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Inheritance and combining ability studies for yield and yield-attributing traits of crossing big and curly fruit lines in chili (Capsicum annuum L.)

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Abstract. Big and curly fruit lines of Capsicum annuum L. were crossed according to Griffing’s Method (Diallel) Method 1. The objectives of this paper were to show the assessment of the general combining ability (GCA) and specific combining ability (SCA) of C. annuum L. lines through diallelic crosses providing information about the genetic effect, heritability and heterosis on expression of yield and yield component traits. Thirty cross combination and six parent lines were evaluated in a randomized complete block design with three replications. The experiment was conducted at Leuwikopo experiment field, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University on October 2012 to April 2013. The GCA and SCA means square were significant for all traits. The higher values of mean squares associated to GCA indicates a strong contribution of additive genetic effects to the expression of some traits. C5 scored highly for GCA in some traits and can be used to develop an open pollinated variety. Estimates of heritability showed that some of the traits were highly heritable, and weight per plant trait should readily be improved by selection. The SCA of cross C2×C5, C5×C120, C19×C120, C120×C159 were found to be high, with progeny showing high positive heterosis for some traits, thereby indicating that those crosses have the potential to function as a superior cultivar within commercial breeding programmes.

1. Introduction
Chili is classified to some types based on its fruit size, such as cayenne chili, big chili, curly chili, and peppers[1]. The productivity of chili in Indonesia was only 6.18 ton per hectare in 2011, much lower than its potential of 20 tons per hectare [2, 3]. The low productivity of chili might be caused by the difference of habit of Indonesian farmers in case of planting and consuming chili based on its size. Genetically, the productivity of curly chili is lower than big chili [1]. Plant breeding activities to construct new superior varieties with specific fruit size is needed to increase its productivity [4] One of the effort in constructing the new superior varieties is using diallelic crossing analysis.

Method of diallellic crossing analysis is developed to obtain information of genetic mechanism involved in previous generation [5]. Complete diallellic crossing will create population that approximate to Hardy-Wienberg balanceness. With this crossing, it is possible for us to do complete and systematic genetic analysis [6]. This analysis method can be used to predict additive variance, dominance, genetic variability, and heritability value for each character observed, so it can be used for identifying the crossing activities to provide best potential selection for initial generation [7]. This
analysis provides benefit for helping the breeder to produce chili with high productivity in specific size.

Construction of new superior varieties with specific size is closely related to the potential of parental used, that has high combining ability. The examination of generation produced can be used to identify parental combination with high productivity and preferable fruit size. Dialellic analysis can provide information about general combining ability (GCA) and specific combining ability (SCA) from parental used. GCA is parental performance in single crossing combination compared to other parents, meanwhile, SCA is the result of hybridization between parents [8]. Several researches have been published about combining ability in chili [9], [10-14]. The objective of this study is to obtain information about genetic parameter of productivity and crossing result components of big chili and curly chili, and to provide information about combining ability of parental used.

2. Materials and methods
Research was conducted in Leuwikopo Experimental Field and Laboratory of Plant Breeding, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University from October 2012 until April 2013. This research used 6 parental lines and 30 F1 hybrids combinated from complete dialellic crossing of 6 chili lines, collection of Laboratory of Plant Breeding, there were semi-curly chili (IPBC2), big chili (IPBC5), curly chili (IPBC19, IPBC111, IPBC120, and IPBC159). The experimental design used was complete randomized block design (CRBD) with 6 parental lines and 30 F1 as factor in 3 replications. Fruit weight, fruit length, fruit stalk length, fruit thickness, and total fruit weight per plant were observed. Data observed were analyzed by F-test with \( \alpha = 0.05 \). Data with significant difference was furtherly analyzed by diablellic analysis to predict the value of general combining ability (GCA) and specific combining ability (SCA) and parental reciprocal effect by Griffing1 method [8].

3. Results and discussion
Analysis of variance showed significant difference at alpha 1% for variables observed, there were weight per plant, thickness of fruit, diameter of fruit, and length of fruit (table 1). Genetic parameter using diablellic crossing analysis can be predicted if divided result of mean square and error mean square in variables observed are below 0.01 [8]. Information obtained from GCA and SCA is very important in chili breeding activities. Information obtained from GCA and SCA analysis provide benefit to determine the parent and suitable breeding method in improving characters prefered in a plant [15].

| Source of variance | df | Weight per plant mean square | Fruit weight mean square | Thickness of fruit mean square | Diameter of fruit mean square | Lenght of fruit mean square |
|--------------------|----|-------------------------------|--------------------------|-------------------------------|------------------------------|----------------------------|
| Replication        | 2  | 1154.8742**                  | 0.2442**                 | 0.0017ns                     | 1.8584ns                    | 0.7104ns                   |
| Genotype           | 35 | 11462.2556**                 | 23.8584**                | 0.4025**                     | 51.3397**                   | 21.5592**                  |
| Error              | 70 | 2121.1149                    | 0.8250                   | 0.0211                        | 0.8552                      | 1.7329                     |

Note: * = significantly different at \( \alpha = 5\% \); ** = significantly different at \( \alpha = 1\% \); ns = not significantly different

Result of GCA and SCA analysis of variance showed significant difference for weight per plant, weight per fruit, diameter of fruit, and length of fruit characters (table 2). This data indicated the effect of additive and dominant genes action in all of those variables. Characters having significant difference of GCA and SCA were controlled by action of additive and dominant genes [6]. In this research, additive variance value in each of characters observe was higer that dominat variance value (table 2). In addition, the genetic ratio value showed that additive gen action played more important role that affecting the performance of characters observed compared to dominant gen action.
Table 2. Mean square of GCA, SCA, reciprocal, additive variance, and dominant variance and productivity of chili.

| Source of variance | df  | Weight per plant | Weight per fruit | Thickness of fruit | Diameter of fruit | Length of fruit |
|-------------------|-----|------------------|------------------|-------------------|------------------|----------------|
| GCA               | 5   | 11258.32**       | 47.23**          | 0.72**            | 107.34**         | 40.25**        |
| SCA               | 15  | 3003.31**        | 1.76**           | 0.05**            | 2.83**           | 2.73**         |
| Resiprocal        | 15  | 2159.01**        | 1.04**           | 0.01*             | 1.31**           | 0.61**         |
| Error             | 70  | 707.04           | 0.27             | 0.01              | 0.28             | 0.57           |
| Additive variance |      |                  |                  |                   |                  |                |
| Dominant variance |      |                  |                  |                   |                  |                |
| Genetic variance  |      |                  |                  |                   |                  |                |

Note: * = significantly different at $\alpha = 5\%$; ** = significantly different at $\alpha = 1\%$; ns = not significantly different

Result of general combining ability analysis for each character observed is presented in Table 3 which showed that C5 line has highest GCA value compared to other five parents. C5 line is quietly good combiner parent to provide chili with big size that related to weight per plant, weight per fruit, thickness of fruit, and diameter of fruit. Based on length of fruit, C120 line has highest GCA value compared to other five parents. This data indicated that C120 line is quietly good combiner parent to provide chili with long fruit size.

Table 3. Prediction value of general combining ability of fruit characters and productivity of chili.

| Lines  | Weight per plant | Weight per fruit | Thickness of fruit | Diameter of fruit | Length of fruit |
|--------|------------------|------------------|--------------------|-------------------|----------------|
| C2     | -1.23            | 1.20             | 0.10               | 1.85              | 0.01           |
| C5     | 23.32            | 1.58             | 0.19               | 2.44              | -0.55          |
| C19    | 21.88            | 1.18             | 0.11               | 1.97              | -0.46          |
| C111   | -1.47            | -0.60            | -0.06              | -0.70             | -0.31          |
| C120   | 9.28             | 0.11             | -0.02              | -0.13             | 1.78           |
| C159   | -12.27           | -0.80            | -0.11              | -0.89             | -0.41          |

Specific combining ability is the expression of non-additive genetic variance including dominant and epistatic variance. Based on Table 4, crossing combinations with highest SCA value were C120xC159 for weight per fruit, C2xC5 for weight per plant, C2xC111 for thickness of fruit, C19xC2 for diameter of fruit, and C5xC159 for length of fruit. Based on SCA value, not all of lines with high GCA value will also deliver high SCA value. Positive value of SCA showed that certain parents have high hybrid combination with one of parents used. Contrarily, negative value of SCA indicated that certain parents have no hybrid combination with one of lines used [15].

Based on the result of genetic parameters and evaluation of combining ability examined, each of productivity component characters was affected by additive and dominant (non-additive) gene action. The higher effect of additive gene action than dominant gene action in all characters showing the level of partial dominance for each character. This indicates that the performance of characters observed is not only affected by additive gene only, but also affected by dominant gene action. If dominant gene action higher than additive gene action, over dominant dominance level will happen. Determination of all heredity characters can be directed to additive gene action if the breeder wanted to do pure line selection. Dominant gene action was also affecting the performance of all characters, so it can give opportunity to the breeder in constructing hybrid lines. General description of productivity characters heredity in population used is the consequences of breeding program conducted by breeders in constructing chili parent.
Table 4. Prediction value of specific combining ability of fruit characters and productivity of chili.

| Lines                      | Weight per plant | Weight per fruit | Thickness of fruit | Diameter of fruit | Lenght of fruit |
|----------------------------|------------------|------------------|-------------------|------------------|----------------|
| C2 × C5                    | 19.02            | 1.41             | -0.17             | 1.54             | 0.84           |
| C2 × C19                   | 44.43            | -0.21            | -0.17             | -2.63            | 0.49           |
| C2 × C111                  | -23.39           | 0.43             | 0.34              | -0.43            | 0.51           |
| C2 × C120                  | -21.02           | -0.17            | 0.17              | -0.04            | -0.68          |
| C2 × C159                  | 38.69            | -0.27            | -0.04             | -0.49            | 0.16           |
| C5 × C2                    | -49.63           | -0.77            | -0.04             | -0.64            | -0.35          |
| C5 × C19                   | -31.99           | 1.38             | 0.01              | 1.01             | 1.20           |
| C5 × C111                  | 36.43            | -0.50            | -0.05             | -0.58            | -0.02          |
| C5 × C120                  | -4.80            | 0.38             | 0.08              | 1.09             | -1.11          |
| C5 × C159                  | -19.47           | -0.20            | -0.13             | -1.21            | 1.76           |
| C19 × C2                   | -44.99           | 2.03             | 0.21              | 1.68             | 1.10           |
| C19 × C5                   | 34.96            | -0.52            | -0.07             | -1.56            | -0.42          |
| C19 × C111                 | -9.81            | -0.04            | 0.04              | 0.43             | -0.53          |
| C19 × C120                 | -32.49           | 1.13             | -0.09             | 0.40             | 0.38           |
| C19 × C159                 | -47.65           | -0.27            | 0.16              | -0.33            | 0.95           |
| C111 × C2                  | -15.48           | 0.06             | -0.08             | -0.30            | 0.02           |
| C111 × C5                  | 15.91            | 0.00             | 0.00              | 0.27             | 0.45           |
| C111 × C19                 | 30.43            | -0.39            | -0.05             | -0.32            | -0.15          |
| C111 × C120                | 23.71            | -0.27            | -0.02             | -0.76            | 0.73           |
| C111 × C159                | -9.30            | 0.59             | -0.03             | 0.67             | -0.65          |
| C120 × C2                  | 10.00            | 0.51             | 0.10              | 0.81             | -0.83          |
| C120 × C5                  | -22.30           | -0.73            | -0.17             | -1.54            | 1.28           |
| C120 × C19                 | 20.90            | 1.32             | -0.02             | 0.76             | -0.16          |
| C120 × C111                | 34.28            | 0.00             | 0.05              | 0.09             | 0.14           |
| C120 × C159                | 70.04            | 0.32             | 0.14              | 0.53             | 0.23           |
| C159 × C2                  | 13.70            | 0.04             | 0.01              | 0.45             | 0.03           |
| C159 × C5                  | -55.61           | 0.35             | 0.09              | 0.12             | 0.67           |
| C159 × C19                 | 17.03            | 0.12             | -0.06             | 0.14             | -0.10          |
| C159 × C111                | -9.05            | -0.16            | -0.05             | -0.19            | 0.29           |
| C159 × C120                | -56.59           | -0.01            | 0.00              | -0.21            | -0.02          |

4. Conclusion
Each of characters observed was affected by both additive gene action and dominant (non-additive) gene action with partial dominance level. C5 line has good general combining ability (GCA) value for weight per plant, weight per fruit, thickness of fruit, and diameter of fruit, except C120 line that has good specific combining ability (SCA) value for length of fruit. The highest SCA value was obtained by C120xC159 for weight of plant, C2xC5 for weight per fruit, C19xC2 for diameter of fruit, and C5xC159 for length of fruit characters.
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