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Diversity and genetic parameter of chili pepper (*Capsicum annuum*) based on yield component in three location

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Abstract. *Sayekti TWDA, Syukur M, Hidayat SH, Maharijaya A. 2021. Diversity and genetic parameter of chili pepper (*Capsicum annuum*) based on yield component in three locations. Biodiversitas 22: 823-829.* With the increase in the use of chili, it is necessary to develop these commodities through plant breeding activities. Phenotypes are not only determined by genetics, but also by environmental factors and the GxE interactions, so all the factors need to be considered. The aims of this study were to evaluate the variability of ten elite breeding lines and three commercial varieties of chili pepper (*Capsicum annuum* L.) across three different environments. This experiment was conducted in three environments namely Bogor, Kolaka, and Palembang, from January until July 2019. Thirteen genotypes consisting of ten elite lines and three commercial chili pepper were used. This experiment was arranged in a randomized complete block design (RCBD) with three replications for each environment. To determine the effect of environment, Combined Analysis of Variance was carried out for all environments using PBSTAT-GE. The environment used in this experiment was lowland that varies between each other. The genotype with the fastest harvesting age relative in three environments was F7-145293-19-8-3-113-1. The highest number of fruits per plant was observed in genotype F9-160291-9-4-3-2-1-1-1 with 261 fruits per plant. The highest yield was observed in genotype F7-145174-9-7-1-5-3. From the clustering analysis, this population was grouped into five clusters. The heritability values for the 12 observed traits ranged between 22.68-69.97%, classified into high and moderate criteria.

Keywords: Chili pepper, cluster analysis, genetic parameter, heritability, yield components

INTRODUCTION

Since the demand for chili for consumption and industrial purposes is increasing, chili research becoming important as well. Among several types of chili pepper that are commonly consumed, such as sweet pepper and chili pepper, the most commonly consumed fresh is the chili pepper. The increase in the use of chili for fresh consumption reaches 10.87% each year. Total use of chili pepper reaching 1,925 million tons per year. In order to provide people's needs for chilies, it is necessary to develop these commodities through plant breeding activities. The objectives of plant breeding include improving the quantity and quality of yields, post-harvest resistance, pest and disease resistance, and tolerance to abiotic stress in sub-optimal environments (Wattimena 2011). Plant breeding activities are important to assemble new high-yielding varieties that potential to produce biomass and distribute it to the harvested part (Syukur et al. 2015). According to Syukur et al. (2010), the potential productivity of chili pepper (*Capsicum annuum* L.) in Indonesia can reach more than 20 tons ha^{-1}. The use of elite lines was an important step in determining the amount of production at harvest time (Nsabiyera et al. 2012).

To get the genotype that well growing and has a potential yield, the breeder needs to consider the genetic potential of the genotype to be developed. Besides genetic potential, the environment also needs to be considered because the phenotype of the plant not only determined by genetics, but also by environmental factors and the interaction between genetic and environmental (Roy 2000). This interaction makes breeding activities more complicated. If the interaction of Genetic x Environment (GXE) was not significant, all genotypes can perform stably in each environment (Cabral et al. 2017). However, if this GXE interaction was significant, then there will be differences in plant performance in certain environments (Hu et al. 2013) thus making it difficult for breeders to provide suitable genotype recommendations. It is necessary to study this phenomenon so that it can be used as a basis to recommend the genotypes that are suitable for each environment on purpose to increase productivity. The development of site-specific superior genotypes can be directed to obtain environment-specific varieties, while varieties that are superior in all environments can be released into varieties that are widely adapted (Ganefianti et al. 2009).

From the previous study, some elite lines or genotypes of chili pepper with a high yield potential have been found. These lines are expected to be widely used for consumption and industrial purpose. To get these purposes, it necessary to study the performance of each line at various locations, as well as to see the effect of factors on the yield component. The objective of this experiment is to evaluate the character variability of ten elite lines and three commercial varieties of chili pepper in three different environments.

MATERIALS AND METHODS

Study area and genetic material

This experiment was conducted in three environments. First set (set one) was conducted at Tajur PKHT-LPPM IPB University Experimental Field (250 m asl), Bogor, West Java, Indonesia. Second set (set two) at Universitas Sembilan Belas November Kolaka Experimental Field (38 m asl), Kolaka, Southeast Sulawesi. Third set (set three) was conducted at Universitas IBA (8 m asl.), Palembang, South Sumatra.

Thirteen genotypes consisting of ten elite lines and three commercial chili pepper were used. This experiment was arranged in a randomized complete block design (RCBD) with three replications for each set. The plot that used was a soil bed with 6 m x 1 m soil in size.

Procedures

Seed of thirteen genotypes of chili pepper was sown in the seedling tray for 5 weeks, then transplanted on the soil beds with a spacing 50 cm x 50 cm (24 plants per plot). The seedling that transplanted was a well-growth seedling with green leaves and not affected by pest or disease. The soil beds were covered by black-silver plastic mulch. Watering is done every day to ensure that plants are not affected by drought. Fertilizer was applied every week since seedling phase using NPK (16-16-16) (250 mL per plant) and foliar fertilizer. The concentration of fertilizer that used was 10 g L^{-1} for NPK 16-16-16 and 5 g L^{-1} for foliar fertilizer. Pest and disease management were done using recommended pesticide when needed. Weeding was scheduled for every two weeks after transplanting. Harvesting was done when 75% of plant population already has ripe fruit. The ripe fruit marked by 80% of the fruit has been red. Harvesting was scheduled every week for eight weeks.

Table 1. F-Ratios used to test effects for randomized complete blocks experiments combined over location

Sources of variation	Mean square	Expected mean squares (fixed model)
Location (l)	M1	$\sigma^2e + t\sigma^2_{R(L)} + rt\ \sigma^2_L$
Block (Location) (r)	M2	$\sigma^2e + t\sigma^2_{R(L)}$
Treatment (T)	M3	$\sigma^2e + rl\ \sigma^2_T$
Location x treatment	M4	$\sigma^2e + r\ \sigma^2_{TL}$
Pooler error	M5	σ^2e

Note: σ^2e: environment variance; σ^2_{TL}: location x treatment variance; σ^2_T: treatment variance; σ^2_L: location variance; $\sigma^2_{R(L)}$: block variance

Observations were made on yield and non-yield components based on IPGRI parameters (1995). The non-yield component parameters comprised of plant height, stem diameter, leaf length width, days to flowering, and days to harvest. The yield component parameters consist of fruit length and width, fruit weight, number of fruits per plant, and fruit yield per plant.

Data analysis

To determine the effect of environment, Combined Analysis of Variance (Combined ANOVA) was carried out for all environments using PBSTAT-GE. Genetic parameters (variance and heritability) and interaction of genotypes-by-environment (G*E) were estimated using fixed models by the following method (McIntosh 1983):

$\sigma^2_G = (M3\text{-}M5) / rl$

$\sigma^2_{GXE} = (M4\text{-}M5) / r$

$\sigma^2e = M5$

$\sigma^2_P = \sigma^2_G + (\sigma^2_{GXE} / l) + (\sigma^2e / rl)$

$h^2bs = (\sigma^2_G / \sigma^2_P) \times 100\%$

RESULTS AND DISCUSSION

Variability of 13 chili pepper

The coefficient of variation (C.V) of this experiment was less than 20% for almost all characters indicating the precision in the data recorded. From the result of Combined Analysis of Variance, it can be seen that genotype, environment, and the GxE interaction have a significant effect in the observed characters. This result indicates that the productivity of chili pepper was affected by genotype, environment, and their interactions. Environment, in this study, was the biggest contributor to yield variability, then the genotype and GxE interaction effect (Table 2). These cases indicate that the response to crop yield depends on the environmental conditions.

Days to harvest ranged from 67-95 days after planting (DAP) in Bogor, 69-92 DAP in Kolaka, and 83-94 DAP in Palembang (Table 3). The genotype with the fastest harvesting age in Bogor was F7-145293-19-8-3-113-1 (67 DAP) and this genotype tends to reach harvest early at all three locations. Whereas at Kolaka and Palembang locations, genotypes F9-145291-115-8-1-1-1, F7-145291-10-7-1-1-1-2, and other genotypes had an early harvest age; however, were not significantly different from each other.

The yield components comprised of fruit length, fruit weight, number of fruits per plant, and yield per plant. Genotype F7-160291-4-13-9-8-1 displayed the best fruit length across all environments, which had 5.30 cm fruit length (Table 4), and significant differences were observed for fruit length across environments. The Chili pepper grown in Bogor was significantly longer than in other environments and environmental and climate factors may have caused this. Different results were obtained for fruit weight and significant differences between environments were also observed but chilies are grown in Bogor conversely had a lower weight than other environments. Highest fruit weight was observed in Bara with an average fruit weight of 2.20 g per fruit (Table 5).

Table 2. Estimation of mean square for different characters of 13 chili pepper under combined analysis of variance

Source	df	Mean square						
		Fruit length	Fruit diameter	Fruit weight	Number of fruits per plant	Fruit yield per plant	Days to flowering	Days to harvest
Environment	2	12.423**	0.781**	0.813**	307160.2**	40981.0**	1701.13**	2101.64**
Rep(Env)	6	0.036^{ns}	0.011^{ns}	0.009^{ns}	456.6^{ns}	3362.0**	9.77**	51.35^{*8}
Genotype	12	1.726**	0.094**	1.183**	11829.7**	21636.0**	24.09^{ns}	127.09^{ns}
GxE	24	0.893**	0.036**	0.499**	23885.5**	21709.0**	16.13**	152.82**
Error	72	0.063**	0.063**	0.019**	400.6**	712.9^{ns}	3.48^{88}	17.08^{88}
CV (%)		5.84	10.46	8.70	11.61	11.00	5.43	5.02

Note: CV: Coefficient of Variance; Rep: Replication; Env: Environment; GXE: Genotype x Environment; ** significant at level of 1%; * significant at level 5%; ns: not significant

Table 3. Days to Harvest of 13 chili pepper genotypes across different locations

Genotype	Bogor	Kolaka	Palembang	Mean
	----------Days to Harvest (DAP)----------			
F7-145291-10-7-1-1-1-2	74.00e	70.77ef	96.33a	80.37
F9-160291-9-4-3-2-1-1-1	95.00a	69.97f	88.67abc	84.54
F9-160291-3-12-5-4-5-1-1	88.00b	73.13def	98.33a	86.49
F9-145291-115-8-1-1-1	88.00b	69.93f	87.00abc	81.64
F9-160291-3-12-5-51-1-1-2	74.33d	73.70def	96.33a	81.46
F8-145291-14-10-10-4-9-1	81.00c	81.50bc	98.33a	86.94
F7-145291-14-9-3-12-1	74.00e	73.27def	81.00c	76.09
F7-160291-4-13-9-8-1	74.00e	76.43cde	94.33ab	81.59
F7-145174-9-7-1-5-3	74.00e	83.60b	96.33a	84.64
F7-145293-19-8-3-113-1	67.00f	77.53cd	83.00bc	75.84
Bara	81.00c	76.46cde	90.67abc	82.71
Batari	81.00c	74.97def	83.00bc	79.66
Genie	88.00b	91.49a	83.00bc	87.50
Mean	79.95b	76.37C	90.49A	

Note: Number followed by the same letter in the same column were not significantly different to DMRT 5% level; Number followed by the same capital letter in the same row were not significantly different to HSD 5% level

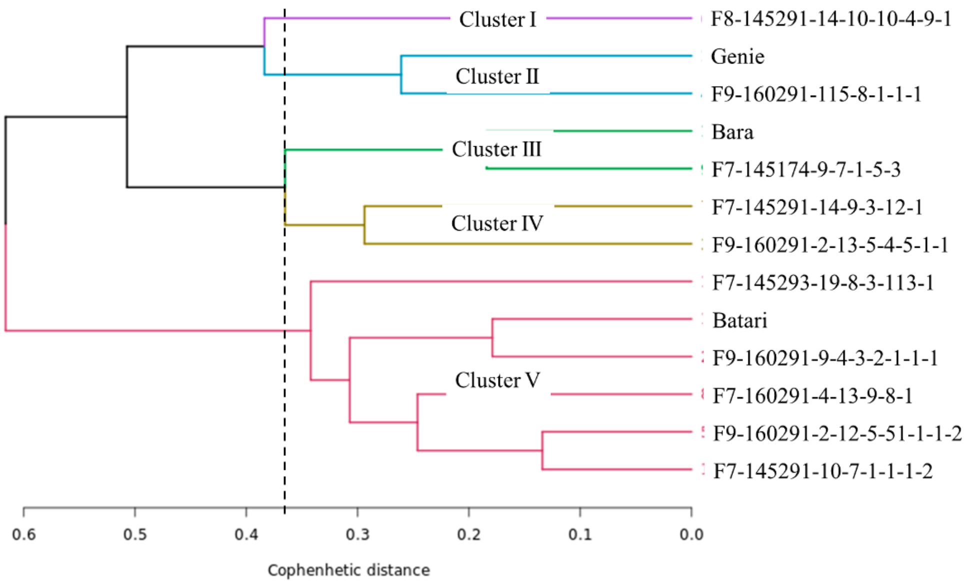

Figure 1. Dendrogram generated by hierarchical cluster analysis showing the relationships among the characterized chili pepper genotypes using 12 quantitative traits

For the number of fruits per plant, the results indicated that there was a large variation between locations (Table 6). Some genotypes have an increase or decrease in the number of fruits per plant when grown in different environments. However, several genotypes were observed to be quite stable across three environments, namely Bara with a difference of 32.58% in the number of fruits per plant. Meanwhile, the genotype with the highest number of fruits per plant was F9-160291-9-4-3-2-1-1-1 with 261 fruits per plant. But in general, these genotypes did not have stable fruit counts per plant in all environments. In general, the genotypes grown in Bogor had a higher number of fruits per plant compared to other environments. Similar results were observed for the yield per plant and F7-145174-9-7-1-5-3 was seen to have highest yield per plant. The yield of evaluated genotype was quite stable in two of the three environments with an average value of 311.80 g fruit per plant.

The genotypes were grouped into two major clusters and several sub-clusters (Figure 1). Partitioning clusters at a similarity coefficient of 0.62 for ease of interpretation generated five different clusters. Cluster I contained six genotypes, including five elite lines and one commercial variety (Batari), with similarity coefficient ranging from 0.637-0.866 (Dissimilarity ranging from 0.134-0.363). Cluster II consisted of two genotypes namely F9-160291-3-12-5-4-5-1-1 and F7-145291-14-9-3-12-1 with coefficient of similarity of 0.71. Cluster III contained two genotypes namely Bara and F7-145174-9-7-1-5-3 with coefficient of similarity of 0.82. The fourth cluster consisted of two genotypes, Genie and F9-145291-115-8-1-1-1 with coefficient of similarity of 0.74, and the fifth cluster consisted of single genotype F8-145291-14-10-10-4-9-1.

Table 4. Mean fruit length of 13 genotypes of chili pepper evaluated across different environments

Genotype	Bogor	Kolaka	Palembang	Mean
	----------Fruit length (cm)----------			
F7-145291-10-7-1-1-1-2	4.85d	3.84efgh	3.28d	3.99f
F9-160291-9-4-3-2-1-1-1	4.88d	3.50h	3.33d	3.91fg
F9-160291-3-12-5-4-5-1-1	6.80a	3.85efgh	3.28d	4.64bc
F9-145291-115-8-1-1-1	5.17cd	4.60c	4.25b	4.67b
F9-160291-3-12-5-51-1-1-2	4.90d	4.14de	3.79bcd	4.27ed
F8-145291-14-10-10-4-9-1	5.12cd	3.77fgh	3.39d	4.09ef
F7-145291-14-9-3-12-1	5.35bc	4.68c	4.06bc	4.70b
F7-160291-4-13-9-8-1	5.66b	5.44a	4.80a	5.30a
F7-145174-9-7-1-5-3	4.80d	4.21d	4.22b	4.41cd
F7-145293-19-8-3-113-1	4.10e	3.56gh	3.48cd	3.71g
Bara	4.08e	5.07b	3.69bcd	4.28ed
Batari	4.02e	4.01def	3.74bcd	3.92fg
Genie	4.09e	3.89defg	4.04bc	4.01f
Mean	4.91A	4.19B	3.79C	

Note: Number followed by the same letter in the same column were not significantly different to DMRT 5% level; Number followed by the same capital letter in the same row were not significantly different to HSD 5% level

Table 5. Fruit weight of 13 genotypes of chili pepper in different location

Genotype	Bogor	Kolaka	Palembang	Mean
	----------Fruit weight (g)----------			
F7-145291-10-7-1-1-1-2	1.47c	1.30gh	1.25fg	1.34fg
F9-160291-9-4-3-2-1-1-1	1.29cde	1.13h	1.13g	1.18h
F9-160291-3-12-5-4-5-1-1	2.75a	1.59ef	1.67cde	1.99bc
F9-145291-115-8-1-1-1	1.75b	1.94cd	1.95c	1.88cd
F9-160291-3-12-5-51-1-1-2	1.28de	1.29gh	1.27fg	1.28gh
F8-145291-14-10-10-4-9-1	1.39cd	1.50fg	1.45ef	1.45ef
F7-145291-14-9-3-12-1	1.74b	1.79de	1.76cd	1.76d
F7-160291-4-13-9-8-1	1.04f	1.69def	1.75cd	1.49e
F7-145174-9-7-1-5-3	1.37cd	2.30b	2.43b	2.03b
F7-145293-19-8-3-113-1	1.22def	1.30gh	1.30fg	1.27h
Bara	1.12ef	2.91a	2.85a	2.20a
Batari	1.09f	1.23gh	1.30fg	1.21h
Genie	1.097f	2.11	1.47def	1.55e
Mean	1.43B	1.69A	1.66A	

Note: Number followed by the same letter in the same column were not significantly different to DMRT 5% level; Number followed by the same capital letter in the same row were not significantly different to HSD 5% level

The heritability values for the 12 observed traits ranged between 22.68-69.97% and were classified into several criteria. The properties of plant height, leaf length, days to flowering, fruit length, fruit diameter, and fruit weight have high heritability. Whereas stem diameter, leaf width, days to harvest, number of fruits per plant, and fruit yield have moderate heritability. Criteria of heritability were determined based on Whirter (1979) as high (> 50%), moderate (20-50%), and low (<20%) (Table 8).

Discussion

The environment used in this experiment was lowland with elevations ranging between Palembang (8 m asl), Kolaka (38 m asl), and Bogor (250 m asl), and climatic conditions varied between these environments. Bogor has a temperature ranging from 25.97-27.05 ºC with 86.5% humidity and rainfall varied from 297.10-679.60 mm per month. Kolaka temperature ranges from 26.9-28.60 ºC with humidity of 83.45% and the rainfall ranging from 45.00-263.9 mm per month. Palembang city temperature ranges from 27.01-28.28 ºC with a humidity of 84.24% and rainfall ranging from 80.70-119.70 mm per month.

The harvest age of plants grown in Bogor was significantly shorter than those grown in Kolaka and Palembang (Table 3). According to (Pimenta et al 2016) environmental factors are known to greatly influence the expression of quantitative traits. However, in some cases, environmental factors affect the qualitative characters and harvesting age (Kandel et al. 2017). All quantitative traits were found to differ significantly among genotypes and also between environments. Variations in growth and yield components have been reported in many studies (Sharma et al. 2010; Thul et al. 2009). The yield per plant in Bogor was significantly higher than in Kolaka and Palembang. Although all the factors that cause this cannot be determined. However, this is thought to be related to the temperature, rainfall, and humidity of the location. Bogor has a relatively lower temperature, sufficient rainfall, while the Kolaka and Palembang locations tend to have high temperatures and humidity with low rainfall. High temperature and humidity accompanied by low rainfall have been negatively correlated to flowering and fruit sets (Wubs et al. 2011).

In this experiment, phenotypic relatedness was evident in cluster analysis, with two major clusters being formed for all genotypes evaluated. To see the grouping of these genotypes, clustering was carried out at a similarity level of 0.62 to produce 5 groups. This may probably have genotypes in the same species (*C. annuum*), so the base gene pool was narrow (Madu and Uguru 2006). This phenotypic relatedness also evidenced by the narrow range of similarity coefficient (0.637-0.866) (Votava et al. 2005).

One of the important information that needs to be known before carrying out further breeding and selection is related to the inheritance pattern of the targeted traits and the dominant factors that control these characters. This information can be found simply through the heritability value (h^2) of the targeted trait. The heritability value itself is a comparison between the values of variety of genotypes and their respective phenotypes. This shows that the heritability value is an estimator of how big the role of genetics plays in the expression of observed phenotypic characters. High heritability value indicates that the trait is more influenced by genetic factors than environmental factors.

Table 6. Number of fruits per plant of 13 genotypes of chili pepper evaluated across different locations

Genotype	Bogor	Kolaka	Palembang	Mean
	----------Number of fruit per plant----------			
F7-145291-10-7-1-1-1-2	227.9de	77.48gha	85.39ea	130.26gh
F9-160291-9-4-3-2-1-1-1	652.70a	67.36haa	63.80ea	261.29a
F9-160291-3-12-5-4-5-1-1	208.57e	94.80efa	213.83ab	172.40cde
F9-145291-115-8-1-1-1	319.97b	115.91cda	158.12cd	198.00b
F9-160291-3-12-5-51-1-1-2	294.67bc	76.90gha	90.56ea	154.04ef
F8-145291-14-10-10-4-9-1	198.74e	89.27fga	65.97ea	117.99h
F7-145291-14-9-3-12-1	206.87e	106.81dea	241.05aa	184.91bcd
F7-160291-4-13-9-8-1	201.17e	100.92def	153.24cd	151.77ef
F7-145174-9-7-1-5-3	257.63cd	137.63baa	180.20bc	191.82bc
F7-145293-19-8-3-113-1	284.63bc	77.70gha	75.86ea	146.06fg
Bara	199.23e	174.07aaa	134.31da	169.21de
Batari	259.47cd	73.69gha	248.30aa	193.82b
Genie	221.97de	125.87bca	155.75cd	167.86de
Mean	271.81A	101.42C	143.57B	

Note: Number followed by the same letter in the same column were not significantly different to DMRT 5% level; Number followed by the same capital letter in the same row were not significantly different to HSD 5% level

Table 7. Fruit yield per plant of 13 chili peppers evaluated across different locations

Genotype	Bogor	Kolaka	Palembang	Mean
	----------Yield per plant (g)----------			
F7-145291-10-7-1-1-1-2	256.49c	153.03e	125.63c	178.38h
F9-160291-9-4-3-2-1-1-1	378.60a	197.13cd	71.48d	215.74fg
F9-160291-3-12-5-4-5-1-1	364.50ab	233.87ab	310.41b	302.92ab
F9-145291-115-8-1-1-1	342.08ab	225.97abc	281.88b	283.31bc
F9-160291-3-12-5-51-1-1-2	314.76b	219.33abc	123.77c	219.29fg
F8-145291-14-10-10-4-9-1	210.82cde	206.87bcd	101.43cd	173.04h
F7-145291-14-9-3-12-1	325.18ab	208.80bcd	400.36a	311.45a
F7-160291-4-13-9-8-1	201.01cde	188.50d	258.72b	216.08fg
F7-145174-9-7-1-5-3	317.20ab	186.44d	431.75a	311.80a
F7-145293-19-8-3-113-1	237.16cd	243.63a	100.03cd	193.61gh
Bara	172.40e	227.83ab	391.12a	263.78cd
Batari	235.96cd	220.13abc	304.97b	253.69de
Genie	192.37de	198.73cd	303.80b	231.63ef
Mean	272.96A	208.48C	246.56B	

Note: Number followed by the same letter in the same column were not significantly different to DMRT 5% level; Number followed by the same capital letter in the same row were not significantly different to HSD 5% level

Table 8. Estimation of genetic parameters of 13 chili pepper genotype

Character	σ^2e	σ^2_{GXE}	σ^2_G	σ^2p	h^2bs (%)	Criteria
Plant height (cm)	13.800	25.667	16.000	26.089	61.329	High
Dichotomous height (cm)	8.518	7.478	7.323	10.762	68.044	High
Stem diameter (cm)	0.006	0.014	0.003	0.008	35.876	Moderate
Leaf width (cm)	0.550	0.250	0.042	0.187	22.683	Moderate
Leaf length (cm)	2.335	0.881	0.590	1.143	51.628	High
Day to flowering (days)	3.480	4.217	2.290	4.082	56.097	High
Day to harvest (days)	17.080	45.247	12.223	29.203	41.856	Moderate
Fruit length (cm)	0.063	0.277	0.185	0.284	65.060	High
Fruit diameter (mm)	0.009	0.009	0.009	0.013	70.334	High
Fruit weight (g)	0.019	0.160	0.129	0.185	69.974	High
Number of fruit per plant	400.576	7828.293	1269.789	3923.728	32.362	Moderate
Fruit yield per plant (g)	712.850	6998.717	2324.794	4736.906	49.078	Moderate

Note: σ^2_G: genetic variance; σ^2_{GXE}: genetic x environment variance; σ^2e: environment variance; σ^2_{P}: phenotypic variance; h^2bs: broad-sense heritability

Selection will be effective if the additive effects are sufficiently higher than the environmental effect, seen from the high genetic coefficient of variation and also high heritability. From the work of Shabanimofrad et al. (2013), high genetic variation and heritability alone provide no indication of the amount of genetic improvement that would result from selection. The information combined from both of these two parameters is more powerful. In this study, all the traits had moderate (stem diameter, leaf width, day to harvest, number of fruits per plant, and fruit yield per plant) to high (plant height, dichotomous height, leaf length, day to flowering, fruit length and diameter, and fruit weight). From the study done by Belay et al. (2020) dan Rosmaina et al. (2016) this high heritability indicating that the traits were more influenced by genetic factors. Generally, characters like fruit length, fruit diameter, and fruit weight with high genetic variation and heritability should be considered as reliable selection criteria for yield improvement in chili pepper. This result is in an agreement with the work of Usman et al. (2014) that study for heat tolerance chili pepper cultivar.

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