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Yield Evaluation of Several Tomato Strains from the Cross-Breeding Product of Mawar x Chung

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Abstract

The unavailability of high-yielding varieties can cause low production of tomatoes. Excellent variety construction in plant-breeding programs is possible as an effort to solve the tomato cultivation problem. This study aimed to evaluate the yield of several tomato strains from the cross-breeding product of *Mawar* × *Chung*. This study was conducted at the experimental garden, Faculty of Agriculture, Hassanuddin University from April to July 2023. From the results, a strain with high productivity level was obtained from the KM 10.10.6 (g6), which produced an average of 1432.64 g and was significantly different from both parent plants. This strain also had high heritability levels of plant height, dichotomic height, number of branches, flowering period, harvesting period, number of fruit bunches, number of fruits, fruit length, fruit diameter, fruit weight and productivity. Moreover, this strain had four characteristics that positively correlated to production, namely plant height, stem diameter, number of branches, and number of fruits

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

A. Introduction

Tomatoes are one of the horticulture commodities with high economic value and are much favoured by the public. Tomatoes are a source of vitamins and minerals that can be consumed as fresh fuit, seasoning or processed as food ingredients in tomato sauce and juice (Wasonowati, 2011). Tomatoes also contain an antioxidant compound called lycopene. Lycopene is a pigment that causes tomatoes to be red, lycopene belongs to carotenoids that can prevent and treat various diseases, such as lung cancer, prostate cancer, cervical cancer, pancreatic tumor, and throat tumor (Cahyono, 2008).

According to the market price, tomato is affordable for all community background, thus opening more significant opportunity for market absorption (Dalimartha, 2011). Indonesia's tomato production in the last 3 years has elevated from 1,020,333 tons in 2019 to 1,084,993 tons in 2020 and 1,114,399 tons in 2021 (BPS, 2022). Increasing demand for tomatoes is supported by relatively affordable price, thus providing an excellent opportunity to increase tomatoes productivity. Therefore, an effort to boost domestic tomato production becomes crucial.

In the amount of average production level, the tomato has a low productivity level inproportional to its potential. The low productivity level of tomato is caused by the lack of high-yielding varieties (Asmara P.E.S., E. Ambarwati & A. Purwantoro, 2011). A variety construction in plant breeding program is considerable to obtain a new excellent variety of tomato plants. Excellent variety construction in plant breeding program is preferable due to being environmental-friendly with high sustainability level in biofortification products of agriculture, which has an important role in plant productivity and excellent variety construction improvement (Jambormias and Riry, 2009; M., S. Sujiprihati & R. Yunianti, 2018). A variety construction is proposed to gain a new variety with better hereditary traits that can produce higher quantity product in better quality (Merintan and Purmaningsih, 2016).

The improvement potential of tomato plant products in plant breeding program is conducted by measuring and comparing the conformity among genotypes in tomato plants (Sari, R.E.P., D. Saptadi Kuswanto, 2018). Diversity level can be improved through plant-crossing with far genetical distance (Fadhilah, A. N., M. Farid, I. Ridwan, M.F. Anshori & A. Yassi, 2022). In plant-crossed breeding product, genetical diversity occurs as the plant has different genetic characteristics from both parent plants. Each generation level has different conformity levels, whereas next generation has a higher conformity level than previous generation (Sari et al., 2018). Farid, M., M.F. Anshori, I. Ridwan, N.E. Dungga & I. Ermiyanti (2022) have performed a half-diallele crossing on several tomato varieties with extremely far genetic distance. Crossing between *Mawar* and *Chung* tomato varieties are considered a hybrid product with a high productivity level and lycopene content. Following the description above, a further experiment was necessary to evaluate the product of several tomato strains from the cross breeding of *Mawar* × *Chung*.

B. Methodology

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 LSD test results in Table 1 present the best plant height character in MC 27.12.5 strain (g11) at an averperiod value of 156.00 cm, which was significantly different from the comparative varieties, namely *Mawar* (a) and *Chung* (b). This strain also presents the best stem diameter character at 19.60 mm. Meanwhile, the best dichotomic height character was obtained from the MC 27.7.3 strain (g9) with an average value of 69.00 cm and was significantly different from the comparative varieties.

Table 1. Plant height, dichotomic height, and stem diameter of tomato strains as the cross-breeding products of *Mawar* × *Chung*

Genotypes	Plant height	Dichotomic height	Stem diameter
(g1) MC 9.2.4	88.00	34.00	13.80
(g2) MC 11.4.1	136.00 ab	48.00 b	14.90
(g3) MC 35.7.1	142.00 ab	39.00 b	15.30
(g4) MC 38.8.8	91.00	40.00 b	13.30
(g5) MC 27.12.2	132.00 ab	41.00 b	19.50
(g6) MC 10.10.2	166.00 ab	67.00 ab	16.00
(g7) MC 38.1.1	102.00 b	55.00 ab	14.70
(g8) MC 8.3.1	102.00 b	34.00	15.50
(g9) MC 27.7.3	139.00 ab	69.00 ab	14.20
(g10) MC 9.4.1	150.00 ab	44.00 b	12.90
(g11) MC 27.12.5	156.00 ab	44.00 b	19.60
(g12) MC 9.2.6	97.00 b	35.00	16.20
(g13) MC 11.4.4	123.00 ab	45.00 b	14.50
(g14) MC 27.12.3	124.00 ab	38.00 b	15.60
(g15) MC 10.7.8	127.00 ab	51.00 ab	14.80
(g16) MC 8.3.2	129.00 ab	45.00 b	15.80
(g17) MC 35.7.5	127.23 a	38.23 b	13.63
(g18) MC 9.2.7	87.00 ab	33.00	13.30
(g19) MC 27.12.6	129.00	41.00	15.60
(g20) MC 11.4.5	130.00	46.00	14.70
(g21) MC35.7.6	134.00	39.00	14.50
(g22) MC 27.12.4	123.00	36.00	14.50
(g23) Mawar (a)	103.14	43.63	9.47

(g24) Chung (b)	86.46	29.79	10.83
NP LSD (5%)	7.56	6.92	6.90

Note: Values in the same columns followed by the same letters (ab) present a significantly different condition with comparative varieties of *Mawar* (a) and *Chung* (b), following the LSD test of 0.05.

Table 2 presents the LSD test results of the best number of branches character in MC 10.10.2 strain (g6) at 34.00, which was significantly different from both comparative varieties, *Mawar* (a) and *Chung* (b). The best flowering period character was obtained from the MC 27.7.3 strain (g9) at 29.00 DAP and was significantly different from both comparative varieties. Meanwhile, the best harvesting period character was found in the MC 9.2.6 strain (g12) at 62.00 DAP and was significantly different from the comparative variety of *Chung* (b).

Table 2. Number of branches, flowering period, and harvesting period of tomato strains from the cross-breeding product of *Mawa*r × *Chung*.

Genotypes	Number of branches	Flowering period	Harvesting period
(g1) MC 9.2.4	16.00	31.00	68.00
(g2) MC 11.4.1	22.00 [a]	39.00	68.00
(g3) MC 35.7.1	18.00 [a]	36.00	90.00
(g4) MC 38.8.8	17.00	34.00	71.00
(g5) MC 27.12.2	25.00 [ab]	36.00	67.00
(g6) MC 10.10.2	34.00 [ab]	31.00	70.00
(g7) MC 38.1.1	20.00 [a]	36.00	69.00
(g8) MC 8.3.1	16.00	30.00	73.00
(g9) MC 27.7.3	18.00 [a]	29.00	62.00
(g10) MC 9.4.1	25.00 [ab]	36.00	69.00
(g11) MC 27.12.5	29.00 [ab]	36.00	95.00[b]
(g12) MC 9.2.6	20.00 [a]	31.00	65.00
(g13) MC 11.4.4	16.00	53.00	68.00
(g14) MC 27.12.3	21.00 [a]	41.00	67.00
(g15) MC 10.7.8	20.00 [a]	50.00	71.00
(g16) MC 8.3.2	17.00	30.00	69.00
(g17) MC 35.7.5	16.23	36.90	85.00
(g18) MC 9.2.7	12.00	31.00	68.00
(g19) MC 27.12.6	24.00	37.00	71.00
(g20) MC 11.4.5	17.00	52.00	68.00
(g21) MC35.7.6	17.00	36.00	69.00
(g22) MC 27.12.4	20.00	39.00	71.00
(g23) *Mawar* (a)	10.92	54.53	96.93
(g24) *Chung* (b)	17.70	49.13	87.90
NP LSD (5%)	6.95	4.27	5.03

Note: Values in the same columns followed by the same letters (ab) present a significantly different condition with comparative varieties of *Mawar* (a) and *Chung* (b), following the LSD test of 0.05.

The LSD test results in Table 3 indicate that the best number of flowers per bunch, number of fruits per bunch, and number of fruit bunches are shown in MC 10.10.2 strain (g6) at 12.00, 9.70, and 37.00, respectively. These values are significantly different from both comparative varieties of *Mawar* (a) and *Chung* (b).

Table 3. Number of flowers per bunch, number of fruits per bunch, and number of fruit bunches in strains produced from *Mawar* × *Chung* cross-breeding program

Genotypes	Number of flowers per bunch	Number of fruits per bunch	Number of fruit bunches
(g1) MC 9.2.4	6.00	5.70	24.00 [a]
(g2) MC 11.4.1	9.33	7.33	25.00 [a]
(g3) MC 35.7.1	7.67	6.00	26.00 [a]
(g4) MC 38.8.8	6.70	6.30	19.00 [a]
(g5) MC 27.12.2	8.70	6.30	23.00 [a]
(g6) MC 10.10.2	12.00	9.70	37.00 [ab]
(g7) MC 38.1.1	8.67	7.67	35.00 [ab]
(g8) MC 8.3.1	7.30	7.00	28.00 [a]
(g9) MC 27.7.3	8.70	7.33	22.00 [a]
(g10) MC 9.4.1	9.30	7.30	30.00 [a]
(g11) MC 27.12.5	8.70	6.30	30.00 [a]
(g12) MC 9.2.6	6.00	6.00	30.00 [a]
(g13) MC 11.4.4	7.30	6.30	17.00 [a]
(g14) MC 27.12.3	7.00	5.30	15.00 [a]
(g15) MC 10.7.8	8.33	7.67	35.00 [ab]
(g16) MC 8.3.2	7.70	7.00	30.00 [a]
(g17) MC 35.7.5	6.90	4.60	17.23 [a]
(g18) MC 9.2.7	6.00	5.33	23.00
(g19) MC 27.12.6	7.30	5.70	21.00
(g20) MC 11.4.5	7.33	7.00	18.00
(g21) MC35.7.6	9.30	4.67	22.00
(g22) MC 27.12.4	8.67	5.33	14.00
(g23) *Mawar* (a)	4.56	3.83	6.38
(g24) *Chung* (b)	6.82	5.73	25.57
NP LSD (5%)	3.88	3.87	7.05

Note: Values in the same columns followed by the same letters (ab) present a significantly different condition with comparative varieties of *Mawar* (a) and *Chung* (b), following the LSD test of 0.05.

The LSD test results in Table 4 present that the best number of fruits character was obtained from the MC 10.10.2 strain (g6) at 191.00 and significantly different from both comparative varieties of *Mawar* (a) and *Chung* (b). The best character of fruit length was also obtained from the MC 10.10.2 strain (g6) at 44.26 mm, that was significantly different from the comparative varieties of *Mawar* (a) and *Chung* (b). This strain showed the best fruit thickness at 29.98 mm.

Table 4. Number of fruits, fruit length, and fruit thickness in strains produced from *Mawar* × *Chung* cross-breeding activity.

Genotype	Number of fruits	Fruit Length	Fruit Thickness
(g1) MC 9.2.4	86.00 [a]	27.12 [b]	25.40
(g2) MC 11.4.1	102.00 [ab]	34.22 [ab]	25.76
(g3) MC 35.7.1	95.00 [ab]	32.72 [b]	28.22
(g4) MC 38.8.8	127.00 [ab]	27.00 [b]	22.08
(g5) MC 27.12.2	101.00 [ab]	36.38 [ab]	26.06
(g6) MC 10.10.2	191.00 [ab]	44.26 [ab]	29.98

(g7) MC 38.1.1	105.00 ab	29.76 b	23.90
(g8) MC 8.3.1	121.00 ab	30.78 b	24.44
(g9) MC 27.7.3	91.00 a	27.64 b	26.16
(g10) MC 9.4.1	102.00 ab	37.24 ab	27.70
(g11) MC 27.12.5	196.00 ab	31.38 b	26.28
(g12) MC 9.2.6	88.00 a	27.22 b	25.40
(g13) MC 11.4.4	100.00 ab	31.06 b	24.02
(g14) MC 27.12.3	167.00 ab	30.38 b	24.80
(g15) MC 10.7.8	85.00 a	38.70 ab	22.82
(g16) MC 8.3.2	129.00 ab	30.80 b	24.50
(g17) MC 35.7.5	86.23 a	27.33 b	23.37
(g18) MC 9.2.7	81.00	27.12	23.88
(g19) MC 27.12.6	172.00	30.42	25.40
(g20) MC 11.4.5	101.00	31.10	24.50
(g21) MC35.7.6	95.00	31.78	26.02
(g22) MC 27.12.4	120.00	27.18	23.46
(g23) *Mawar* (a)	14.00	26.47	20.15
(g24) *Chung* (b)	85.07	16.62	16.38
NP LSD (5%)	7.05	6.91	6.92

Note: Values in the same columns followed by the same letters (ab) present a significantly different condition with comparative varieties of *Mawar* (a) and *Chung* (b), following the LSD test of 0.05.

The LSD test results in Table 5 describe that the best fruit diameter, fruit weight, and number of cavities characters are presented in the MC 10.10.2 strain (g6) at 49.46 mm, 40.94 g, and 10.60, respectively. In this strain group, fruit diameter and weight were significantly different from the comparative variaties, namely *Mawar* (a) and *Chung* (b).

Table 5. Fruit diameter, fruit weight, number of cavities in strains from the *Mawar* × *Chung* cross-breeding product

Genotypes	Fruit diameter	Fruit Weight	Number of Cavities
(g1) MC 9.2.4	31.70 b	8.48	7.80
(g2) MC 11.4.1	38.70 b	26.98 b	9.60
(g3) MC 35.7.1	37.04 b	29.17 b	7.80
(g4) MC 38.8.8	31.63 b	22.32 b	7.80
(g5) MC 27.12.2	36.30 b	27.07 b	9.20
(g6) MC 10.10.2	49.46 ab	40.94 ab	10.00
(g7) MC 38.1.1	34.40 b	24.95 b	9.60
(g8) MC 8.3.1	35.66 b	11.34 b	6.80
(g9) MC 27.7.3	32.60 b	23.14 b	7.00
(g10) MC 9.4.1	42.32 b	30.90 ab	8.40
(g11) MC 27.12.5	41.00 b	30.83 ab	10.00
(g12) MC 9.2.6	32.78 b	22.90 b	7.80
(g13) MC 11.4.4	35.36 b	25.12 b	9.40
(g14) MC 27.12.3	34.88 b	23.89 b	7.40
(g15) MC 10.7.8	43.66 b	29.32 b	10.00
(g16) MC 8.3.2	36.14 b	11.79 b	9.00
(g17) MC 35.7.5	33.33 b	9.12	7.10
(g18) MC 9.2.7	31.54	8.46	7.40
(g19) MC 27.12.6	35.48	25.31	7.60

(g20) MC 11.4.5	37.28	25.27	9.60
(g21) MC35.7.6	36.92	12.98	7.40
(g22) MC 27.12.4	32.06	8.06	5.60
(g23) *Mawar* (a)	36.97	23.50	7.31
(g24) *Chung* (b)	21.88	3.40	2.03
NP LSD (5%)	6.92	6.88	3.87

Note: Values in the same columns followed by the same letters (ab) present a significantly different condition with comparative varieties of *Mawar* (a) and *Chung* (b), following the LSD test of 0.05.

As presented in Table 6 and the LSD test results, the total dissolved solids (brix) obtained the best value at the MC 9.2.6 strain (g12) with an averperiod of 7.94. The best number of seeds per fruit was obtained from the MC 38.1.1 strain (g7) at 75.20, while the best productivity level was shown in the MC 27.12.5 strain (g11) at 1432.64 g, which indicates a significant different value between the comparative varieties, namely *Mawar* (a) and *Chung* (b).

Table 6. Total dissolved solids (brix), number of seeds per fruit, and productivity level of different tomato strains from the *Mawar* × *Chung* cross-breeding product

Genotypes	Total dissolved solids	Number of seeds per fruit	Productivity level
(g1) MC 9.2.4	7.18	64.20	360.46 ab
(g2) MC 11.4.1	6.28	66.20	558.59 ab
(g3) MC 35.7.1	6.00	68.20	658.35 ab
(g4) MC 38.8.8	6.70	74.40	422.22 ab
(g5) MC 27.12.2	6.08	70.60	1133.13 ab
(g6) MC 10.10.2	5.94	63.40	1432.64 ab
(g7) MC 38.1.1	6.92	75.20	472.49 ab
(g8) MC 8.3.1	6.28	56.40	694.15 ab
(g9) MC 27.7.3	6.32	63.80	505.59 ab
(g10) MC 9.4.1	6.18	74.60	698.18 ab
(g11) MC 27.12.5	6.98	70.60	719.90 ab
(g12) MC 9.2.6	7.94	65.60	434.61 ab
(g13) MC 11.4.4	6.00	64.40	437.94 ab
(g14) MC 27.12.3	6.86	66.00	909.52 ab
(g15) MC 10.7.8	5.16	72.60	504.06 ab
(g16) MC 8.3.2	6.38	59.00	816.73 ab
(g17) MC 35.7.5	6.50	60.23	435.12 ab
(g18) MC 9.2.7	6.60	63.60	283.03
(g19) MC 27.12.6	7.02	68.80	1079.52
(g20) MC 11.4.5	6.68	64.80	557.11
(g21) MC35.7.6	5.24	64.00	501.66
(g22) MC 27.12.4	6.32	56.60	860.15
(g23) *Mawar* (a)	3.44	63.67	186.78
(g24) *Chung* (b)	3.73	48.53	331.08
NP LSD (5%)	3.15	18.81	12.91

Note: Values in the same columns followed by the same letters (ab) present a significantly different condition with comparative varieties of *Mawar* (a) and *Chung* (b), following the LSD test of 0.05.

The heritability analysis results in Table 7 showed that the productivity character obtained the highest heritability rate (99.93%), while stem diameter presents the lowest heritability rate. Following the height category, characters that can be considered as selective characters are plant height, dichotomic height, number of branches, flowering period, harvesting period, number of fruit bunches, number of fruits, fruit length, fruit diameter, fruit weight, and productivity level.

Table 7. Heritability value of tomato strains from the *Mawar* × *Chung* heritability product

No.	Character	Heritability	Category
1.	Plant height	95.99	High
2.	Dichotomic height	83.37	High
3.	Stem diameter	-7.05	Low
4.	Number of branches	53.50	High
5.	Flowering period	89.96	High
6.	Harvesting period	91.62	High
7.	Number of flowers per bunch	8.35	Low
8.	Number of fruits per bunch	-5.24	Low
9.	Number of fruit bunches	72.61	High
10.	Number of fruits	98.85	High
11.	Fruit length	56.00	High
12.	Fruit thickness	7.29	Low
13.	Fruit diameter	54.87	High
14.	Fruit weight	82.97	High
15.	Number of cavities	20.08	Middle
16.	Total dissolved solids (brix)	-6.15	Low
17.	Number of seeds per fruit	-2.53	Low
18.	Productivity	99.93	High

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

The correlation analysis results in Table 8 are focused on productivity as the main character. These results describe the characters that are significantly and positively correlated to productivity are plant height, stem diameter, number of branches, and number of fruits, while characters that have no significant correlation to productivity character are dichotomic height, flowering period, harvesting period, number of flowers per bunch, number fruits per bunch, number of fruit bunches, fruit length, fruit thickness, fruit diameter, fruit weight, number of cavities, total dissolved solids (brix), and number of seeds per fruit.

Table 8. Correlation Analysis

	TT	TD	DIB	JC	UB	UP	JBG	JBH	JT	JBHT	PB	TB	DB	BB	JR	KB	JBP	PROD
TT	1.00																	
TD	0.54*	1.00																
DIB	0.37tn	0.04tn	1.00															
JC	0.70**	0.46*	0.56**	1.00														
UB	0.16tn	0.02tn	-0.05tn	-0.07tn	1.00													
UP	0.42tn	0.23tn	0.19tn	0.10tn	-0.16tn	1.00												
JBG	0.77**	0.69**	0.24tn	0.73**	-0.02tn	0.11tn	1.00											
JBH	0.37tn	0.77**	0.11tn	0.53*	-0.02tn	-0.07tn	0.63**	1.00										
JT	0.16tn	0.30tn	0.15tn	0.35tn	-0.26tn	-0.01tn	0.33tn	0.60**	1.00									
JBHT	0.25tn	-0.13tn	0.75**	0.48*	-0.02tn	0.12tn	0.08tn	-0.11tn	-0.13tn	1.00								
PB	0.67**	0.49*	0.29tn	0.70**	0.18tn	-0.11tn	0.77**	0.68**	0.49*	0.08tn	1.00							
TB	0.67**	0.37tn	0.30tn	0.64**	-0.31tn	0.20tn	0.60**	0.39tn	0.34tn	0.06tn	0.59**	1.00						
DB	0.75**	0.51*	0.29tn	0.74**	0.19tn	0.05tn	0.76**	0.68**	0.54**	0.07tn	0.94**	0.59**	1.00					
BB	0.62**	0.60**	0.37tn	0.75**	0.26tn	0.10tn	0.57**	0.66**	0.39tn	0.23tn	0.72**	0.56**	0.73**	1.00				
JR	0.36tn	0.47*	0.37tn	0.44*	0.41tn	-0.09tn	0.39tn	0.63**	0.52*	0.10tn	0.64**	0.18tn	0.67**	0.67**	1.00			
KB	-0.44*	-0.28tn	0.11tn	-0.02tn	-0.31tn	-0.08tn	-0.54**	-0.20tn	-0.08tn	0.19tn	-0.57**	-0.12tn	-0.48*	-0.13tn	-0.19tn	1.00		
JBP	0.07tn	0.20tn	0.09tn	0.32tn	0.19tn	-0.01tn	0.11tn	0.23tn	0.43*	0.20tn	0.27tn	0.06tn	0.24tn	0.61**	0.51*	0.03tn	1.00	
PROD	0.54**	0.00tn	0.79**	0.65**	-0.03tn	0.29tn	0.31tn	0.02tn	0.03tn	0.90**	0.26tn	0.30tn	0.31tn	0.32tn	0.14tn	0.06tn	0.09tn	1.00

Note: TT: plant height, TD: dichotomic height, DIB: stem diameter, JC: number of branches, UB: flowering period, UP: harvesting period, JBG: number of flowers per bunch, JBH: number of fruits per bunch, JT: number of fruit bunches, JBHT: number of fruits, PB: fruit length, TB: fruit thickness, DB: fruit diameter, BB: fruit weight, JR: number of cavities, KB: total dissolved solids (brix), JBP: number of seeds per fruit, PROD: productivity.

The analysis of variance results showed that different genotypes had a highly significant effect on the characteristics of plant height, dichotomic height, number of branches, flowering period, harvesting period, number of fruit bunches, number of fruits, fruit length, fruit diameter, fruit weight, and productivity. In contrast, stem diameter, number of flowers, number of fruits, fruit thickness, number of cavities, brix content, and number of seeds per fruit had no significant effect in each genotype.

Different genotypes have a significant effect on plant height and dichotomic height. Almost all genotypes obtained significantly different results to the comparative varieties, except in the MC 9.2.4 (g1), MC 38.8.8 (g1), MC 27.12.6 (g19), MC 11.4.5 (g20), MC 35.7.6 (g21), MC 27.12.4 (g22) for plant height character and MC 9.2.4 (g1), MC 8.3.1 (g8), MC 9.2.6 (g12), MC 9.2.7 (g18), MC 27.12.6 (g19), MC 11.4.5 (g20), MC35.7.6 (g21), MC 27.12.4 (g22) for dichotomic height character. Different results are influenced by genetic differences in each genotype due to *Mawar* × *Chung* cross-breeding program. These results were in accordance with Nazirwan, A., Wahyudi & Dulbari (2014), who stated that differences in plant height were influenced by genetic factors of each line/number and environment, such as light intensity, temperature, and nutrient availability.

The number of branches affects tomato growth and production. Each branch influences the number of leaves on the plant used in photosynthesis to produce food reserves. The best number of branches in MC 10.10.2 (g6) significantly differed from two parents as comparative varieties. According to Nasrulloh A.T., W. Mutiarawati & Sutari (2016), the number of branches is directly proportional to the number of leaves, so many branches will produce a greater number of leaves, where the photosynthesis process occurs. Along with the results, the number of branches also influences the formation of tomato plant bunches, whereas MC 10.10.2 (g6) also obtained the best number of fruit bunches. This condition was similar to Syuriani E.E., J. Kartahadimaja, M.F. Sari, & B. Purwanto (2021), who stated that a large number of primary branches could positively contribute to the number of flower bunches.

The characteristics of flowering period and harvesting period for each genotype showed different results. Flowering period started from 29 to 53 HST, and harvesting period started from 62 to 95 HST due to genetic differences in each genotype. According to (Ester et al., 2014), the different flowering periods and harvesting periods are thought to be due to the nature of the plant genotype itself. The genetic characteristics of the plant influence the period from which the flowers appear until the fruit ripens. Different flowering periods and harvesting periods of the tomato genotypes were caused by genetic factors that could influence each genotype's growth period, resulting in differences in the harvesting period for each genotype.

A proper fruit shape is determined by the fruit length, thickness, and diameter characters. The results showed that fruit length was 27.00-44.26 mm, fruit thickness was 22.08-29.98 mm, and fruit diameter was 41.54-49.46 mm. These results indicate that almost all strains from the *Mawar* × *Chung* cross-breeding program have relatively medium to large fruit sizes. However, one of the parents is a cherry tomato species. The preferred quality criteria for tomatoes in the modern market are medium-sized tomatoes with a slightly round shape (Irsyad E.P., A. Yoesdiarti & H. Miftah, 2018). The MC 10.10.2 strain (g6) obtained the best fruit thickness, length, and diameter for the fruit shape characters. Rofidah and Respatijarti (2016) added that the characteristics of fruit length and diameter were positively correlated with the fruit weight, so longer fruit produces larger fruit diameter and greater fruit weight.

Different genotypes also significantly affected the number of fruits per plant, as the MC 10.10.2 (g6) obtained the highest number of fruits per plant at 191 units. In line with these results, the MC 10.10.2 (g6) strain also presents the highest number of cavities with an average value of 10.00. According to Hidayat (1995), the number of cavities in each fruit can determine the number of seeds per fruit, which are useful in cultivating and propagating the plant.

The number of fruits per plant is also closely related to the fruit weight characteristics, whereas these two are directly proportional. The MC 10.10.2 (g6) also obtained the best fruit weight at 40.94 g. Haydar A., M.A. Mandal, M.B. Ahmed, M.M. Hannan, R. Karim, M. Razvy, U.K. Roy & M. Salahin (2007) and Hidayatullah S.A. Jatoi, A. Gafoor & T. Mahmood (2008) reported that the number of fruits per plant could highly influence the fruit weight of tomato plants. Moreover, other characteristics were related to fruit weight, namely fruit shape (fruit thickness, length, and diameter) and number of cavities, which are directly proportional. According to Ester (D., A. Adiwirman, & E. Zuhry 2014), the smaller the fruit size and the lower the number of fruit cavities, the lower the fruit weight per plant, and *vice versa*. However, this condition is also influenced by the plant genetics. According to Comlekcioghi (2010), the weight of fruit yield depends on the cultivar that will be developed, following its genetic potential, which can adapt to a particular environment.

The production characters showed that the MC 10.10.2 (g6) obtained the best productivity at 1432.64 g. These results are in line with the results obtained for other characters, namely number of branches, number of flowers per bunch, number of fruits per bunch, number of fruit bunches, number of fruits, fruit thickness, fruit length, fruit diameter, fruit weight, and number of cavities. A genotype that presents the best results in almost all observed characters indicates that the genotype has good genetics and adaptability. The adaptable genotype to the environment influences the growth and yield of tomato plants. Genotypes that can adapt more quickly to their environment tend to respond better to growth and yield than genotypes that slowly adapt, although having the same growth ability (Ginting, 1991).

In the heritability analysis, the characteristics of plant height, dichotomic height, number of branches, flowering period, harvesting period, number of fruit bunches, number of fruits, fruit length, fruit diameter, fruit weight, and productivity are categorized as high heritability rate. These results indicate that genetic factors influence characters with high heritability rates more than environmental factors. The high heritability rate describes a high relationship between genotype and phenotype, which suggests that the environment has less influence than genetic factors (Handayani and Hidayat, 2012). The upregulated heritability rate is caused by the environmental variation decline or genetic variation increase, thus making it easier for a character to be inherited in the next generation, as the genetic factors are more significant than environmental factors (Sutarman, 2013; Mangoendidjojo, 2012; Sami R.A., M.Y. Yeye, I.S. Usman, L.B. Hassan, & M. Usman, 2013; Syukur M., S. Sujiprihati & R. Yunianti, 2015). A high heritability rate also indicates that the selection progress can be achieved, and strains produced can rapidly be prepared to become new superior varieties (Saputry D.H., A. Daryanto, M.R.A. Istiqlal & S. Widiyanto, 2022). As selection progress increases, the results are better than those of the previous generation (Jameela H., A. Sugiharto, A., & A. Soegiantor, 2012).

The correlation analysis is carried out to determine characters closely related to the main character (productivity). Four characters have a significantly positive correlation with the main character, namely plant height (0.54**), stem diameter (0.79**), number of branches (0.65**), and number of fruits (0.90**). These characters can be used as standards or considerations in determining the best tomato genotype in this study. Therefore, strain selection can be based on plant height, stem diameter, number of branches, and number of fruits to produce a high productivity level. This concept has also been reported previously by Sabouri H., B. Rabieim & M. Fazlalipour (2008), Khapte and Jansirani (2014), Kumar V., N. Koshta, N. Sohgaura, & G.K. Koutu (2014), Mustafa M., M. Syukur, S.H. Sutjahjo & Sobir (2019), and Akbar M.R., B.S. Purwoko, I.S. Dewi, W.B. Suwarno, Sugiyanta & M.F. Anshori (2021).

D. Conclusion

A strain produced from the *Mawar* × *Chung* cross-breeding program with the best productivity level was obtained from the MC 10.10.6 (g6) with an average productivity level of 1432.64 g and was significantly different from its two parents. Characters with high heritability values are plant height, dichotomic height, number of branches, flowering period, harvesting period, number of fruit bunches, number of fruits, fruit length, fruit diameter, fruit weight, and productivity level. Four characters are positively correlated with the productivity level, namely plant height, stem diameter, number of branches, and number of fruits.

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