Bulgarian Journal of Agricultural Science, 22 (No 3) 2016, 431–436
Agricultural Academy

ESTIMATION OF VARIABILITY, HERITABILITY AND GENETIC ADVANCE AMONG LOCAL CHILI PEPPER GENOTYPES CULTIVATED IN PEAT LANDS

ROSMAINA, SYAFRUDIN, HASROL, F. YANTI, JULIYANTI AND ZULFAHMI*
State Islamic University of Sultan Syarif Kasim Riau, Department of Agrotechnology, Faculty of Agriculture and Animal Science, Panam, Pekanbaru 28293, Indonesia

Abstract

ROSMAINA, SYAFRUDIN, HASROL, F. YANTI, JULIYANTI and ZULFAHMI, 2016. Estimation of variability, heritability and genetic advance among local chili pepper genotypes cultivated in peat lands. *Bulg. J. Agric. Sci.*, 22: 431–436

Investigation and better understanding on the variability existing in a population base of crop is pivotal to crop improvement so that it can be exploited by plant breeder for crop improvement. The objectives of the study were to estimate the magnitude of genetic variability, heritability and genetic advance for yield and contributing characters of the sixteen of local chili genotypes cultivated in peat land. The experiment was carried out in a randomized complete block design with six replications. Analysis of variance revealed that there are highly significant difference ($p < 0.01$) among the genotypes tested for all characters studied indicating the presence of variability. In this study, PCV value was relatively greater than GCV for all traits; however, GCV values were near to PCV values for the characters like plant height, stem length, leaf width, fruit Length, fruit diameter, day to flowering, day to first harvest, and single fruit weight indicating high contribution of genotypic effect for phenotypic expression of such characters. High heritability coupled with high genetic advance per percent of mean was obtained for, plant height, stem length; leaf width; plant canopy width, days to flowering, fruit length; fruit diameter, single fruit weight, number of fruit per plant, fruit weight per plant reflecting the presence of additive gene action for the expression of these traits, and improving of these characters could be done through selection.

Key words: quantitative characters, *Capsicum* spp., genetic gain, heritability
Abbreviation: PCV – phenotypic coefficient of variance, GCV – genotypic coefficient of variance

Introduction

Chili pepper (*Capsicum* spp.) is belonging to a member of the Solanaceae family (Knapp, 2002) and is cultivated in tropical and sub-tropical regions. This species is a diploid ($2n = 2x = 24$) (Rohami et al., 2010) and it is genetically self-pollinated (Allard, 1960), however, under open pollinated its out-crossing rate can sometime exceed 90% (Berke, 2000), 7 to 91% (Bhagowati and Changkija, 2009) and 11 to 64% (Krishnamurthy et al., 2013). This cross pollination is assisted by some pollinators like bee (Berke, 2000), Apis spp, and butterflies moths (Carr and Davidar, 2015). Chili pepper is usually grouped based on fruit characteristic, as pungency, color, shape, flavor, size, intended use and genetic (Bosland, 1992). The fruits contained of essential nutrients such as vitamins A, C, E so that it is often consumed as fresh, dried or processed product as vegetables and as spices or condiment. In addition, fruits also contained of numerous biological actives that are utilized to medicines, for example, as antioxidant, antimicrobial, antiviral, anti-inflammatory and anticancer (Khan et al., 2014).

In Riau province – Indonesia, many farmers interested to cultivated of chili pepper because it is considered promising excellent income to them. In totally, the productivity of chili pepper in Riau Province was low (4.65–4.95 tons per hectare)

**Corresponding author:* zulfahmi@uin-suska.ac.id

compared with other regions in Indonesia (> 6–12 tons per hectare) (SYI, 2015). This is caused by many factors including biotic (disease, insect, and virus), a biotic (drought, heat, low soil fertility, etc.) and not using appropriate technology (improving variety, fertilizer). Therefore, tailoring new variety of chili pepper have high potential yield, resistance to disease and good adaptability in the peat land through breeding works must be a high priority.

The systematic breeding works involved the several steps, like collecting of germplasm, assessing of genetic variability, creating of genetic variability, implementing of selection, and developing of selected genotypes to be released as commercial variety (Allard, 1960; Poehlman and Sleper, 1995; Syukur et al., 2012). For efficient and effective breeding work, investigation and better understanding of the variability existing in a population base of crop is required so that it can be exploited by plant breeder for crop improvement. Moreover, the successful of any crops improvement program depends not only on the amount of genetic variation present in a crop but also on magnitude of variation which is heritable from the parent to the progeny (Bello et al., 2014).

Knowledge on genetic variability of the local chili pepper genotypes in the peat land was limited. Therefore, there is a need to generate information on genetic variability, genotypic coefficient of variation, heritability, and genetic advance of the chili pepper to estimate the progress of their breeding program in future. Heritability estimate of a character is important for plant breeder because it provides information on the extent to which a particular character can be transmitted from the parent to the progeny (Allard, 1960; Poehlman and Sleper, 1995; Syukur et al., 2012). Similarly, genetic advance is also considered important because genetic advance shows the degree of the gain obtained in a character from one cycle of selection. High genetic advance coupled with high heritability estimates offers the most suitable condition to decide the criteria of selection (Allard, 1960; Poehlman and Sleper, 1995; Syukur et al., 2012). In view of these, the present study was done with the objectives to assess genetic variability, heritability and genetic advance of sixteen local chili pepper genotypes cultivated in the peat land.

Materials and Methods

Experimental materials and sites

Sixteen of local chili pepper genotypes namely UIN-C1, UIN-C2, UIN-C3, UIN-C4, UIN-C5, UIN-C6, UIN-C7, UIN-C8, UIN-C9 UIN-C10, UIN-C11, UIN-C12, UIN-C13, UIN-C14, UIN-C15 and UIN-C16 were used in this study. The germplasm accessions are maintained at Breeding and Genetic Laboratory, Faculty of Agriculture and Animal Science of State Islamic university of Sultan Syarif Kasim Riau. The experimental was conducted at Rimbo Panjang peat land, Riau province – Indonesia during the crop season 2013/2014.

Experimental design

The experiment was carried out in a randomized complete block design with six replications. In each plot, an intra-row spacing of 0.5 m and inter-row spacing of 0.5 m were maintained to accommodate four plants per row and eight plants per plot. All recommendation agriculture practices of chili productions were followed to raise normal plant growth.

Data collection

Four plants were selected randomly from each plot and observation on plant height, stem length; stem diameter; leaf length; leaf width; plant canopy width, days to flower, days to first harvest, fruit length; fruit diameter, single fruit weight, number of fruit per plant, fruit weight per plant were collected according to International Plant Genetic Resource Institute (IPGRI, 1995) to evaluate the genotypes.

Data analysis

Analysis of variance (ANOVA)

The data collected for each character was subjected to analysis of variance (ANOVA) using randomized complete block design to test the variations among genotypes. The analysis of variance was calculated using Statistical Analysis System (SAS) software version 9.2 (SAS, 2008). After testing the ANOVA assumption, treatment means were tested with Duncan multiple range testing (DMRT) at 5% probability levels (SAS, 2008).

***Estimates of variance components**:*

The variability present in the population was estimated by measure mean, phenotypic and genotypic variance and coefficient of variation. To estimate the phenotypic and genotypic variance, genotypic and phenotypic coefficients of variation were estimated based on formula Syukur et al. (2012) as follow:

$$\sigma^2_G = [(MSG) - (MSE)] / r$$
$$\sigma^2_P = [\sigma^2_G + (\sigma^2_E/r)],$$

where: σ^2_G = Genotypic variance; σ^2_P = Phenotypic variance; σ^2_E = environmental variance (error mean square from the analysis of variance); MSG = mean square of genotypes; MSE = error mean square; r = number of replications.

$$\text{Genotypic coefficient of variation (GCV)} = [(\sigma^2_G)^{1/2}/\bar{x}] \times 100;$$
$$\text{Phenotypic coefficient of variation (PCV)} = [(\sigma^2_P)^{1/2}/\bar{x}] \times 100,$$

where: σ^2_G = Genotypic variance; σ^2_P = Phenotypic variance; is grand mean of a character.

Estimation of heritability in broad sense

Broad sense heritability (h^2) of the all traits were calculated according to the formula as described by Allard (1960) as follow:

$$h^2_{bs} = [(\sigma^2_G) / (\sigma^2_P)] \times 100,$$

where: h^2_{bs} = heritability in broad sense; σ^2_G = Genotypic variance; σ^2_P = Phenotypic variance.

Estimation of genetic advance

Genetic advance (GA) was determined as described by Johnson et al. (1955):

$$GA = K\,(\sigma_P)\,h^2,$$

where: K = the selection differential (K = 2.06 at 5% selection intensity); σ_P = the phenotypic standard deviation of the character; h^2 = broad sense heritability.

The genetic advance as percentage of the mean (GAM) was calculated as described by Johnson et al. (1955) as follow:

$$GAM(\%) = \frac{GA}{\overline{x}} \times 100,$$

where: GAM = genetic advance as percentage of the mean, GA = genetic advance, and $\overline{x}$ = grand mean of a character.

Results and Discussion

Analysis of variance

The analysis of variance showed that genotype mean squares for all traits studied were highly significant (Table 1). It reflected the existing of large variability among tested genotypes and this variability can be further utilized in the chili pepper improvement program. The Duncan multiple range test (DMRT) was applied to know the variation between genotypes for all the characters. Performance of all the genotypes using DMRT (Table 2) indicated that UIN-C1 genotype attained maximum plant height (86.27 cm), plant canopy width (91.93 cm), fruit weight per plant (340.10 g). UIN-C2 had maximum value in fruit length (13.20 cm), fruit diameter (1.06 cm), and single fruit weight (6.33 g). The higher estimates for days to flowering (42.22 HST), leaf length (12.66 cm) and stem length (44.61 cm) were observed in UIN-C16 genotype, while UIN-C9 had maximum value in stem diameter (1.69 cm), and number of fruit per plant (147.50 g). UIN-C11 and UIN-C6 genotypes maintained maximum value in stem length (22.64 cm) and leaf width (3.04 cm), respectively.

Estimates of variance components

The estimates of phenotypic variances (σ^2_P), genotypic variances (σ^2_G), Phenotypic Coefficients of Variation (PCV) and Genotypic Coefficients of Variation (GCV) are given in Table 3. Genetic variance values ranged from 0.02 for fruit diameter to 8092.05 for fruit weight per plant while phenotypic variance values ranged from 0.03 to 8761.17 for fruit diameter and fruit weight per plant, respectively. The PCV values were ranged from 8.86 % for days to first harvest to 56.80% for single fruit weight. Similarly, the GCV values ranged from 8.59% for days to first harvest to 56.45% for single fruit weight (Table 3). According to Deshmukh et al. (1986) PCV and GCV val-

Table 1

Analysis of variance for different quantitative characters in Chili pepper

Traits	Error Mean Square (d.f.= 75)	Genotype Mean Square (d.f. = 15)	Block Mean Square (d.f.= 5)
Plant height (cm)	65.35	1116.88**	26.92
Stem length (cm)	8.51	243.38**	29.47
Stem diameter (cm)	0.21	0.46**	0.38
Plant canopy width (cm)	164.89	1221.59**	58.75
Leaf length(cm)	3.10	18.88**	1.04
Leaf width (cm)	0.28	6.22**	0.06
Fruit length (cm)	0.39	105.50**	0.36
Fruit diameter (cm)	0.01	0.15**	0.01
Days to flowering	9.86	210.66**	16.96
Days to first harvest	3.59	241.22**	6.17
Single fruit weight (g)	0.14	11.43**	0.15
Fruit weight per plant (g)	4014.68	52567.00**	3138.30
Number of fruit per plant	1393.08	7414.86**	779.89

ues greater than 20% are regarded as high and values between 10% and 20% to be medium, whereas values less than 10% are considered to be low. Accordingly, high PCV and GCV were recorded for single fruit weight, fruit length, fruit weight per plant, number of fruit per plant, leaf width, fruit diameter, plant copy width, and plant height, while traits with moderate PCV and GCV were leaf length and days to flowering, and days to first harvest had low PCV and GCV. High values of PCV and GCV indicated the existence of substantial variability for such characters and selection may be effective based on these characters. Similar finding was reported by earlier researchers for fruit per plant, fruit weight, fruit length, fruit girth, and yield per plant (Sreelatkumary and Rajamony, 2004), for fruit yield per plant and average fruit weight (Sharma et al., 2010), for fruit weight, fruit diameter, fruit per plant, fruit yield per plant (Yadeta et al., 2011), for yield per plant, number of fruit per plant, plant height (Johri and Kumar, 2007).

In this study, the PCV was relatively greater than GCV for all traits; however, GCV was near to PCV for the characters like plant height, stem length, leaf width, fruit length, fruit diameter, days to flowering, days to first harvest, and single fruit weight (Table 3), indicating high contribution of genotypic effect for phenotypic expression of such characters. Similar result was reported by Yadeta et al., (2011) for days to flower and days to maturity. In other traits, there are wider gaps between estimate of PCV and GCV showed distinct contribution of environmental factors in addition to genotypic effect for expression of the traits. Similar finding was reported by Sharma et al. (2010).

Genotypic coefficient of variance provides information on the genetic variability present in quantitative characters in base population, but it is not possible to determine the amount of the variation that was heritable only from the genotypic coefficient of variance. Genetic coefficient of variance together with heritability estimates would give the best picture of the amount of advance to be expected from selection (Burton and Devane, 1953). Thus, the heritable portion of the variation could be more useful with help of heritability estimates.

Heritability and genetic advance

Heritability values are helpful in predicting the expected progress to be achieved through selection process. Estimates of heritability in broad sense ranged from 54.35% for stem diameter to 99.63% for fruit length (Table 3). According to Singh (2001) that heritability values greater than 80% were very high, values from 60–79% were moderately high, values from 40–59% were medium and values less than 40% were low. Accordingly, the estimate of heritability of stem diameter was medium category and other traits were very high. The characters having very high heritability indicated relative small contribution of the environment factors to the phenotype and selection for such characters could be fairly easy due to high additive effect. High estimates of broad sense heritability have been also reported by

Table 2
Performance Mean of genotypes for some morphological traits in chili pepper

Genotypes	PH	SL	SD	LP	LW	PCW	FL	FD	DF	DH	SFW	NF/P	FW/P
UIN-C1	59.17^{de}	28.50^{feg}	0.99^{bcd}	8.40^{edc}	3.40^{c}	59.57^{ecd}	10.43^{c}	0.77b^{c}	38.00^{b}	75.72^{cd}	2.95^{c}	84.42^{bdec}	193.04^{bdc}
UIN-C2	61.12^{de}	30.55^{fed}	1.25^{ba}	9.72^{dc}	3.57^{c}	60.75^{ecd}	13.20^{a}	1.06^{a}	28.33^{f}	73.67^{ed}	6.33^{a}	48.75^{e}	272.65^{ba}
UIN-C3	66.11^{dc}	35.62^{cd}	0.98^{bcd}	10.77^{bac}	3.32^{c}	67.33^{bcd}	10.78^{c}	0.74^{dc}	33.00^{d}	73.00^{cd}	2.89^{c}	112.47^{bac}	259.38^{bac}
UIN-C4	73.00^{bc}	31.60^{ed}	1.21^{bac}	10.38^{bdc}	3.33^{c}	74.29^{bcd}	12.43^{b}	0.82^{c}	33.33^{d}	75.28^{cd}	3.85^{b}	105.11^{bdac}	325.24^{a}
UIN-C5	80.54^{ba}	36.53^{d}	I.14^{bdac}	9.10^{bdc}	3.36^{c}	78.03^{ba}	11.98^{b}	0.72^{d}	32.78^{b}	74.99^{cd}	2.85^{c}	145.89^{a}	326.25^{a}
UIN-C6	77.49^{ba}	34.17^{cbd}	1.11^{bdac}	8.40^{bdc}	3.09^{c}	80.12^{ba}	11.96^{b}	0.71^{d}	35.67^{b}	81.55^{a}	2.74^{c}	79.84^{bdec}	201.35^{bac}
UIN-C7	62.65^{d}	23.87^{ih}	1.03^{bdc}	8.05^{ed}	3.23^{c}	66.45^{bcd}	10.91^{c}	0.70^{d}	33.28^{d}	81.56^{a}	3.10^{c}	68.61^{dec}	194.94^{bac}
UIN-C8	86.27^{a}	30.92^{efd}	1.22^{ba}	9.01^{edc}	3.58^{c}	91.93^{a}	12.42^{b}	0.70^{d}	32.78^{d}	75.00^{cd}	2.97^{c}	147.00^{a}	340.10^{a}
UIN-C9	65.55^{dc}	32.58^{cd}	1.69^{a}	10.75^{bac}	4.54^{b}	57.11^{ed}	3.92e^{d}	0.60^{fe}	26.00^{f}	73.72^{ed}	0.99^{gf}	147.50^{a}	170.40^{ed}
UIN-C10	54.83^{f}	27.58^{fg}	0.59^{dc}	7.29^{e}	3.45^{c}	39.78^{f}	3.58e^{d}	0.54^{fg}	19.33^{g}	72.39^{e}	0.82^{g}	89.17^{bdec}	91.38^{ef}
UIN-C11	44.78^{f}	22.64^{i}	0.58^{d}	7.26^{e}	3.45^{c}	40.06^{f}	3.30^{e}	0.46^{g}	29.39^{d}	77.33^{cd}	0.93^{gf}	102.17^{bdac}	105.13^{ef}
UIN-C12	64.89^{dc}	32.94^{cbd}	0.86^{bdc}	12.76^{a}	5.94^{a}	46.50^{ef}	3.75^{ed}	0.68^{de}	39.44^{b}	79.00^{d}	1.68^{ed}	57.50^{de}	78.56^{f}
UIN-C13	52.11^{fe}	26.50^{ag}	0.77^{bdc}	9.04^{edc}	3.73^{a}	65.45^{bcd}	4.24^{d}	0.77^{dc}	24.72^{f}	59.17^{i}	2.10^{d}	124.67^{da}	184.55^{dc}
UIN-C14	48.24^{f}	25.50^{ihg}	0.75^{bdc}	9.01^{edc}	3.54^{c}	60.19^{ecd}	3.49e^{d}	0.75^{dc}	28.61^{f}	61.67^{h}	1.39^{ef}	122.61^{ba}	137.12^{edf}
UIN-C15	83.64^{a}	44.22^{a}	0.92^{bdc}	12.30^{ba}	6.08^{a}	74.61^{bc}	4.23^{d}	0.92^{b}	37.56^{b}	66.76^{g}	1.55^{e}	50.78^{e}	73.45^{f}
UIN-C16	81.25^{ba}	44.61^{a}	1.05^{bdc}	12.66^{a}	5.68^{a}	68.88^{bcd}	3.56e^{d}	1.05^{a}	42.22^{a}	68.89^{f}	1.78^{ed}	52.17^{e}	71.26^{f}

Means followed by the same letter in the same column are not significant different. *Note*: PH: plant height (cm). SL (cm): Stem Length (cm); SD: Stem Diameter (cm); LP: leaf length (cm); LW: leaf width (cm); PCW: plant canopy width (cm). FL: Fruit length (cm); FD: Fruit diameter (cm); DF: days to flowering (HAT). DH: days to first harvest (HAT). SFW: single fruit weight (g). NF/P: number of fruit per plant. FW/P: fruit weight per plant (g).

previous researchers for plant height, stem diameter, days to flowering, days to first harvest, fruit length, and fruit diameter (Syukur and Rosidah, 2014); for plant height, fruit diameter, number of fruit per plant, fruit weight, fruit weight per plant (Qosim et al., 2013); for number of fruit per plant, weight per fruit, fruit diameter, and days to flowering (Lestari et al., 2006); for plant height, days to flowering, fruit per plant, fruit length, fruit diameter, fruit weight, canopy diameter, and fruit yield per plant (Yadeta et al., 2011); for plant height, days to flowering, fruits per plant, fruit length, fruit girth, fruit weight, yield per plant (Sreelatkumary and Rajamony, 2004).

Heritability alone provides no indication of the amount of genetic improvement that would result from selection of individual genotype. Hence, knowledge on heritability coupled with genetic advance is more useful. Genetic advance (GA) under selection referred to the improvement of characters in genotypic value for the new population compared with the base population under one cycle of selection at given selection intensity (Singh, 2001). Furthermore, Hamdi et al. (2013) stated that Genetic advance (GA) is importance to predicting the expected genetic gain from one cycle of selection. Estimates of GA values for all characters studied are displayed in Table 3. Estimates of genetic advance for fruit weight per plant was 178.07 g, indicating that whenever we select the best, 5% high yielding genotypes as parents, mean fruit weight per plant of the offspring could be improved a large of 178.09 g, that is, mean genotypic value of the new population for fruit weight per plant will be improved from 189.05 to 367.14 g. In the same way, number of fruit per plant will be improved from 96.16 to 154.97 and 7.76 to 16.37 for fruit length (Table 3).

Genetic advance as percent of the mean (GAM) in this study ranged from 17.57% to 115.64% for days to first harvest and fruit weight per plant, respectively (Table 3). According to Jonhson et al. (1955) that the value of genetic advance as percent of the mean is categorized as low (< 10%), moderate (10–20%) and high (> 20%). The GAM of days to first harvest is classified as moderate, whereas other characters were high (Table 3). According to Jonhson et al. (1955) high heritability estimates along with the high genetic advance as per mean is usually more helpful in predicting gain under selection than heritability alone. In the present study, high heritability along with high genetic advance as percent of the mean are exhibited by plant height, stem length; stem diameter; leaf length; leaf width; plant canopy width, days to flowering, fruit length; fruit diameter, single fruit weight, number of fruit per plant, fruit weight per plant characters reflecting the presence of additive gene action for the expression of these traits which is fixable for next generations, and selection in next population based on this character would be ideal. Similar results were also reported by Sreelathakumary and Rajamory (2004). Johri and Kumar (2007) reported high heritability combined with high genetic advance for yield per plant.

The traits having high values of heritability coupled with moderate genetic advance as percent of the mean viz. day to first harvest suggest that selection for improvement of these characters may be rewarding. It also indicates greater role of

Table 3

Estimates of range, mean ($\bar{x}$), standard error (SE), Genotypic variation (σ^2_G), phenotypic variation (σ^2_P), Genotypic coefficient of variation (GCV), Phenotypic coefficient of variation (PCV), heritability in broad sense (h^2_{bs}), Genetic advance (GA), genetic advance as percentage of the mean (GAM) for 13 traits of chili pepper

Traits	Range	$\bar{x}$ ± SE	σ^2_G	σ^2_P	GCV (%)	PCV (%)	h^2_{bs} (%)	GA	GAM
PH (cm)	44.78 – 86.27	65.79 ± 8.08	175.26	186.15	20.12	20.74	94.15	26.46	40.22
SL (cm)	22.64 – 44.61	31.77 ± 2.92	39.15	40.56	19.69	20.05	96.50	12.66	39.85
SD (cm)	0.58 – 1.69	1.01 ± 0.46	0.04	0.08	20.21	27.41	54.35	0.32	31.68
PCW (cm)	39.78 – 91.93	64.44 ± 12.84	176.12	203.60	20.59	22.14	86.50	25.43	39.46
LL (cm)	7.26 – 12.66	9.68 ± 1.76	2.63	3.15	16.75	18.33	83.58	3.00	30.99
LW (cm)	3.09 – 6.08	3.96 ± 0.52	0.99	1.04	25.13	25.71	95.49	2.00	50.51
FL (cm)	3.30 – 13.20	7.76 ± 0.63	17.52	17.58	53.94	54.04	99.63	8.61	110.96
FD (cm)	0.46 – 1.06	0.75 ± 0.07	0.02	0.03	20.37	21.08	93.33	0.33	44.00
DF	19.33 – 42.22	32.15 ± 3.14	33.47	35.11	17.99	18.43	95.31	11.63	36.17
DFH	59.17 – 81.56	73.23 ± 1.89	39.61	40.20	8.59	8.66	98.51	12.87	17.57
SFW (g)	0.82 – 6.33	2.43 ± 0.38	1.88	1.91	56.45	56.80	98.77	2.81	115.64
FWP (g)	71.26 – 340.10	189.05 ± 63.36	8092.05	8761.17	47.58	49.51	92.36	178.09	94.20
NFP	48.75 – 147.50	96.16 ± 37.32	1003.63	1235.81	32.95	36.56	81.21	58.81	61.16

Note: PH : plant height (cm). SL(cm): Stem Length (cm); SD: Stem Diameter (cm); LP: leaf length (cm); LW: leaf width (cm); PCW: plant canopy width (cm). FL: Fruit length (cm); FD: Fruit diameter (cm); DF: days to flowering (HAT). DH: days to first harvest (HAT). SFW: single fruit weight (g). NF/P: number of fruit per plant. FW/P: fruit weight per plant (g).

non-additive gen action in their inheritance. These results are in agreement with the findings of Ibrahim et al. (2001) and Johri and Kumar (2007) for days to flower. Yadeta et al. (2011) was also reported that plant height and days to flower characters had high heritability and moderate genetic advance.

Conclusion

Based on the findings in this study, we concluded that nine characters viz. plant height, stem diameter, leaf width; plant canopy width, leaf width, fruit length, fruit diameter, single fruit weight, number of fruit per plant, fruit weight per plant characters could be used as good criteria for selection in the chili improvement in the peat land because these characters had high genotypic coefficient of variation, heritability estimate and genetic advance as percent of the mean.

Acknowledgement

The authors thank to Institute of Research and Community Services of State Islamic University of Sultan Syarif Kasim Riau for financial support to this research.

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Received May, 12, 2016; accepted for printing May, 16, 2016