J. Agron. Indonesia 38 (3) : 212 - 217 (2010)

Combining Ability of Several Introduced and Local Chilli Pepper (*Capsicum annuum* L.) Genotypes and Heterosis of the Offsprings

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Received 11 August 2010/Accepted 8 November 2010

ABSTRACT

The objective of the study was to identify the combining ability of several introduced and local chilli genotypes and heterosis effects of their offsprings, as a result of the hybridisation process. This information will be used for production of hybrid varieties. The study was conducted from November 2006 to May 2007 at Tajur experimental station, Bogor, West Java, Indonesia. The five parents with their ten F1 hybrids were evaluated in a randomized complete block design (RCBD) with three replications. The results showed that hybrid IPB C15 x IPB C19 had the highest fruit weight per plant, and hybrid IPB C8 x IPB C19 had the highest heterosis for this character. Hybrid IPB C8 x IPB C15 has highest number of fruits per plant and showed heterosis effects. Crosses among introduced and local genotypes resulted a high heterosis values. Additive variance of weight and number of fruits per plant were greater than the dominant variance. IPB C19 had the best general combining ability for fruit weight per plant character.

Keywords: capsicum, combining ability, heterobeltiosis, heterosis

INTRODUCTON

Chilli pepper (*Capsicum annuum* L.) is an annual plant that has been commercially cultivated in the tropics. According to Central Bureau of Statistics (2009), the national productivity of chilli pepper in Indonesia in 2008 was 6.44 ton ha^{-1}, and it is very low compared to the yield potential. Purwati *et al*. (2000) stated that the potential of national production of chilli pepper is about 12 ton ha $^{-1}$.

Many efforts can be done to improve the productivity of chilli pepper; one of them is through creating a superior chilli pepper variety. The formation of basic population to create the novel varieties can be conducted in several ways, e.g. through hybridization or crossbreeding. One crossing design, diallel, is a cross between all pairs of parental lines to make hybrids in all possible combinations, heterosis value, combining ability, and genetic diversity of a character.

The objective of chilli pepper breeding is generally to improve the plant production and its quality, pest and disease resistance, improving some horticultural traits, as well as to improve the ability against the environmental stress condition (Kusandriani and Permadi, 1996). Chilli pepper breeding is directed to the formation of open pollinated varieties and hybrids.

Creating hybrid variety is utilizing heterosis effect. Heterosis is the increasing of character value of F1 hybrids compared to the average value of both parents. The information concerning the effect of heterosis in crossing determines the choice of potential parental lines to obtain high productivity hybrids as well as having a good endurance (Sujiprihati *et al.*, 2008). High heterosis level can be obtained from crossing between genetically different parents. Some studies on chilli pepper showed that high heterosis in F1 was obtained from crossing between chilli pepper species of *C. annuum* L. (Milerue and Nikorpun, 2000; Seneviratne and Kannangara, 2004; Sujiprihati *et al*., 2007; Reddy *et al*., 2008; Kamble *et al*., 2009b; Marame *et al*., 2009; Daryanto *et al*., 2010).

Combining ability is a measurement of plant genotype ability in crossing to produce superior plants. Combining ability which is obtained from a cross between two parental lines can provide information regarding cross combinations for better heredity (Sujiprihati *et al*., 2008). Combining Ability Analysis can be performed using Griffing analysis (Griffing, 1956). The use of this analysis has been performed for various crops such as chilli pepper (Geleta *et al*., 2006; Sujiprihati *et al*., 2007; do Rego *et al*., 2009; Kamble *et al*., 2009; Daryanto *et al*., 2010), barley (Kakani *et al*., 2007), peanuts (Novita *et al*., 2007), papaya (Hafsah *et al*., 2007), and green pea (Kalia and Sood, 2009).

Combining ability tests and the prediction of heterosis value must be done to identify the prospective parents with a good combining ability in order to determine the direction of desired varieties (hybrids or open pollinated). The objective of this study is to estimate combining ability and heterosis of hybrid chilli pepper based on diallel analysis.

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MATERIALS AND METHODS

The research was conducted from November 2006 to May 2007. Seeds were sown at the Laboratory of Plant Breeding IPB before planting at IPB experimental field station at Tajur, Bogor (± 250 m above sea level; S 6° 36' 14.3" E 106° 50' 16.79").

There were five chilli pepper promising lines used as plant materials, namely IPB C2 (PSPT C11) and C19 IPB ('Randu') which are an Indonesian genotype, IPB C8 (ICPN 7#3), IPB C9 (ICPN 12#4), IPB C15 (0209-4) which are the introduced genotype from AVRDC, Taiwan, as well as 10 half-diallel crosses of hybrid (half diallel). Research was conducted using randomized complete block design using 15 genotypes as the treatments with 3 replications. Each experimental unit consisted of 20 plants, and from each experimental unit 10 plants were taken as samples. Scoring were made of the character of fruit weight per plant, number of fruits per plant and harvesting time.

The data were analyzed by F-test. Duncan's Multiple Range Test (DMRT) was used to analyze significant difference at level α = 5%. Values of heterosis and heterobeltiosis were calculated using the formula:

$$Heterosis = \frac{\mu_{F1} - \mu_{MP}}{\mu_{MP}} \times 100\%$$

$$Heterobeltiosis = \frac{\mu_{F1} - \mu_{BP}}{\mu_{BP}} \times 100\%$$

Annotation:

μ_{F1} = mean of F1

μ_{MP} = mean of male and female parents ((P1 + P2)/2)

μ_{BP} = median of the best parental line

The general combining ability (GCA) and specific combining ability (SCA) of pure lines were estimated by the methods 1- Griffing (Singh and Chaudhary, 1979) which is based on the half-diallel cross (five parental lines and 10 hybrids) with the assumption of no reciprocal effect occur.

RESULTS AND DISCUSSION

Analysis of Combining Ability

The general combining ability (GCA) for the character of fruit weight and fruit number per plant was significantly different, whereas the specific combining ability (SCA) for both characters were similar (Table 1). This is in contrast with some other studies reporting chilli pepper combining ability. According to Kamble *et al*. (2009a), do Rego *et al*. (2009), and Daryanto *et al*. (2010), GCA and SCA are significantly different for the character of the production (yield) in the population studied.

GCA is more influenced by additive gene action while SCA is affected more by dominant gene action (Roy, 2000). This can be seen in the additive variance of character of harvesting time and dominant variance of character of fruit number per plant. Additive variance of characters of harvesting time is negative and the value of its GCA is not significant; whereas the dominant variance of character of fruit number per plant is negative and the value of its SCA is not significant.

The weight of fruit per plant in F1 was strongly influenced by the value of GCA and/ or SCA. The parental lines with high GCA are IPB C19, IPB C15 and IPB C2, with values of 90.13, 41.14 and 24.65, respectively (Table 2). This fact demonstrated that the three of parental lines have a good combining ability to increase their fruit weight. Genotypes IPB C19 and IPB C2 are the local genotypes.

The highest GCA value for the characters of fruit number per plant shown by the parent line IPB C8 (13.51) and IPB C15 (12.34). This is consistent with its heterosis values: the highest heterosis value exists in the offspring from this parental hybridization. This fact also showed that besides their good combining ability, crossing result between IPB C8 and IPB C15 produced high heterosis.

When a random sampling from a line population showing the greatest additives variance, it is better not to direct the selection program towards the formation of hybrid

Table 1. Analysis of variance of half diallel crossing of chilli pepper

Source of variance	Degree of freedom	Mean square		
		Fruit weight per plant	Fruit number per plant	Time to harvest (dap)
GCA	4	50056.47**	1361.100*	37.24ns
SCA	10	1941.07 ns	314.33ns	41.93*
Error	28	3040.13	455.24	14.74
V_{add}		13747.26	299.33	-1.34
V_{dom}		-1099.05	-140.91	27.18
CV (%)		26.34	44.40	7.52

Keterangan: * = significant at level α = 5%; ** = significant at level α = 1%; ns = not significant; GCA = General Combining Ability; SCA = Specific Combining Ability; V_{add} = Additive Variance; V_{dom} = Dominant Variance; CV = Coefficient of Variance

(Sujiprihati *et al*., 2008). Additive variance is larger than the dominant variance in the character of fruit weight per plant and fruit number per plant. Genotypes that can be directed to be the open pollinated variety is IPB C19 because it has the best general combining abilities for the character of fruit weight per plant.

Heterosis dan Heterobeltiosis

The fruit weight per plant from all crossing parent was ranged from 66.01 - 384.12 g, while all cross combinations gave a higher yield than those of the average of both parents. The highest heterosis found in hybrids IPB C8 x IPB C19 with fruit weight 352.19 g and heterosis value of 29.76%. The fruit weight of hybrid IPB C15 x IPB C19 (528.65 g) was the highest among all hybrids, followed by hybrid IPB C2 x IPB C15 (482.47 g), IPB C19 x IPB C9 (475.77 g), and IPB C2 x IPB C19 (463.49 g) (Table 3). According to Sousa and Maluf (2003), Sujiprihati *et al*. (2007), Marame *et al*. (2009), and Daryanto *et al*. (2010), some combinations of chilli pepper crossing showed high heterosis value for variable of production. Herison *et al.* (2001), also stated that more than 50% of chilli pepper cross combination tested showed high values of the heterobeltiosis for variable of production.

The character of fruit number per plant also showed positive heterosis effect. This means an increasing vigor for the two characters, compared to the average of both parents. The parent line had 50.26-83.51, fruits per plant whereas, the hybrid had 63.11-140.93, with heterosis values ranged from 7.33-68.76%. The hybrid of IPB C8 x IPB C15 had the highest number of fruits (62.93) compared to other hybrids with high heterosis (68.76%) (Table 4). High heterosis on characters of fruit number per plant was also reported in previous studies such as Seneviratne and Kannangara (2004), Reddy (2008), and Kamble *et al*. (2009b).

The value of heterosis for the characters of time to harvest ranged from -6.86% to 17.42%, while the value heterobeltiosis ranged from -9.44% to 17.19%. IPB hybrid C8 x IPB C19 showed the lowest value of heterosis and heterobeltiosis for the character of time to harvest. This fact shows that the hybrid could be harvested 6 days earlier than average of both parents and 3.5 days earlier than the best parent (IPB C19) (Table 5). The nature of early maturing is beneficial for breeders in selecting hybrid varieties with characters of early maturing and high production.

Based on the high heterosis value of some crosses, it is assumsed that the genetic distance of parental genotype is quite far. Some crosses are combination of introduced genotypes (IPB C8 and IPB C15) and local genotypes (IPB C2 and IPB C19). For instance, for the character of fruit weight per plant, crosses of IPB C8 x IPB C19 produced the highest heterosis values whereas crossbreeding between IPB C2 x IPB C15 produced the highest heterobeltiosis values. According to Marame *et al*. (2009), the maximum heterosis and heterobeltiosis obtained in F1 from crossbreeding

Table 2. General combining ability (GCA) and specific combining ability (SCA) of some characters of chilli pepper

Genotype	Fruit weight per plant	Fruit number per plant	Harvesting time
GCA:			
IPB C2	24.65	2.27	3.17
IPB C8	-132.84	13.51	-0.51
IPB C9	-23.08	-18.69	-2.31
IPB C15	41.14	12.34	1.50
IPB C19	90.13	-9.43	-1.85
SCA:			
IPB C2 x IPB C8	8.08	6.87	-6.40
IPB C2 x IPB C9	-12.20	-3.69	5.73
IPB C2 x IPB C15	54.12	12.88	9.25
IPB C2 x IPB C19	8.40	0.80	10.26
IPB C8 x IPB C9	-2.37	19.78	2.07
IPB C8 x IPB C15	13.40	31.58	0.26
IPB C8 x IPB C19	42.60	0.97	-1.15
IPB C9 x IPB C15	19.07	0.66	-0.94
IPB C9 x IPB C19	46.16	1.72	-3.93
IPB C15 x IPB C19	34.83	-2.55	-5.74

between Ethiopian and Asian genotypes. Roy (2000) stated that a cross between unrelated varieties will generally result a high hybrid vigor than those from related varieties.

The heterosis of fruit weight per plant in some cross combinations showed different results from those obtained in other studies. Studies conducted by Sujiprihati *et al*. (2007) at different locations demonstrated that the heterosis of fruit weight per plant in hybrid IPB C2 x IPB C8 and IPB C9 x IPB C8 were negative. This is not in accordance with the results obtained in this study, since the heterosis for both are positive.

Table 3. Mean of parent line and hybrid, and the value of heterosis and heterobeltiosis of chilli pepper for the character of fruit weight per plant

Genotype	Fruit weight per plant (g)				Heterosis (%)	Heterobeltiosis (%)
	P1	P2	MP	F1		
IPB C2 x IPB C8	382.66	66.01	224.33	262.45c	16.99	-31.41
IPB C2 x IPB C9	382.66	291.06	336.86	351.93abc	4.47	-8.03
IPB C2 x IPB C15	382.66	384.12	383.39	482.47ab	25.84	25.60
IPB C2 x IPB C19	382.66	476.82	429.74	485.74ab	13.03	1.87
IPB C8 x IPB C9	66.01	291.06	178.54	204.26c	14.41	-29.82
IPB C8 x IPB C15	66.01	384.12	225.06	284.25bc	26.30	-26.00
IPB C8 x IPB C19	66.01	476.82	271.41	352.19abc	29.76	-26.14
IPB C9 x IPB C15	291.06	384.12	337.59	399.68abc	18.39	4.05
IPB C9 x IPB C19	291.06	476.82	383.94	475.77ab	23.92	-0.22
IPB C15 x IPB C19	384.12	476.82	430.47	528.65a	22.81	10.87

Note: mean of hybrid (F1) followed by the same letter is not significant based on DMRT at level α = 5%. P1 = parent 1, P2 = parent 2, MP = mid parent, F1 = Zuriat 1

Table 4. Mean of parent line and hybrid, and the value of heterosis and heterobeltiosis of chilli pepper for the character of fruit number per plant

Genotype	Fruit number per plant				Heterosis (%)	Heterobeltiosis (%)
	P1	P2	MP	F1		
IPB C2 x IPB C8	79	81	80	106a	32	32
IPB C2 x IPB C9	79	37	58	63ab	9	-20
IPB C2 x IPB C15	79	87	83	111a	34	28
IPB C2 x IPB C19	79	64	72	77ab	7	-3
IPB C8 x IPB C9	81	37	59	98ab	67	22
IPB C8 x IPB C15	81	87	84	141a	69	63
IPB C8 x IPB C19	81	64	72	108a	50	35
IPB C9 x IPB C15	37	87	62	78ab	26	-10
IPB C9 x IPB C19	37	64	50	57b	13	-11
IPB C15 x IPB C19	87	64	75	84ab	11	-3

Note: mean of hybrid (F1) followed by the same letter is not significant based on DMRT at level α = 5%. P1 = parent 1, P2 = parent 2, MP = mid parent, F1 = Zuriat 1

Table 5. Mean of parent line and hybrid, and the value of heterosis and heterobeltiosis of chilli pepper for the character of harvesting time

Genotype	Harvesting time (days)				Heterosis (%)	Heterobeltiosis (%)
	P1	P2	MP	F1		
IPB C2 x IPB C8	85.33	90.00	87.67	84.67cd	-3.42	-5.93
IPB C2 x IPB C9	85.33	82.33	83.83	95.00abc	13.32	11.33
IPB C2 x IPB C15	85.33	90.00	87.67	102.33a	16.73	13.70
IPB C2 x IPB C19	85.33	85.00	85.17	100.00ab	17.42	17.19
IPB C8 x IPB C9	90.00	82.33	86.17	87.67cd	1.74	-2.59
IPB C8 x IPB C15	90.00	90.00	90.00	89.67bcd	-0.37	-0.37
IPB C8 x IPB C19	90.00	85.00	87.50	81.50d	-6.86	-9.44
IPB C9 x IPB C15	82.33	90.00	86.17	86.67cd	0.58	-3.70
IPB C9 x IPB C19	82.33	85.00	83.67	80.33d	-3.98	-5.49
IPB C15 x IPB C19	90.00	85.00	87.50	82.33d	-5.90	-8.52

Note: mean of hybrid (F1) followed by the same letter is not significant based on DMRT at level α = 5%. P1 = parent 1, P2 = parent 2, MP = mid parent, F1 = Zuriat 1

CONCLUSION

The value of additive variance is greater than the dominant variance either for the character of fruit weight per plant or fruit number per plant. Genotypes that can be directed to assembly the open pollinated variety is IPB C19 since it has the best general combining ability for the character of fruit weight per plant.

The cross between IPB C15 x IPB C19 produced the highest fruit weight per plant, while the highest heterosis value for that character found in the hybrid IPB C8 x IPB C19, and the highest heterobeltiosis value was in hybrids IPB C2 x IPB C15. Hybrid of IPB C8 x IPB C15 has the highest number of fruit per plant and the highest value of heterosis and heterobeltiosis. Crossbreeding between local genotypes and the introduced one produced high heterosis value.

ACKNOWLEDGEMENT

The authors thank Directorate of Higher Education, National Educational Ministry who provided funding for these research (contract No. 317/SP3/PP/DP2M/II/2006 on behalf of Sriani Sujiprihati), and Faperta-AVRDC 2006 Collaboration Research Team.

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