53
G11 (Katokkon) d	4.19	2.44	22.79	2.42	203.32
NP BNT 0.05 %	0.51	0.57	1.22	0.34	101.83

Note: Numbers followed by the same letters in columns (a,b,c,d) mean that they are significantly different from the genotypes for comparison G11 Bara (a), G12 Dewata 43 F1 (b), G13 Ungara IPB (c), G14 Katokkon (d), in the BNT test α = 0.05%. (B = Bara, D = Dewata, U = Ungara, K = Katokkon).

Table 3. Heritability

No.	Parameter	Heritability Value of h^2 (%)	Note
1	Plant Height	49	Medium
2	Dichotomous Height	80	High
3	Plant Habitus	70	High
4	Stem Diameter	39	Medium
5	Flowering Age	70	High
6	Harvesting Age	86	High
7	Fruit Weight	89	High
8	Fruit Length	71	High
9	Fruit Diameter	93	High
10	Fruit Stalk Length	53	High
11	Yield	74	High

Note: $0 < h^2 \leq 20$ (low), $21 < h^2 \leq 50$ (medium), $50 < h^2 \leq 100$ (high)

Table 3 shows that all the characters observed, both vegetative, generative and production components have moderate to high heritability values based on the index value of each character. The results of the heritability analysis in Table 3 show that there are 9 characters that have high heritability values and two characters have moderate heritability values. The highest heritability value was indicated by the character of fruit diameter (93%), weight per fruit (89%), harvest age (86%), dichotomous height (80%), crop production (74%), plant habitus (70%), age flowering (70%), fruit length (71%), fruit stalk length (53%). Characters with moderate heritability values were owned by plant height and stem diameter with (49%) and (39%) values.

The results of the correlation coefficient analysis in Table 4 show the relationship between crop production characters and other characters. The results showed that the characters that were positively correlated were highly significant with the production of cayenne pepper, namely dichotomous height and fruit length with values of 0.41 and 0.56. The characters that have a very significant negative correlation with cayenne pepper crop production are harvesting age, fruit weight, and fruit diameter with each correlation value being -0.50, -0.73, and -0.86. While the other characters have no significant correlation with the production character of cayenne pepper plants.

Table 4. Correlation

	1	2	3	4	5	6	7	8	9	10	11
1	1.00	0.56**	0.39*	0.37*	-0.24tn	-0.29*	-0.10tn	0.19tn	-0.18tn	0.64**	0.19tn
2		1.00	0.57**	-0.35*	0.02tn	-0.27tn	-0.28tn	0.57**	-0.42**	0.55*	0.41**
3			1.00	-0.02tn	-0.04tn	-0.24tn	0.01tn	0.39*	-0.16tn	0.32*	0.27tn
4				1.00	-0.18tn	0.01tn	0.16tn	-0.35tn	0.23tn	0.15tn	-0.27tn
5					1.00	0.78**	0.50**	0.01tn	0.47**	-0.30*	-0.16tn
6						1.00	0.74**	-0.17tn	0.76**	-0.32*	-0.50**
7							1.00	-0.24tn	0.93**	-0.25tn	-0.73**
8								1.00	-0.49**	0.46**	0.56**
9									1.00	-0.42**	-0.86**
10										1.00	0.28tn
11											1.00

Note: numbers followed by signs are significantly different from table r 0.05 = 0.29 (*) ; r 0.01 = 0.40 (**)

1. **Plant Height**
2. **Dichotomous Height**
3. **Plant Habitus**
4. **Stem Diameter**
5. **Flowering Age**
6. **Harvesting Age**
7. **Fruit Weight**
8. **Fruit Length**
9. **Fruit Diameter**
10. **Fruit Stalk Length**
11. **Yield**

Based on this research, four varieties of double cross were carried out with double crosses which had specific characteristics and differed between varieties (Bara, Dewata 43 F1, Ungara IPB, and Katokkon). From the evaluation of these crosses, it was obtained characters that had a variety that had a very significant effect on several parameters except plant height and stem diameter. All genotypes observed showed differences due to the different genetic background of each cayenne pepper genotype. Therefore, these characters can be used as the defining character of the diversity of plant crosses. According to Ritonga, Sujiprihati, & Anggoro (2016), genetic diversity can describe variation between individuals in a population, so deeper studies are needed to determine the role of genetic factors in the variation that appears in each character.

Based on research conducted on several genotypes of cayenne pepper on the growth and production of cayenne pepper, three genotypes with high crop production were obtained and significantly different from the Ungara and Katokkon comparison varieties. The treatments were U/D//B/U (G2), U/D//D/B (G5), and U/B//D/U (G6) genotypes. This is due to the provision of a combination of fertilizers, namely organic and inorganic fertilizers. Where organic fertilizer (patent fertilizer) contains macro and micro nutrients and is easily absorbed by plants. The addition of a combination of fertilizers will trigger the addition of new branches and shoots, and will lead to the production of cayenne pepper. This is supported by the statements of Ege & Julung (2019), that a lack of nutrients in the soil can result in low productivity of cayenne pepper. If nutrients in the soil are not available, plant growth will be stunted and production will decrease. The expected crop production can be achieved if the amount and type of nutrients in the soil for plant growth are sufficient, balanced, and available according to the needs of the cayenne pepper plant.

Analysis of heritability can be a genetic parameter that needs to be known in relation to the process of selecting and incorporating important characters into a genotype. Characters that have a high heritability value are dichotomous height, plant habitus, flowering age, harvesting age, fruit weight, fruit length, fruit diameter, fruit stalk length, crop production, and characters that have moderate heritability values, namely plant height and stem diameter. These characters indicate that high heritability values are influenced by genetic factors and can be used as characters for the selection process because they have a great chance of inheriting the next offspring. This is supported by the statement of Hakim, Syukur, & Wahyu (2019) that characters with high heritability values will facilitate character improvement through selection compared to characters with low heritability values. Estimation of heritability value has not fully demonstrated that this character is very effective as a reference as a selection character. So, it needs to be supported by knowing the magnitude of the direct and indirect influence given to these characters in influencing crop production. According to Sofian, Nandariyah, Djati & Sutarno (2019), selecting populations with high heritability proved more effective than the selection with low heritability. High heritability values indicated that most of the phenotypic variability resulted from genetic variability, hence, selection will experience genetic improvement. So, according to Amas et al. (2023), based on the analysis of variance and heritability, the selection process for the double and three-way cross populations of cayenne pepper was effective.

The results of the correlation analysis in Table 4 show that dichotomous height and fruit length have a very significant positive and negative correlation with crop production. This means that the height of the dichotomous and the length of the fruit will increase along with the increase in some characters of cayenne pepper. Characters that have a very significant positive and negative correlation show a high relationship between these traits, so that they can support the selection according to these characters. This is supported by the statement of Yakub, Kartina, Isminingsih, & Suroso (2012) that the correlation of two or more positive traits will facilitate selection because it is followed by an increase in one trait followed by another, so one or a selection index can be determined. However, this correlation cannot yet be an accurate proof. This is because the correlation value between the two characters is still influenced by the variety of the other characters which are indirect. According to Akbar, Bambang, Iswari, Willy & Sugiyanta (2019) and Hastini, Willy, Munif, & Hajrial (2019), correlation analysis aims to evaluate the relationship between the traits and their association with yield.

D. Conclusion

All the evaluation characters of double cross and three way-cross based on high heritability predictive value and followed by high genetic diversity are possessed by the characters of plant height, dichotomous height, plant habitus, flowering age, harvesting age, fruit weight, fruit length, fruit diameter, fruit stalk length, and crop production.

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