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Interaction genetic x environment putatif mutant lines tomato M5 on two agro ecosystems

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Abstract

Tomato is a very important horticultural commodities in Indonesian. Tomato plants grow in the Highlands to the lowlands. Tomato fruit production in the Highlands is higher than production in the lowlands due to interaction genetic x environment. The existence of interactions genetic x environment causes a change of the production of a mutant line. The aim of this research is to know the interaction genetic x environment on putatif mutant lines and The lines which has a great adaptation on two test environments. The research was carried out at the Experimental Farm, Lembang, Bandung and at the Experimental Farm, Dramaga, Bogor. The genetic material used as many as 17 putatif mutant lines M5 and 6 comparisons are Opal, Berlian, Zamrud, Tora, Ratna, and Aceh 5. The experiment results show that the presence of interaction genetic x environment effect on real characters of plant height, fruit weight per plant, percentage weight of cracking fruit, percentage number of cracking fruit, the number fruit per plant, and c raking fruit index. The most percentage weight of cracking fruitat Bogor about 0.00-85.34% compared to that in the Lembang about 0.00-19.51%. The line M5/495 Berlian (U2) 4-1-2-5 has the highest productivity and can adapt in a test environment. The putatif mutan lines such as M5/495 GL 2-8-10-5 (U2) 5, M5/495 Lombok 1-2-2-7 (U1), M5/495 6-4-3-7 Kefa (U1), M5/495 STBBK 1-2-3-2 (U3), M5/495 STBGL 1-2-3-7 (U3), M5/990 STBGL 1-2-9-1 (U2), and M5/990 Kudamati 1-1-1-5 (U3) has a good environment adaptability test of Bogor.

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Introduction

Tomato is a very important horticultural commodities in Indonesia. Tomatoes can grow in the Highlands to the lowlands. BPS, (2015) stated that the tomato production in Indonesia by 2014 amounted to 915.987 tons and suffered in the previous year amounted to 992,780 tonnes. The productivity of the tomato plants in the Highlands as much 26.60 ton ha^{-1} while in the lowlands as 6 tons ha^{-1} (Purwati, 2007). Lestari *et al.,* (2010) States that the existence of interaction the G x E on fruit weight per plant showed that genotypes with high yield potential in a particular location is not necessarily the result will remain high at other locations.

The production of tomatoes in the lowlands is less than that of highland production due to extreme climate change and unsuitable production environments for tomato plants. Decline in quality and quantity of fruit as one cause of a breeder to assemble superior varieties. The assembly of high yielding and good performance varieties are the main target of tomato plant breeders in the lowlands so as to produce the same production as tomato cultivation in the highlands. High yielding and good performance varieties are desirable to everyone but there are constraints that are genetic x environmental influences.

The genetic influence of the environment causes changes in tomato production, making it difficult for plant breeders to select the results. The existence of genetic and environmental interactions will impact on the performance of tomatoes such cracking fruit in the lowlands in addition to the role of genetic influences also affect the crops. Interactions genetic x environmental do not exist indicate the stability of a variety so that the variety can be planted in all areas.

In the absence of interaction genetic and environmental effects so that breeder may select suitable lines in the highlands or in the lowlands or in two environments. The aim of this research is to know the interaction genetic x environment on putatif mutant lines M5 tomato that have a good adaptations on two test environments.

Interactions genetic × environment are complex and affects the process of selection and testing superior lines (Rao *et al.,* 2011). Expansion of area planting tomatoes in low land causes dropping and going cracking fruit. Cracking fruit caused by genetic, environment, and genetic x environment. Extreme environment changes such as drought and then rain so that an increase in moisture content and soil moisture is accompanied by a very large land temperatures dropped dramatically. Ohta *et al.,* (1997) stated that the weak cell permeability during moisture absorption and rapid nutrient at a time when the rainy season after the long dry season was not able to offset fruit skins cause the fruit undergoes cracking fruit. The nature of the resistance double gene (poligenic) was controlled by the cracking fruitare the dominant portion (Hernandes and Nassar, 1970). Genes controlling radial cracking fruit such as gen *cr cr* and *Ir Ir* (Young, 1959) whereas according to Phasar and Lambeth, (1960) that the resistance properties of the cracking fruit including quantitative trait controlled by genes of the major and minor genes. One way to obtain the fruit burst resistant genotypes with mutations. The mutation causes a change in the gene structure of chromosomes even ultimately lead to diversity on a population. The existence of diversity makes it easy to perform a selection on a superior character.

Material and methods

The research was carried out at the Experimental Balitsa, Lembang, Bandung, West Java (highland) with an altitude of 1250m above sea level as well as Experiment Leuwikopo IPB, Bogor, West Java (lowland) with an elevation of 196 m above sea level, the climate is wet in September - January 2016. The genetic material used is 17 genotype M5 gamma ray irradiation results among others M5/495 Lombok 1-9-2-9 (U2), M5/495 Lombok 1-9-2-4 (U1), M5/495 GL 2-8-10-5 (U2), M5/495 Lombok 1-2-2-7 (U1), M5/495 Lombok 4-1-3-2 (U1), M5/495 Lombok 4-1-3-7 (U3), M5/495 Kemir 1-4-7-8 (U2), M5/495 6-4-3-7 Kefa (U1), M5/495 1-2-2-10 CLN (U1), M5/495 STBBK 1-2-3-2 (U3) , M5/495 Berlian 4-1-2-5 (U2), M5/495 Aceh 5-4-10-6 (U2), M5/495 STBGL 1-2-3-7 (U3),

M5/990 STBGL 1-2-9-1 (U2), M5/990 Kudamati 1-1-1-5 (U3), M5/990 Lombok 1-5-1-5 (U2), and M5/990 Lombok 1-5-1-7 (U3) also six comparasions six Berlian, Opal, Ratna, Tora, Aceh 5, and Zamrud. The first stage in this study was the seedbed. The next routine maintenance includes fertilizing and watering the leaves. Leaf fertilization using fertilizer leaves (2g L^{-1}), and liquid NPK Mutiara fertilizers (2g L^{-1}) interval of one week. Cultivation with the making of the dike wall size 4 m x 1 m and 60 dike walls with a distance of planting 40 cm x 40 cm. Application of manure by as much as 12 tons ha^{-1} Urea fertilizer and 300 kg ha^{-1}, SP-36 500 kg ha^{-1}, KCl 300 kg ha^{-1} was done a week before planting. Seeds moved after appearing four strands of true leaves. Maintenance includes the stitching, cutting shoots water, fertilizing, watering, pest control and disease. Cutting shoots water on vegetative phase appears to bunches of flowers. Regular fertilizing is done every week with 250ml of solution of NPK fertilizer. Pest control and disease fungicides mankozeb 80 % or propineb 2 g L^{-1}, as well as the insecticide prevonofos with a dose of 2 ml L^{-1}. Harvesting is done for six times the harvest, when the tomatoes are already starting to change color to reddish. The characters are observed such high plants, flowering periode, harvesting periode, fruit weight per plant, percentage weight of cracking fruit, percentage number of cracking fruit, the number fruit per plant, and craking fruit index.

Percentage number of cracking fruit (% per plant).

Calculation of the percentage number of cracking fruit dehiscent by observing cracking fruit that the entire fruit is harvested, the cracking fruit calculated from six times the harvest. The percentage of the total number of fruit burst = (number of fruit burst)/(total pieces) x 100%.

The percentage of total number cracking fruit = $\frac{\text{number cracking fruit}}{\text{total amount of harvested fruits}} \times 100\%$

Craking fruit index

The value of the Skoring and the number cracking fruit per plant is used to get the craking fruit index (CFI). CFI = (Σ (ni x score)/Σn x maximum score) x 100%,

ni = number of fruit in the score to the-i (i = 0, 1, 2, 3, 4; maximum score = 4). Score 0 = no cracking fruit; 1 = a little cracking fruit (< 25%); 2 = undergoes cracking fruit (25% ≤ 50%); 3 = undergoes cracking fruit a bit heavy (50%-75%); 4 = undergoes cracking fruit weight (> 75%). Resistance criteria used are Highly Resistant (HR) if CFI = 0%; Resistant (R) If 0<CFI ≤ 5%; Rather Resistant (RR) if 5 < CFI ≤ 10%; Rather Susceptible (RS) if 10 < CFI ≤ 20%; Susceptible (S) if 20 < CFI ≤ 40% and Very Susceptible (VR) if CFI ≥ 40% (Djatmiko *et al.*, 2000; Purwati *et al.,* 2008; Faizah, 2010). Analysis using varian combined analysis conducted to know the influence of the environment against the experiment. Lines are fix model while the environments are random so that the varian combined analysis model used was the model mix. Linear Randomized Completely block Design (RCBD) model used is as follows (Table 1):

$Yijk = \mu + Lk + \beta i/Lk + Gj + (LG)kj + \varepsilon ijk$

Information:

Y_{ijk}	=	The observed value of the to-i, genotype to-j, environment to-k
μ	=	General average values
Lk	=	Environmental influence to-k (k = 1,2)
βi/Lk	=	The effect of repeat to i (1,2,3) in environmental (1,2)
Gj	=	The influence of genotype to-j (j = 1,2,3, ..., 23)
(LG)kj	=	The effect of interaction environment to-k with genotype to-j
Eijk	=	The effect of experimental error on environment to-k, genotype to-j, and repeat to- i (i = 1,2,3)

Result and discussion

Putatif mutant lines tomato M5 are tested an advanced generation of gamma ray irradiation results that from local tomatoes. Testing in two different environments in agro-ecosystem aiming to obtain information on interaction genetic x environment (G x E) so it can make it easier to identify a candidate breeding lines of superior (Dewi *et al.,* 2015). Information G x E is very useful for the development of a lines on all the desired environmental or development of lines specific to the target environment (Sherly *et al.,* 2013). Environment that is used for research on generation M5 are two different environments.

Average temperature ranges in lowland (Bogor) is higher than the highland (Lembang). The average temperature in Bogor on when the research revolves around 16.2-16.3°C while temperatures in lembang ranging between 11.4-19.5°C. Different environment conditions provide a great influence towards agronomic character and yield of a particular genotype on the environment. The influence of genotype, environment, interaction genetic x environment (GxE) effect on the phenotipic of plants tested. Vange *et al.*, (2014) States that the existence of interaction genetic x environment due to the difference in the two extreme environments. Interaction genetic x environment has no effect on real shows putatif mutant lines M5 tested at two environments (Lembang and Bogor) have relatively equal phenotipic. Gumelar *et al.,* (2016) stated that phenotipic relatively the same on two different test environments, these characters can be used as character selection. Limbongan, (2008) stated that stable varieties can be identified by the absence of interaction G x E so as to reduce the risk of environmental changes such as changes in weather, the level of soil fertility, pests, and diseases. The same genotype will give a different response because of the influence of the environment. The results of the experiment showed the presence of interaction genetic x environment effect on real characters of height plant, fruit weight per plant, percentage weight of cracking fruit, percentage number of cracking fruit, the number fruit per plant, and craking fruit index (Table 2).

Tabel 1. Analyze of combined varian (mix model) (Roy, 2005).

Source diversity	Degrees of free	Mean of square	Expected mean of square
Environment (E)	(l-1)	M5	$\sigma^2 + r g \sigma^2_e$
Ulangan/E	1(r-1)	M4	$\sigma^2 + g\ \sigma^2_{r/E}$
Galur (G)	(g-1)	M3	$\sigma^2 + r\sigma 2_{gE} + rE\sigma^2_g$
G x E	(l-1)(g-1)	M2	$\sigma^2 + r\sigma^2_{gE}$
Error(e)	(g-1) (r-1) ml	M1	σ^2

Keterangan: r = repeat, E = Environmet, g = genotype, $\sigma^2 g$= genotype varian, $\sigma^2 gl$ = interaction varian, σ^2 = error varian.

Plant Height

Character of height plant is one of the selection criteria. Character of height plant putatif mutant lines tomato M5 in Lembang revolves around 65.73-133.58 cm higher than the putatif mutant lines M5 tested in Bogor, around 60.03-100.73cm (Table 3). The height difference of the plant caused by environment conditions to grow accordingly as well as lower light intensity causes vegetative growth of plants become longer. Increased plant height then it will increase the fruit weight per plant, this is caused by the higher a plant then forms many branches so it will be a lot of flowers (Surtinah, 2007).

Table 2. Results of the analysis of the combined interaction G x E on agronomic characters putatif mutant lines M5 gamma ray irradiation in two agroecosystem.

Agronomic characters	Mean square Genetic (G) x Environmet (E)
Plant height	137.50**
Period flowering	25.79ns
Period harveting	5.40ns
Fruit weight per plant	449146.00**
Percentage weight of cracking fruit	1793.42**
Percentage number of cracking fruit	1744.76**
Number fruit per plant	109638.00**
Grade of fruit hardness	115749.00ns
Cracking fruit index	10358.00**
Productivity	283236.00ns

Description: * significantly different on the level 5%, ** = significantly different on the level 1%, ns= not significantly different.

Table 3. Mean value of plant height and the number fruit per plant of putatif mutant lines M5 on two agro ecosystem.

Lines	Plant height (cm)		Number fruit per plant	
	Lembang	Bogor	Lembang	Bogor
M5/495 Lombok 1-9-2-9 (U2)	83.47^{a-e-}	69.30^{a-e-}	52.64^{c+e+f+}	22.67
M5/495 Lombok 1-9-2-4 (U1)	87.24^{e-}	75.53^{e-}	52.73^{c+e+f+}	22.00
M5/495 GL 2-8-10-5 (U2)	121.55$^{a+b+c+d+f+f+}$	91.60^{b+c+d+}	50.34^{c+e+f+}	64.33^{a+}
M5/495 Lombok 1-2-2-7 (U1)	126.32$^{a+b+c+d+e+f+}$	91.83$^{b+c+d+f+}$	41.62^{f+}	56.00^{a+}
M5/495 Lombok 4-1-3-2 (U1)	65.73$^{a-b-d-f-\ e+f+}$	60.03^{a-e-f+}	23.83^{a-b-}	32.33
M5/495 Lombok 4-1-3-7 (U3)	78.51^{a-e-}	64.48^{a-e-}	40.02^{f+}	29.33
M5/495 Kemir 1-4-7-8 (U2)	65.93$^{a-b-d-e-f-}$	60.93^{a-e-}	48.53^{e+f+}	29.00
M5/495 Kefa 6-4-3-7 (U1)	133.58$^{a+b+c+d+e+f+}$	100.73$^{a+b+c+d+f+}$	49.36^{e+f+}	72.33^{a+}
M5/495 CLN 1-2-2-10 (U1)	108.75$^{b+c+d+f+}$	86.67^{c+}	43.60^{f+}	26.33
M5/495 STBBK 1-2-3-2 (U3)	113.63$^{b+c+d+f+}$	83.77^{c+}	61.29$^{c+d+e+f+}$	48.67^{a+}
M5/495 Berlian 4-1-2-5 (U2)	93.72^{c+}	75.90^{e-}	31.49^{b-}	12.00
M5/495 Aceh 5- 4-10-6 (U2)	93.94^{c+}	75.43^{e-}	29.68^{b-}	18.67
M5/495 STBGL 1-2-3-7 (U3)	119.07$^{a+b+c+d+f+}$	86.97^{c+d+f+}	64.49$^{c+d+e+f+}$	69.00^{a+}
M5/990 STBGL 1-2-9-1 (U2)	125.53$^{a+b+c+d+e+f+}$	91.10$^{b+c+d+f+}$	44.37^{f+}	56.33^{a+}
M5/990 Kudamati 1-1-1-5 (U3)	127.20$^{a+b+c+d+e+f+}$	92.10$^{b+c+d+f+}$	47.38^{e+f+}	42.00^{a+}
M5/990 Lombok 1-5-1-7 (U3)	99.87^{c+}	83.20^{c+}	55.07$^{c+d+e+f+}$	24.67
M5/990 Lombok 1-5-1-5 (U2)	92.16	78.61	56.20$^{c+d+e+f+}$	8.00
Opal	99.33	84.67	47.08	10.33
Berlian	86.07	73.9	56.40	23.67
Tora	77.27	67.53	30.23	22.33
Zamrud	89.47	72.37	35.01	24.50
Ratna	106.63	91.5	25.53	17.50
Aceh 5	90.12	71.07	20.19	21.50
Rata-rata	99.35A	79.53B	43.79A	31.56B

The numbers followed by small letters on the same column is the result of a Dunnet test extent 5% read vertically on the same character. +/-, b+/-, c+/-, d+/-, e+/-, f+/- = real more or less different than Opal (a), Berlian (b), Tora (c), Zamrud (d), Ratna (e), and Aceh 5 (f). Capital letters on a line of the same character to t test levels 5% alpha.

Fruit Weight per Plant

Fruit weight per plant is one of the most important selection criteria in plant breeding. Fruit weight per plant putatif mutant lines tomato M5 that tested in Lembang ranging between 592.43-1380.95g as well as higher putatif mutant lines M5 tested in Bogor that range 470.32-1686.35 g (Table 5).

This is due to the absence of light intensity that so much buildup results fotosintat in Lembang. Salisbury and Ross, (1995) stated that an increase in temperature causes an increase in the rate of photosynthesis and translocation.

Percentage Weight of Cracking Fruit

Cracking fruit caused by genetic and environmental. Genetic factors in the form of a fruit thin cell walls, while environmental factors in the form of sudden weather changes by the time the fruit filling and lacking the elements of Ca. Percentage weight of cracking fruit most heavily in Bogor range 0.00-85.34% compared to that in Lembang.

Ranging from 0.00-19.00% (Table 5) due at the time of charging the fruit of sudden weather changes for a few days while the skin of the fruit cannot withstand increased turgor pressure so that the occurrence of cracking fruit. The addition of calcium shall improve the structure and function of the cell wall, cell membrane, and cell metabolism (Naradisorn, 1995).

The decline cracking fruit plant pears is made possible because of the increased strength of the wall because of the direct interaction between the content of pectin which can increase the power of the cell wall (Gerasopoulus and Richardson, 1999).

Percentage Number of Cracking Fruit

Percentage number of cracking fruit of putatif mutant lines tomato M5 in Bogor range (0.00-91.39%) as well as higher than putatif mutant lines tomato M5 in Lembang (0.00-54.52%) (Table 4).

The abundance of percentage number of cracking fruit in Bogor happened because at the time the fruit filling period an increase in rainfall in the month of

November 585.0 mm the previous month of 397.8 mm while in the test environment.

Lembang unchanged high rainfall. In addition the levels of calcium in the test environment of Bogor is lower than the test environment Lembang thereby encouraging the occurrence of cracking fruit. The same thing explained in the research Ichwan *et al.,* (2014) stated that cracking fruit on duku fruit is caused by lack of calcium macro nutrient elements.

Table 4. Mean value of persentage number of cracking fruit and craking fruit index of putatif mutant lines M5 on two agro ecosystem.

Lines	Percentage number of cracking fruit		Craking fruit index	
	Lembang	Bogor	Lembang	Bogor
M5/495 Lombok 1-9-2-9 (U2)	0.00	8.48	0.00	15.13^{d-e-}
M5/495 Lombok 1-9-2-4 (U1)	0.00	0.00	0.00	0.00^{d-e-}
M5/495 GL 2-8-10-5 (U2)	6.58	63.01	36.74	190.63
M5/495 Lombok 1-2-2-7 (U1)	5.70	91.39^{d+}	20.55	236.18^{c+}
M5/495 Lombok 4-1-3-2 (U1)	54.52^{a+b+f+}	33.21	71.87	67.58
M5/495 Lombok 4-1-3-7 (U3)	19.51	12.14	42.45	25.00
M5/495 Kemir 1-4-7-8 (U2)	8.39	15.52	10.54	16.52
M5/495 Kefa 6-4-3-7 (U1)	7.17	90.62^{d+f+}	28.42	275.09^{c+}
M5/495 CLN 1-2-2-10 (U1)	4.50	52.22	21.81	21.24
M5/495 STBBK 1-2-3-2 (U3)	3.75	23.62	10.98	66.34
M5/495 Berlian 4-1-2-5 (U2)	11.03	71.14	37.63	138.55
M5/495 Aceh 5- 4-10-6 (U2)	11.84	0.00	16.37	25.00
M5/495 STBGL 1-2-3-7 (U3)	3.20	71.40	11.69	206.63^{c+}
M5/990 STBGL 1-2-9-1 (U2)	4.56	84.11^{f+}	23.29	220.68^{c+}
M5/990 Kudamati 1-1-1-5 (U3)	5.02	88.87^{f+}	19.26	150.90
M5/990 Lombok 1-5-1-7 (U3)	1.70	5.56	1.39	21.98
M5/990 Lombok 1-5-1-5 (U2)	2.97	0.00	0.00	0.00^{d-e-}
Opal	6.61	0.00	7.85	0.00
Berlian	13.55	83.68	37.82	69.43
Tora	27.58	16.67	28.17	32.87
Zamrud	12.25	6.23	36.54	121.73
Ratna	17.54	18.26	22.44	32.35
Aceh 5	3.52	7.71	0.00	0.00
Rata-rata	9.83B	33.48A	20.84B	76.59A

The numbers followed by small letters on the same column is the result of a Dunnet test extent 5% read vertically on the same character. +/-, b+/-, c+/-, d+/-, e+/-, f+/- = real more or less different than Opal (a), Berlian (b), Tora (c), Zamrud (d), Ratna (e), and Aceh 5 (f). Capital letters on a line of the same character to t test levels 5% alpha.

The Number Fruit per Plant

The number fruit per plant high will increase yield a commodity. The large number of bunches of flowers become fruits as one of the success factors of the occurrence of an increased the number fruit per plant and the appropriate temperature also affect the success of the formation of the fruit.

Putatif Mutan line that tested in Lembang has meanthe number fruit per plant ranged 23.83-82.00 higher than putatif mutant lines M5 tested in Bogor revolves around 12.00-72.33 (Table 3).

Craking fruit index

The cracking fruit index shows the severity of the fruit that undergoes cracking fruit.

The higher craking fruit index then the greater rate of occurrence of cracking fruit. Testing putatif mutant lines tomato M5 tested in Bogor on the character craking fruit index ranges from 0.00-275.09% higher than lembang is 0.00-71.87% (Table 4). The value of the craking fruit index putatif mutant lines M5 in two agro ecosystems obtained different results with different test environments. The putatif mutant lines tomato M5 which belongs to the category of highly resistant in Lembang such as M5/495 Lombok 1-9-2-9 (U2), M5/495 Lombok 1-9-2-4 (U1), and M5/990 Lombok 1-5-1-5 (U2) as well as the M5/990 Lombok 1-5-1-7 (U3) including resistant category. The putatif mutant lines tomato M5 tested in Bogor obtained highly resistant lines such as M5/495 Lombok 1-9-2-4 (U1) and the M5/990 Lombok 1-5-1-5 (U2) (Table 6).

Table 5. Mean value of fruit weight per plant and percentage weight of cracking fruit of putatif mutant lines M5 on two agro ecosystem.

Galur	Fruit weight per plant (g)		Percentage weight of cracking fruit %)	
	Lembang	Bogor	Lembang	Bogor
M5/495 Lombok 1-9-2-9 (U2)	1375.61^{f+}	470.32^{a+}	6.38	7.99
M5/495 Lombok 1-9-2-4 (U1)	1183.91^{f+}	594.84^{a+}	0.00	0.00
M5/495 GL 2-8-10-5 (U2)	855.68^{f+}	1203.60^{a+}	10.77	84.08^{a+e+}
M5/495 Lombok 1-2-2-7 (U1)	592.43^{a-e-}	1608.30^{a+}	10.66	73.29^{a+e+}
M5/495 Lombok 4-1-3-2 (U1)	695.88^{f+}	662.04^{a+}	49.26^{a+b+d+}	27.80^{a+e+}
M5/495 Lombok 4-1-3-7 (U3)	846.53^{f+}	689.78^{a+}	19.11^{a+}	39.14^{a+e+}
M5/495 Kemir 1-4-7-8 (U2)	1177.59^{f+}	675.56^{a+}	9.31	21.01^{a+e+}
M5/495 Kefa 6-4-3-7 (U1)	988.50^{f+}	1571.50^{a+}	8.44	82.61^{a+e+}
M5/495 CLN 1-2-2-10 (U1)	1300.81^{f+}	570.97	2.44^{c-d-f-}	51.44^{a+e+}
M5/495 STBBK 1-2-3-2 (U3)	753.93^{f+}	900.04^{a+}	4.52^{c-}	34.34^{a+e+}
M5/495 Berlian 4-1-2-5 (U2)	1380.95^{f+}	948.48^{a+}	15.44^{a+}	85.34^{a+e+}
M5/495 Aceh 5- 4-10-6 (U2)	1010.22^{f+}	569.53	16.03^{a+}	0.00
M5/495 STBGL 1-2-3-7 (U3)	849.20^{f+}	1686.35^{a+}	6.62^{c-}	79.58^{a+e+}
M5/990 STBGL 1-2-9-1 (U2)	765.43^{f+}	1059.73^{a+}	8.91	78.69^{a+e+}
M5/990 Kudamati 1-1-1-5 (U3)	966.99^{f+}	1267.83^{a+}	10.46	71.80^{a+e+-}
M5/990 Lombok 1-5-1-7 (U3)	1370.95^{f+}	755.88^{a+}	1.35$^{c-d-e-f-}$	7.08
M5/990 Lombok 1-5-1-5 (U2)	1327.97^{f+}	145.64^{d-f-}	0.00	0.00
Opal	1266.10	246.33	3.58	0.00
Berlian	1070.86	683.35	15.21	48.55
Tora	832.69	800.80	26.29	20.02
Zamrud	910.91	526.74	11.39	100.00
Ratna	1219.98	992.30	13.56	28.78
Aceh 5	116.96	552.56	20.11	0.00
Rata-rata	993.92A	808.06B	10.73B	34.30A

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Table 6. Craking fruit index of putatif mutant lines M5 on two agro-ecosystems.

Lines	Craking fruit index			
	Lembang	Resistance level	Bogor	Resistance level
M5/495 Lombok 1-9-2-9 (U2)	0.00	HR	15.13	RS
M5/495 Lombok 1-9-2-4 (U1)	0.00	HR	0.00	HR
M5/495 GL 2-8-10-5 (U2)	36.74	S	190.63	VS
M5/495 Lombok 1-2-2-7 (U1)	20.55	S	236.18	VS
M5/495 Lombok 4-1-3-2 (U1)	71.87	VS	67.58	VS
M5/495 Lombok 4-1-3-7 (U3)	42.45	VS	25.00	S
M5/495 Kemir 1-4-7-8 (U2)	10.54	RS	16.52	RS
M5/495 Kefa 6-4-3-7 (U1)	28.42	S	275.09	VS
M5/495 CLN 1-2-2-10 (U1)	21.81	S	21.24	S
M5/495 STBBK 1-2-3-2 (U3)	10.98	RS	66.34	VS
M5/495 Berlian 4-1-2-5 (U2)	37.63	S	138.55	VS
M5/495 Aceh 5- 4-10-6 (U2)	16.37	RS	25.00	S
M5/495 STBGL 1-2-3-7 (U3)	11.69	RS	206.63	S
M5/990 STBGL 1-2-9-1 (U2)	23.29	R	220.68	S
M5/990 Kudamati 1-1-1-5 (U3)	19.26	RS	150.90	VS
M5/990 Lombok 1-5-1-7 (U3)	1.39	R	21.98	S
M5/990 Lombok 1-5-1-5 (U2)	0.00	HR	0.00	HR
Opal	7.85	RR	0.00	HR
Berlian	37.82	S	69.43	VS
Tora	28.17	S	32.87	S
Zamrud	36.54	S	121.73	VS
Ratna	22.44	S	32.35	S
Aceh 5	0.00	HR	0.00	HR

Information: Highly Resistant (HR), Resistant (R), Rather Resistant (RR), Rather Susceptible (RS), Susceptible (S), Very Susceptible (VR).

Sutjahjo *et al.*, (2015) stated the weather conditions effect on the quality of tomato fruit. High temperature conditions can cause damage to the fruit, that led to cracks or rind called cracking. Tomatoes that have craking fruit index the highest fruit causes fruit fast stinking same as research Kong *et al.*, (2013) stated that the stinking in the fresh figs comes from the side of the skin cracks caused by temperature above 20°C while according to Usenik *et al.,* (2005) and Simon, (2006) stated that fruit craking will increase at a time when the process of ripening fruit. Cracking fruit type concentric with the lowest score will be the same as the medium-high score on the radial type so that cracking fruit type concentric causes more rapid stinking fruit tomato. The research indicates that many radial cracking fruit of fruit flattened while the type craking a lot of concentric of fruit round. The higher craking fruit index score can damage the fruit due to the higher carcking fruit. Cracking appearance and fruit occur is one of the three types of cracking fruit. The third type of cracking that occurs between other fruit 1) cracking fruit near the base of the fruit, 2) apical part fruit dehiscent fruit, and 3) cracking fruit that happened the side of fruit (Measham, 2011). The putatif mutant lines tomato M5 tested in Bogor many experienced rupture of fruit types 1 and type 2 while in Lembang a lot of fruit type 1.

Evaluation of the influence interaction Genetic × Environment Putatif Mutant Lines M5 in two of agro ecosystem

There is a difference in ranking putatif mutant lines M5 tested in two agroecosystem based on the productivity. The appearance of the different phenotipic of the same lines caused by interaction genetic x environment (Amare *et al.,* 2015).

The results of the test putatif mutant lines M5 tested at two agroecosystem caused ranking changes so that it will be difficult for breeder in determining the appropriate lines. Same of thing on the research of Pabendon *et al.* (2012) stated that interaction genetic x environment will benefit the variety if there is no change in the rankings. The highest productivity ranking in test environment Lembang is M5/495 Berlian 4-1-2-5 (U2), whereas the rankings of the test environment in Bogor productivity dropped to number eight. The lines the M5/495 Berlian (U2) 4-1-2-5 has the highest productivity and can adapt to the environment of test Lembang (Table 6)

Table 7. Ranking changes productivity character putatif mutant lines M5 on two agro-ecosystems.

Lines	Ranking	
	Lembang	Bogor
M5/495 Lombok 1-9-2-9 (U2)	02	21
M5/495 Lombok 1-9-2-4 (U1)	08	16
M5/495 GL 2-8-10-5 (U2)	15	05
M5/495 Lombok 1-2-2-7 (U1)	22	02
M5/495 Lombok 4-1-3-2 (U1)	21	15
M5/495 Lombok 4-1-3-7 (U3)	17	12
M5/495 Kemir 1-4-7-8 (U2)	09	14
M5/495 Kefa 6-4-3-7 (U1)	12	03
M5/495 CLN 1-2-2-10 (U1)	05	17
M5/495 STBBK 1-2-3-2 (U3)	20	09
M5/495 Berlian 4-1-2-5 (U2)	01	08
M5/495 Aceh 5- 4-10-6 (U2)	11	18
M5/495 STBGL 1-2-3-7 (U3)	16	01
M5/990 STBGL 1-2-9-1 (U2)	19	06
M5/990 Kudamati 1-1-1-5 (U3)	13	04
M5/990 Lombok 1-5-1-7 (U3)	03	11
M5/990 Lombok 1-5-1-5 (U2)	04	23
Opal	06	22
Berlian	10	13
Tora	18	10
Zamrud	14	20
Ratna	07	07
Aceh 5	23	19

The putatif mutant lines tomato M5 with rounded fruit shape fall into the five highest ranks in Lembang as M5/495 Berlian 4-1-2-5 (U2), M5/495 Lombok 1-9-2-9 (U2), M5/990 Lombok 1-5-1-7 (U3), M5/990 Lombok 1-5-1-5 (U2), and M5/495 CLN 1-2-2-10 (U1) but if planted in Bogor suffered a significant ratings change. The putatif mutant lines M5 circular fruit has a good adaptation in the Lembang. The same thing happened on most of the putatif mutant lines tomato M5 with flat fruit shape has a low rating Lembang as M5/495 GL 2-8-10-5 (U2) 5, M5/495 Lombok 1-2-2-7 (U1), M5/495 6-4-3-7 Kefa (U1), M5/495 STBBK 1-2-3-2 (U3), M5/495 STBGL 1-2-3-7 (U3), M5/990 STBGL 1-2-9-1 (U2), and M5/990 Kudamati 1-1-1-5 (U3) but the lines increase whether the are very significant in Bogor so they have a good adaptation in Bogor. Distinction of ranking characters of productivity shows that the putatif mutant lines tomato M5 have a wide diversity of adaptation (Table 7) (Fig. 1).

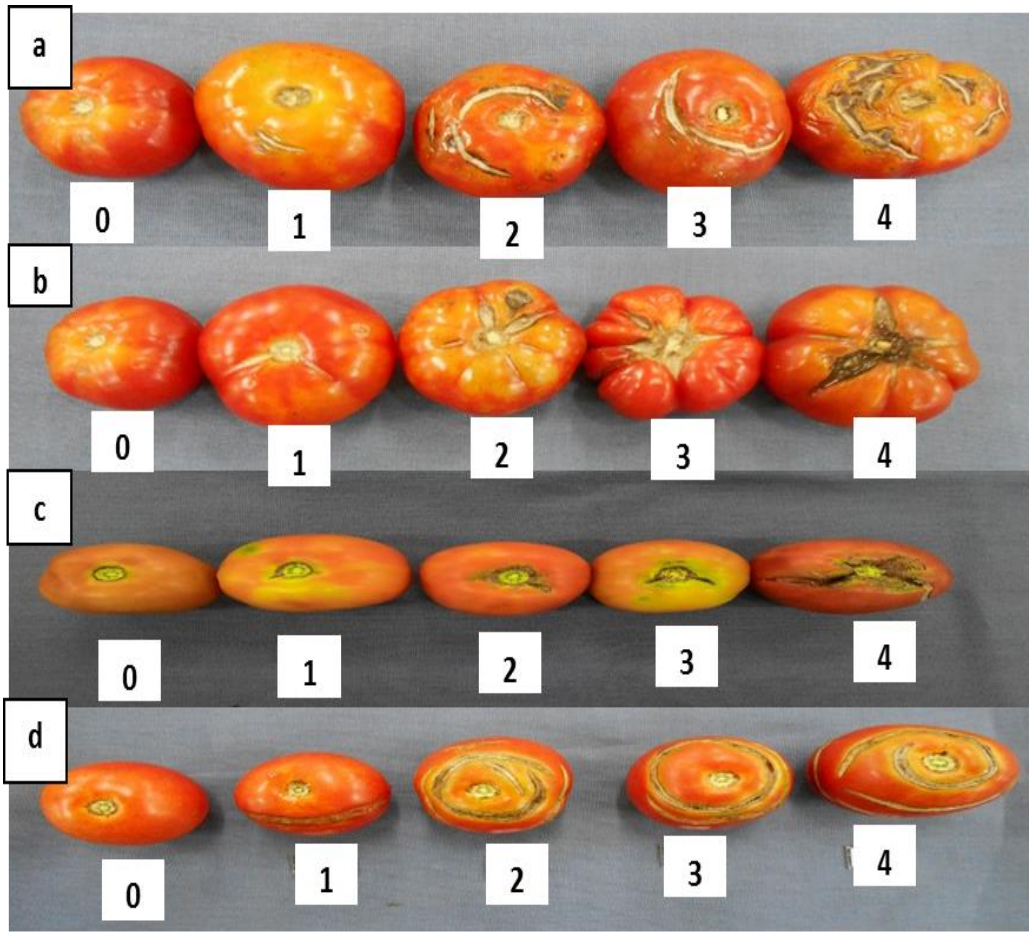

Fig. 1. The The appearance cracking fruit type (a) concentric dan (b) radial of flat fruit, (c) radial (d) concentric of round fruit.

Conclusion

The appearance of the different phenotipic of the same lines caused by interaction genetic x environment. The experiment results show that the presence of interaction genetic x environment effect on real characters of plant height, fruit weight per plant, percentage weight of cracking fruit, percentage number of cracking fruit, the number fruit per plant, and craking fruit index. Character of cracking fruit on the test environment of Bogor about 0.00–85.34% and higher than the environment Lembang about 0.00-19.00%.

The line the M5/495 Berlian 4-1-2-5 (U2) has the highest productivity and can adapt on Lembang. The lines such as M5/495 GL 2-8-10-5 (U2) 5, M5/495

Lombok 1-2-2-7 (U1), M5/495 6-4-3-7 Kefa (U1), M5/495 STBBK 1-2-3-2 (U3), M5/495 STBGL 1-2-3-7 (U3), M5/990 STBGL 1-2-9-1 (U2), and M5/990 Kudamati 1-1-1-5 (U3) has a good environment adaptability on Bogor. The character of period flowering, period harvesting, grad of fruit hardness, and productivity can be used as selection character because it has the same performance.

The putatif mutant lines tomato M5 which belongs to the category of highly resistant in Lembang such as M5/495 Lombok 1-9-2-9 (U2), M5/495 Lombok 1-9-2-4 (U1), and M5/990 Lombok 1-5-1-5 (U2) as well as the M5/990 Lombok 1-5-1-7 (U3) including resistant category. The putatif mutant lines tomato M5 tested in Bogor obtained highly resistant strains such as M5/495 Lombok 1-9-2-4 (U1) and the M5/990 Lombok 1-5-1-5 (U2).

Recommendation

The lines M5/495 Berlian 4-1-2-5 (U2) as a putatif mutant lines M5 can further testing was undertaken in all environments. Planting tomatoes in the lowlands had better pay attention to the crop season so that can reduce the occurrence of cracking fruit as well as choosing resistant lines craking fruit so that it can increase the production of tomatoes.

References

Amare K, Zeleke H, Geremew B. 2015. Variability for yield, yield related traits and association among traits of sorghum (*Sorghum bicolor* (L.) Moench) varieties in Wollo, Ethiopia. J Plant Breed Crop Sci **7(5),** 125-133.

Dewi SM, Sobir, Syukur M. 2015. Genotype x environment interaction of yield and yield components of 14 tomato genotypes in four lowland environments . J Agron Indonesia **43(1),** 59-65.

Djatmiko HA, Kharisun, Prihatiningsih N. 2000. Potensi *Trichoderma harzianum, Pseudomonas fluorescens* dan Zeolit Terhadap Penekanan Layu *Scelrotium*, Peningkatan Pertumbuhan dan Produksi Kedelai. J. Penel. Pert. Agron **4,** 14-24.

Faizah R. 2010. Karakterisasi beberapa genotipe cabai (*Capsicum* spp.) dan mekanisme ketahananya terhadap begomovirus penyebab penyakit daun keriting kuning. Master Thesis, Bogor Agricultural University Bogor.

Gerasopoulus D, Richardson DG. 1999. Storage temperature and fruit calcium after the sequence of ripening event of d"anjau pears. Hort Science **34,** 316-318.

Gumelar, RMR, Surjono HS, Desta W. 2016. Pendugaan parameter genetik seleksi ketahanan terhadap layu bakteri pada tomat hibrida hasil persilangan antar genotipe lokal. Master Thesis, Bogor Agriculture University Indonesian.

Hernandes TP, Nassar H. 1970. Breeding tomato for radial fruit crack resistance and other character. J Am Soc Hort Sci **95(2),** 223-226.

Ichwan B, Mapegau, Irianto. 2014. The control of broken skin on fruit of Duku *(Lansium domesticum* Corr.) by calcium carbon at in suboptimal land. Jurnal Lahan Suboptimal **3(1),** 24-30.

Kong M, Lampinen B, Shackel K, Crisosto CH. 2013. Fruit skin side cracking and ostiole-end splitting shorten postharvest life in fresh figs (*Ficus carica* L.), but are reduced by deficit irrigation. Postharvest Biology and Technology **85,** 154-161.

Lestari PL, Abdullah B, Junaedi A, Aswidinnoor H. 2010. Yield stability and adaptibility of aromatic New Plant Tipe (NPT) rice lines. J. Agron. Indonesia **38,** 199-204.

Limbongan Y. 2008. Analisis genetik dan seleksi genotipe unggul padi sawah (*Oryza sativa* L.) untuk adaptasi pada ekosistem dataran tinggi. PHD thesis, Bogor Agricultural University.

Measham P. 2011. Rain-Induced Fruit Cracking in Sweet Cherry (*Prunu s avium* L.). School of Agricultural Science, University of Tasmania, America.

Naradisorn M. 2013. Effect of calcium nutrition on fruit quality and postharvest diseases. International Journal of Science Innovations and Discoveries **3(1),** 8-13.

Ohta K, Hosoki T, Inaba K. 1997. Relationships between fruit cracking and changes of fruit diameter associated with solute flow to fruit in cherry tomatoes. J. Japan. Soc. Hort. Sci **65,** 753-759.

Pabendon MB, Mas'ud S, Sarungallo RS, Amin N. 2012. Penampilan Fenotipik dan Stabilitas Sorgum Manis untuk Bahan Baku Bioetanol. Penelitian Pertanian Tanaman Pangan **31(1),** 29-40.

Pashar DP, Lambeth VN. 1960. Inheritance of radial fruit cracking in tomatoes. Proc Am Soc Hort Sci **76,** 530-537.

Purwati E. 2007. Varietas unggul harapan tomat hibrida (F1) dari BALITSA. Iptek Hortikultura **3,** 34-40.

Purwati RD, Hidayah N, Sudjindro, Sudarsono. 2008. Inoculation methods and conidial densities of *Fusarium oxysporum* f. sp. *cubense* in Abaca. J. Biosci **15(1),** 1-7.

Roy D. 2005. Plant Breeding Analysis and Exploitation of Variation. New Delhi, IN: Narosa.

Salisbury FB, Ross CW. 1995. Fisiologi Tumbuhan Jilid 3. Terjemahan: Lukman RD, Sumaryono. Bandung, ID: Bogor Agriculture University Press.

Sherly R, Dewi AK, Yulidar, Wirnas D, Aswidinnoor H. 2013. Stability and adaptability analysis of highland rice genotypes resulted from induced mutation **9(2),** 81-90.

Simon G. 2006. Review on rain induced fruit cracking of sweet cherries (*Prunus avium* L.), its causes and the possibilities of prevention. International Journal of Horticultural Science **12,** 27-35.

Surtinah. 2007. Kajian tentang hubungan pertumbuhan vegetatif dengan produksi tanaman tomat (*Lycopersicum esculantum,* Mill). Jurnal ilmiah pertanian **4(1),** 1-9.

Sutjahjo SH, Herison C, Sulastrini, Marwiyah S. 2015.The estimation of genetic variability of growth and yield traits on 30 local tomato genotypes J. Hort **25(4),** 304-310.

Usenik V, Kastelec D, Stampar F. 2005. Physiochemical changes of sweet cherry fruits related to application of gibberellic acid. Food Chemistry **90,** 663-671.

Vange T, Ango, Nache I, Adedzwa DK. 2014. Stability analysis of six improved sorghum genotypes across four environment in the southern Guinea savana agroecological zone of Nigeria. Int Adv Agric Sci Technol **2(2),** 1-14.

Young HW. 1959. Inheritance of radial fruit cracking in a tomato cross. Florida State Hort Soc **59,** 207-210.