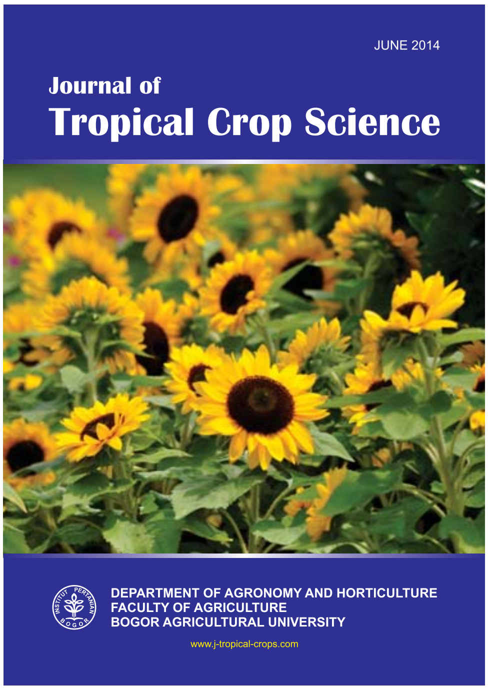

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ON THE COVER

The cover image shows sunflowers by Darda Effendi

SHORT COMMUNICATION

RESEARCH ARTICLES

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RESEARCH ARTICLE

Estimation of Genetic Parameter for Quantitative Characters of Pepper (*Capsicum annuum* L.)

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Abstract The research was conducted at Leuwikopo Experimental Field and Plant Breeding Laboratory of IPB, Dramaga, Bogor, West Java, Indonesia from October 2012 to April 2013. Crossing population between C15 and C2 genotype were used to study genetic parameters for quantitative characters in pepper. All the characters were not controlled by maternal effect, except fruit length. Broad-sense heritability were high for plant height, stem diameter, dichotomous height, day to flowering, day to harvesting; and medium for fruit length and diameter. Narrow-sense heritability was high for stem diameter, dichotomous height, day to flowering; medium for plant height, day to harvesting; and low for fruit length and diameter. The ratio of additive variance was high for all the characters, except for fruit length and fruit diameter.

Keywords: heritability, heterosis, heterobeltiosis, additive variance, dominant variance

Introduction

Estimation of genetic parameters for quantitative characters is important for plant breeding programs. Analysis of genetic parameters is used to obtain information on gene actions, genetic variability, heritability, and other genetic information. The genetic information is of great importance to allow more efficient and effective plant selection (Syukur et al., 2012).

There are potentials to increase pepper production in the tropics through breeding. Pepper has wide range of genetic resources which are crucial for plant breeding program (Syukur et al., 2012). Pepper breeding has been conducted through hybridisation, followed by selection (Hilmayanti et al., 2006). The selection process has high probability to bring genetic improvements if the selected characters have high heritability.

Previous studies have reported that broad and narrow-sense heritability for quantitative characters range from low to high (Ben-Cham and Paran, 2000). Broad- sense heritability, which captures the proportion of phenotypic variation due to genetic values, was high for dichotomous (Arif et al., 2012); day to flower (Lestari et al., 2006), day to harvesting (Arif et al., 2012), fruit length and diameter (Syukur et al., 2010a). Narrow-sense heritability was low for day to harvesting, medium for dichotomous (Arif et al., 2012); and high for fruit length and diameter. The objective of the study was to estimate genetic parameters for quantitative characters in pepper.

Materials and methods

The research was conducted at Leuwikopo research station (6° 24' S, 106° 33'E) and Plant Breeding Education Laboratory, Department of Agronomy and Horticulture, Bogor Agricultural University at Darmaga, Bogor, West Java, Indonesia, in October 2012 to April 2013.

Genotypes of IPB C-15 (Source: AVRDC), IPB C2 (Source: Department of Agronomy and Horticulture, IPB), F1 (IPB C15 X 1PB C2), F1 of IPB C2 and IPB C15 crossing, BCP1 (FI X 1PB C15), BCP2 (F1 X 1PB C2), and F2 were used in this study. Twenty plants each of P1, P2, F1, and F1R; 50 plants each of BCP1 and BCP2; and 126 plants of F2 were planted.

Pepper seeds were sown on trays with pasteurised media and grown up to 6 weeks after sowing. The growing area was covered with black and silver plastic mulch prior to planting. Seedlings were then transplanted to the field with planting distance of 50 cm x 50 cm. Organic fertiliser at 1 kg per plant, Urea at 200 kg ha^{-1}, SP-36 at 150 kg ha^{-1} and KCl at 150 ha^{-1} were applied one week before planting. Pest and diseases were controlled by alternate weekly application of insecticide and fungicide application, or as required, at the recommended doses. Plants were fertilized weekly using 10 $g.L^{-1}$NPK Mutiara 16N-16P-16K at 250 mL per plant.

Scoring was conducted on the following quantitative characters: day to flowering (DAS), day to harvesting (DAS), plant height (cm), dichotomous height (cm), fruit length (cm) and fruit diameter (mm).

Broad-sense heritability was estimated using a method developed by Allard (1960): $h^2_{bs} = ((V_{F2} – (V_{F1} + V_{P1} + V_{P2})/3)/V_{F2}) \times 100\%$; where h^2_{bs} = broad-sense heritability, V_{P1} = P1 population variance, V_{P2} = P2 population variance, V_{F1} = F1 population variance, and V_{F2} = F2 population variance. Narrow-sense heritability was estimated using a method developed by Warner (1952): $h^2_{ns} = ((2V_{F2} - (V_{BCP1} + V_{BCP2}))/V_{F2}) \times 100\%$; where h^2_{ns} = narrow-sense heritability,

V_{BCP1} = BCP1 population variance, V_{BCP2} = BCP2 population variance, and V_{F2} = F2 population variance. Estimated heritability value was considered low if h^2 < 20%, medium if 20% < h^2 < 50%, and high if h^2 > 50% (Halloran et al., 1997). Maternal effects were tested by comparing means of F1 and F1R using t-test at =5%. Additive variance ratio was calculated using formula of a = (h^2_{ns}/h^2_{bs}) x 100%; where a is additive variance ratio, h^2_{ns} is narrow-sense heritability, and h^2_{bs} is broad-sense heritability. Heterosis was calculated using formula of mid parent heterosis = (X_{F1}/MP) x 100%; where X_{F1} is mean average of F1 and MP is mean average of both parents. Heterobeltiosis was measured using the formula = (X_{F1}/HP) x 100%, where X_{F1} is average of F1 and HP is mean average of the best parents.

Results

Normality test was conducted to study the frequency distribution of F2. All F2 variables had a normal frequency distribution. Continuous and normal distribution showed that the characters were controlled by polygenic genes.

F2 population had the highest variability, followed by BCP1 and BCP2 populations. P1, P2, F1 and F1R populations were more uniform than BCP1, BCP2, and F2 (Table 1). The highest variability in F2 population was due to the maximum segregation in the population. P1 and P2 populations were homozygous and homogeneous, which means that each individual had the same genetic composition. F1 and F1R were heterozygous and each individual had the same genetic composition (homogeneous).

The maternal effect test showed that there was no significant difference between F1 and F1R for all variables (Table 2). This suggests that female parent did not affect the inheritance of the character, which indicates that these characters are controlled by genes in the nucleus.

Broad-sense heritability of all characters ranged from 43.01% to 79.5%, or classified as moderate to high. Broad-sense heritability estimates were high for plant height, stem diameter, dichotomous height, day to flowering and day to harvesting, whereas it was were moderate for fruit length and fruit diameter. This was a reflection of the role of genetic variance. Genetic variances were greater than the environmental variance

Table 1. Means, variance, and standard deviation of quantitative characters in pepper population

Characters	Population						
	P1	P2	F1	F1R	BCP1	BCP2	F2
Plant height (cm)							
Means	49.08	54.32	52.18	59.82	54.78	50.87	63.65
Variance	138.48	95.98	89.23	87.80	185.58	146.89	214.62
Standar deviation	11.68	9.80	9.45	9.37	13.62	12.12	14.65
Steam diameter (mm)							
Means	9.44	9.18	9.09	9.60	9.76	8.30	10.87
Variance	3.50	2.29	2.60	3.94	5.65	4.18	6.93
Standar deviation	1.87	1.51	1.61	1.99	2.38	2.04	2.63
Dichotomous height (cm)							
Means	8.32	20.70	12.39	14.76	11.17	14.98	15.72
Variance	2.50	4.55	5.03	7.71	8.01	17.84	19.66
Standar deviation	1.58	2.13	2.24	2.78	2.83	4.22	4.43
Day to flowering (DAS)							
Means	92.60	85.20	92.00	94.90	95.42	91.08	98.95
Variance	14.93	20.62	30.44	42.10	41.68	68.56	85.10
Standar deviation	3.86	4.54	5.52	6.49	6.46	8.28	9.22
Day to harvesting (DAS)							
Means	139.90	130.30	137.89	138.70	142.58	137.24	141.46
Variance	6.32	26.93	36.55	22.94	34.86	40.36	48.89
Standar deviation	2.51	5.19	6.05	4.79	5.90	6.35	6.99
Fruit length (cm)							
Means	10.10	14.20	13.17	11.23	12.72	13.74	12.70
Variance	2.91	1.22	2.10	4.62	2.84	4.33	3.65
Standar deviation	1.71	1.10	1.45	2.15	1.69	2.08	1.91
Fruit diameter (mm)							
Means	15.85	17.27	17.25	16.23	17.64	15.29	16.65
Variance	3.07	3.40	1.37	4.12	4.49	4.66	5.04
Standar deviation	1.75	1.84	1.17	2.03	2.12	2.16	2.24

Note: P1 = IPB C15, P2 = IPB C2, F1 = IPB C15 x IPB C2, F1R = IPB C2 x IPB C15, BCP1 = F1 x IPB C15, BCP2 = F1 x IPB C2, F2 = F1 selfing for all characters (Table 3).

Narrow-sense heritability for all character ranged from 3.28% to 70.46%, or classified as low to high. Narrow-sense heritability estimates were high for stem diameter, dichotomous height, and day to flowering; moderate for plant height and day to harvesting, and low for fruit length and fruit diameter. This was a reflection of the role of additive variance, which was reflected in the ratio of additive variance. The ratio of additive variance was high for all the characters, except for fruit length and fruit diameter (Table 3).

Heterosis values were positive for plant height, day to flowering, day to harvesting, fruit length and fruit diameter, while was negative for fruit length. However, heterobeltiosis was positive in day to flowering and day to harvesting (Table 4). Negative heterobeltiosis means the value of F1 was lower than that of the best parent. Heterosis and heterobeltiosis for day to flower and day to harvesting were expected to be negative as the selection for this character was directed to obtain earliness character.

Table 2. Means, standard deviation and mean value t-test of quantitative character in F1 and F1R

Characters	F1	F1R	t-value
Plant height (cm)	52.18 ± 9.45	59.82 ± 9.37	-0.60^{ns}
Steam diameter (mm)	9.09 ± 1.61	9.60 ± 1.99	-1.77^{ns}
Dichotomous height (cm)	12.39 ± 2.24	14.76 ± 2.78	-2.03^{ns}
Day to flowering (DAS)	92.00 ± 5.52	94.90 ± 6.49	-1.08^{ns}
Day to harvesting (DAS)	137.89 ± 6.05	138.70 ± 4.79	-0.35^{ns}
Fruit length (cm)	13.17 ± 1.45	11.23 ± 2.15	2.28*
Fruit diameter (mm)	17.25 ± 1.17	16.23 ± 2.03	1.33^{ns}

Note: F1 = IPB C15 x IPB C2, F1R = IPB C2 x IPB C15, ns = no significant, * = $p < 0.05$

Table 3. Variance component and heritability of quantitative characters in pepper

Variance Component	PH	SD	DH	DF	DH	FL	FD
Environment variance (σ^2_E)	107.23	2.79	4.03	22.00	23.27	2.08	2.61
Phenotype variance (σ^2_P)	214.62	6.93	19.66	85.10	48.89	3.65	5.04
Genetic variance (σ^2_G)	107.39	4.14	15.63	63.10	25.62	1.57	2.43
Additive variance (σ^2_A)	96.77	4.03	13.47	59.96	22.56	0.12	0.93
Additive variance ratio	90.11	97.34	86.18	95.02	88.06	7.64	38.27
Broad-sense heritability (h^2_{bs})	50.04	59.74	79.50	74.15	52.40	43.01	48.21
Narrow-sense heritability (h^2_{ns})	45.09	58.15	68.51	70.46	46.14	3.28	18.45

Note: PH = plant height, SD = stem diamater, DH = dichotomous height, DF = day to flowering, DH = day to harvesting, FL = fruit length, FD = fruit diameter

Table 4. Heterosis and heterobeltiosis of quantitative characters in pepper

Variance Component	PH (cm)	SD (mm)	DH (cm)	DF (DAS)	DH (DAS)	FL (cm)	FD (cm)
P1	49.08	9.44	8.32	92.60	139.90	10.10	15.85
P2	54.32	9.18	20.70	85.20	130.60	14.20	17.27
F1	52.18	9.09	12.39	92.00	137.89	13.37	17.25
MP	51.70	9.31	14.51	88.90	135.25	12.15	16.56
Heterosis (%)	0.93	-2.36	-14.61	3.49	1.95	8.40	4.17
Heterobeltiosis (%)	-3.94	-3.71	-40.14	6.80	7.29	-7.25	-0.12

Note: P1 = IPB C15, P2 = IPB C2, F1 = C15XC2, MP = mid parent, PH = plant height, SD = stem diamater, DH = dichotomous height, DF = day to flowering, DH = day to harvesting, FL = fruit length, FD = fruit diameter

Discussion

If a character is influenced by the female parent, the offspring of the reciprocal will likely be different (from the female parent), and the offspring will show traits of its female parent. F1 and F1 reciprocal (F1R) population cannot be merged because segregation of the F2 population will be different and does not follow Mendelian segregation law. However, if there was no significant difference between F1 and F1R then the two populations can be merged for the purposes of this analysis. A study by Arif *et al*. (2012) showed that dichotomous height and day to harvesting were not affected by maternal characters. In addition, Arif et al. (2011) reported there was no maternal effect for flower position, young fruit color, young stems color and texture of the pepper fruit surface. Therefore the offspring and reciprocal can be merged to obtain the next offspring, and the F2 segregation will follow Mendel's laws.

Heritability estimate of a character is important to predict whether the character is heavily influenced by genetic or environmental factors. High heritability suggests that genetic factors had greater influence over environment on phenotypic appearance. High heritability value, particularly the narrow-sense heritability, plays an important role in increasing the effectiveness of selection (Syukur et al., 2012).

Heritability value is between 0 and 1. Heritability value of close to 0 means the variance of phenotypes is primarily caused by environmental factors; values close to 1 means that it was mainly caused by genotype. Values closer to 1 indicate higher heritability whereas values closer to 0 indicates lower heritability (Syukur et al., 2012).

Broad-sense heritability was moderate to high for all characters. Several studies on pepper showed that broad-sense heritability estimates were high for dichotomous height (Syukur et al., 2010b), stem diameter (Syukur et al., 2010b; Nsabiera et al., 2013), plant height (Syukur et al., 2010b; Nsabiera et al., 2013), day to flowering (Lestari et al., 2006; Syukur et al., 2010c; Syukur et al., 2011; Nsabiera et al., 2013), day to harvesting (Syukur et al., 2011; Arif et al., 2012; Nsabiera et al., 2013), fruit length (Syukur *et al*., 2010a; Syukur *et al*., 2010b; Syukur et al., 2011; Nsabiera et al., 2013) and fruit diameter (Manju and Sreelathakumary, 2002; Sreelathakumary and Rajamony, 2004; Lestari et al., 2006; Syukur *et al*., 2010a; Syukur *et al*., 2010b; Syukur et al., 2010c; Syukur et al., 2011).

Narrow-sense heritability was low to high for all characters. Narrow-sense heritability was low for fruit length and fruit diameter, while the other characters were moderate to high. Several studies showed that narrow-sense heritability estimates in chilli were moderate to high for dichotomous height (Syukur et al., 2010), plant height (Ben-Cham and Paran, 2000; Marame et al., 2008; Singh et al., 2014), day to flowering (Singh et al., 2014), day to harvesting (Ben-Cham and Paran, 2000; Marame et al., 2008), fruit length (Ben-Cham and Paran, 2000; Marame et al., 2008; Syukur et al., 2010a; Singh et al., 2014) and fruit diameter (Ben-Cham and Paran, 2000; Syukur et al., 2010a; Singh et al., 2014).

The appearance of heterosis effects was caused by the accumulation of dominant genes whereas heterobeltiosis was due to the over-dominant gene on the character. Genetic distance among two parents is one of the factors that lead to high heterosis value (Syukur et al., 2012). Daryanto et al. (2010) and Sitaresmi et al. (2010) reported correlation between the parental genetic distance and heterosis. Parental genetic distance that is far apart produces high heterosis values.

The role of dominant effect on the observed character can also be seen from the ratio of additive variance. Fruit length and fruit diameter have a low ratio of additive variance. This ratio indicates that dominant variance was more influential in controlling the character. It can also be seen from the high heterosis values in both fruit length and fruit diameter.

Conclusion

All the characters except for fruit length were not controlled by maternal effect. Broad-sense heritability was high for plant height, stem diameter, dichotomous height, day to flowering, and day to harvesting, and was moderate for fruit length and fruit diameter. Narrow-sense heritability was high for stem diameter, dichotomous height, and day to flowering; moderate for plant height and day to harvesting; and low for fruit length and fruit diameter. The ratio of additive variance was high for all the characters, except for fruit length and fruit diameter.

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