AGRIVITA VOLUME 34 No. 1 FEBRUARY-2012 ISSN : 0126-0537

ANALYSIS OF COMBINING ABILITY, HETEROSIS EFFECT AND HERITABILITY ESTIMATE OF YIELD-RELATED CHARACTERS IN SHALLOT (*Alium cepa* var. *ascalonicum* Baker)

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Received: July 12, 2011/ Accepted: December 12, 2011

ABSTRACT

Low productivity of shallot in Indonesia can be improved through development of high yielding variety. The availability of genetic information related to the character being improved is inevitable for effective breeding program. In this study, seven shallot genotypes were evaluated for their combining ability for yield improvement using half diallel cross. Heterosis effect and heritability estimate was also investigated for yield-related characters. The results showed that there were significant differences in general combining ability (GCA) and specific combining ability (SCA) among the evaluated genotypes. Tiron and Timor had the greatest GCA. The greatest SCA and heterosis value was found in crosses of Kuning/Tiron, Timor/Bima Juna, Tiron/Timor and Kuning/Sibolangit. Heterosis effect varied from low to high. Broad sense heritability estimate for all characters was high, but narrow sense heritability was low for most charaters. The dominant gene action observed on all yield-related characters suggests that the evaluated genotypes are potential to be used in breeding for high yielding hybrid varieties.

Keywords: GCA, SCA, heterosis, heritability, shallot

INTRODUCTION

Asian and world average shallot productivity ranges from 13 to 15 tons ha^{-1}, respectively (Pathak, 1997), but the average shallot productivity in Indonesia is only 9.2 tons ha^{-1} (BPS, 2008). Shallot yield may be improved by the use of high yielding varieties (Duriat *et al*., 1999). However, efforts to improve shallot yield through breeding of high yielding varieties using local varieties from Brebes, Indonesia has, so far, resulted only in 9% yield increase (Farid *et al*., 2007). Therefore, evaluation and selection of shallot parental genotypes with superior genetic potential is inevitable.

The use of closely related shallot varieties in breeding for high yielding varieties did not give a significant increase (Farid *et al*., 2007). The use of gamma radiation has enhanced shallot resistance to purple spot disease, but did not improve yield (Sunarto, *et al.,* 2004). Arifin and Okubo (1996) reported a significant genetic variation for some characters among 153 shallot genotypes. Analysis of genetic variability using Random Amplified Polymhrophic DNA (RAPD) and Amplified Fragment Length Polymorphism (AFLP) markers on 129 shallot genotypes revealed a wide genetic distance in some genotypes (Arifin *et al*., 2000). Variation in anthocyanin and flavonol contents among 15 shallot genotypes was also reported (Arifin *et al*., 1999). Anthocyanins and flavonols are known to affect shallot storability and resistance to disease (Hurst *et al*., 1985).

Genetic potentials of parental genotypes can be evaluated using different types of crossing population. Diallel cross can be used to analyze combining ability, gene action, heterosis effect and heritability of a character

Accredited SK No.: 81/DIKTI/Kep/2011

http://dx.doi.org/10.17503/Agrivita-2012-34-1-p036-043

(Khan *et al,* 2009). Combining ability analysis is a powerful tool in selection of desirable parents and crosses through the exploitation of heterosis (Sarker *et al*., 2002; Rashid *et al*., 2007). Studies of combining ability and heterosis with half diallel cross have been reported in rice (Srivasta dan Verma, 2004), apricots (Couranjou, 1995), and corn (Sudha *et al.*, 2004). The parental genotypes used for half diallel cross in these studies varied from five to seven varieties (Couranjou, 1995; Srivasta dan Verma, 2004; Sudha *et al.*, 2004).

The objectives of this study were to analyze combining ability, and to estimate heterosis effect and heritability of yield-related characters of F_1 hybrids derived from half diallel cross of seven shallot parental genotypes used for yield improvement.

MATERIALS AND METHODS

Shallot genotypes used for crossing comprised Kuning, Bima, Tiron, Timor, Sibolangit, Maja, and Bima Juna. These genotypes were selected based on their wide genetic distances as reported by Arifin *et al*. (1999). Crossing of these parental genotypes was conducted at the Indonesian Vegetable Research Institute (INVEGRI), Lembang, Indonesia from May to August 2009. Evaluation of the progenies was carried out in a screen house at the Experimental Station of Faculty of Agriculture, the University of Jenderal Soedirman (Unsoed) Indonesia from December 2009 to April 2010.

Analysis of combining ability was carried out using F_1 hybrids derived from half diallel cross of seven parental genotypes. Number of crosses was determined following half diallel mating design, i.e.: n (n-1) / 2, where n is the number of parental genotypes, such that the number of F_1 hybrids is 7 (7-1) / 2 = 21. These 21 F_1 hybrids along with their parental genotypes were grown in pots filled with soil and arranged using Randomized Complete Block Design with three replications in a screen house. The observed characters included plant height (cm), number of bulblets, number of bulbs, bulb diameter (cm), bulb fresh weight (g), and bulb dry weight (g). Analysis of combining ability was carried out following Griffing method II (Singh and Chaudari, 1979), heterosis effect was calculated following Fehr (1987), and heritability estimate was calculated following Allard (1960).

Components of analysis of variance (ANOVA) for GCA and SCA are presented in Table 1.

Table 1. Components of analysis of variance (ANOVA) for GCA and SCA

Source of variance	df	SS	MS	E(MS)
GCA	n – 1	SS_{GCA}	MS_{GCA}	$\sigma^2_e + \sigma^2_A + (n+2)\,\sigma^2_D$
SCA	n(n – 1)	SS_{SCA}	MS_{SCA}	$\sigma^2_e + \sigma^2_A$
Error	e	SS_e	MS_e	σ^2_e

Where :

$$SS_{GCA} = \frac{1}{2+n}\left[\Sigma(Yi. + Yii)^2 - \frac{4}{n^2}Y^2..\right]$$

$$SS_{SCA} = \Sigma\Sigma Yij^2 - \frac{1}{2+n}\left[\Sigma(Yi. + Yii)^2\right] + \frac{2}{(n+1)(n+2)}Y^2..$$

Formula for estimation of GCA:

$$g_i = \frac{1}{n+2}\left[\sum(Y_{i.} - Y_{ii}) - \frac{2}{n}Y_{..}\right]$$

where:

g*i* = general combining ability of i^{th} parent
n = number of parental genotypes
Y*i.* = average value of i^{th} hybrid
Y*ii* = average value of i^{th} parent
Y.. = total value of the hybrids

Formula for estimation of SCA:

$$s_{ij} = Y_{ij} - \frac{1}{n+2}(Y_{i.} + Y_{ii} + Y_{.j} + Y_{jj}) + \frac{1}{(n+1)(n+2)}Y_{..}$$

where:

S*ij* = specific combining ability of i^{th} and j^{th} parent
Y*ij* = average value of the hybrids of the cross between parent i^{th} and j^{th}
n = number of parental genotypes
Y*i.* = average value of i^{th} hybrid
Y*ii* = average value of i^{th} parent
Y.*j* = average value of j^{th} hybrid
Y*jj* = average value of j^{th} parent
Y.. = total value of the hybrids

Formula for estimation of heterosis effect:

$$h = \frac{[F1 - HP]}{HP} x100\%$$

where:

h = heterosis effect
F_1 = mean performance of hybrid
HP = mean performance of higher parent

Formula for estimation of broad sense heritability:

$$H_{BS} = \frac{\sigma_A + \sigma_D}{\sigma_A + \sigma_D + \sigma_E}$$

where :

H_{BS} = broad sense heritability
σ_A = additive variance
σ_D = dominant variance
σ_E = error variance

Formula for estimation of narrow sense heritability:

$$H_{NS} = \frac{\sigma_A}{\sigma_A + \sigma_D + \sigma_E}$$

where :

H_{NS} = narrow sense heritability
σ_A = additive variance
σ_D = dominant variance
σ_E = error variance

RESULTS AND DISCUSSION

Analysis of variance of combining ability revealed significant differences among the parental genotypes (Table 2). This result indicated that the evaluated genotypes had a wide genetic diversity for all the characters (Table 2). Additive variances for all characters were smaller than dominant variances (Table 2) indicating the role of dominant genes on all characters. The large role of dominant genes observed in this study suggests greater opportunities to develop high yielding hybrid varieties using the evaluated genotypes. This agreed with previous studies on combining ability in some crops where greater dominant variance was observed, as compared to additive variance, and that the parents could be exploited to develop superior hybrid varieties. (Wang *et al.*, 1995; Zeinanloo *et al.*, 2009; Khan, 2009; Ohara *et al.*, 2004).

Among the evaluated genotypes, Tiron and Timor displayed the greatest GCA on all characters except plant height and bulb diameter (Table 3). This suggests that Tiron and Timor had greatest genetic potentials to be used in a crossing program to produce high yielding hybrid varieties.

The greatest SCA for plant height was observed in the cross of Kuning/Sibolangit, followed by Tiron/Timor and Kuning/Bima Juna, while the greatest SCA for number of bulblets and number of bulbs were observed on the cross of Kuning/ Sibolangit, followed by Tiron/Maja, and Tiron/ Timor (Table 4). These parental combinations are desirable to be used to improve plant height, as well as bulblets and number of bulbs. The greatest SCA for bulb diameter was observed in the cross of Kuning/Timor, followed by then Bima/Maja and Kuning/Bima. These parental combinations are potential to be used to improve number of bulb and bulb diameter.

Table 2. Analysis of variance of combining ability on yield and yield-related characters in shallot

Source of variance	Mean square					
	Plant height (cm)	**Number of bulblets**	**Number of bulbs**	**Bulb diameter (cm)**	**Bulb fresh weight /hill (g)**	**Bulb dry weight/hill (g)**
GCA	41.80**	2.11**	2.11**	0.04^{ns}	43.56**	41.84**
SCA	14.98**	0.98**	0.98**	0.12**	101.05**	76.02**
Error	6.11	0.08	0.08	0.03	5.70	2.34
Additive variance	5.96	0.25	0.25	-0.02	12.77	7.59
Dominant variance	8.87	0.90	0.90	0.08	95.35	73.68
CV (%)	13.54	32.41	32.41	17.56	25.63	19.46

Remarks: ns : not significant (P>0.05), ** : highly significant based on F-test (P<0.01).

Table 3. Estimate of GSA of parental genotypes based on the observed characters

Parental genotypes	Characters					
	Plant height (cm)	**Number of bulblets**	**Number of bulbs**	**Bulb diameter (cm)**	**bulb fresh weight /hill (g)**	**bulb dry weight/hill (g)**
Kuning	-2.24	0.45	0.45	-0.02	-0.99	-0.62^{ns}
Bima	-1.48	-0.63	-0.63	0.06	-1.67	-2.09*
Tiron	1.33	0.71	0.71	0.07	3.75	3.12*
Timor	0.79	0.06	0.06	-0.09	2.34	2.44*
Sibolangit	-2.82	-0.22	-0.22	-0.06	-2.18	-1.84*
Maja	1.69	-0.50	-0.50	0.08	-0.95	-1.85*
Bima Juna	2.73	0.13	0.13	-0.05	-0.29	0.84^{ns}

Remarks: LSD for bulb dry weight = 0.98

The greatest SCA for bulb fresh weight was observed in the cross of Kuning/Sibolangit, followed by Kuning/ Tiron and Timor/Bima Juna (Table 4). In bulb dry weight, however, the greatest SCA was obsersed in the cross of Kuning/Tiron, followed by Kuning/Sibolangit ,and Timor/Bima Juna (Table 4). Selection of parental genotypes used in crossing program for development of new varieties should be based on the value of GCA, SCA and heterosis (Khan *et al.,* 2009; Lawali and Shehu, 2008). \

The heterosis value of observed characters varied from -76 to 111 percent. The cross combination of Kuning/Tiron had highest heterosis value and the greatest yield potential (Table 5). Therefore, this crossing combination was potential to be used for producing hybrid cultivar. Heterosis and yielding potential has been used as the basic consideration for breeding of hybrid onion (Aghora and Pathak, 1991; Netrapal and Singh, 1999; Shashikanthevoor *et al*., 2007).

Heritability value describes the degree of inheritance of character from parent to their offsprings, and also indicate the magnitude of environmental effect on the expression of the character (Allard, 1960). Broad sense heritability of all characters was high. Narrow sense heritability of plant height was moderate, but was low for the rest of yield-realted characters (Table 6). Heritability lower than 0.25 is low, 0.25 to 0.50 is moderate, and greater than 0.50 is high (Stansfield, 1983). In previous study, shallot demonstrated greater broad sense heritability on all characters but bulb weight (Sari, 2007), while the narrow sense heritability varied from low to high (Farid *et al.,* 2010). Differences in heritability estimate of yield-related characters found in the present study and the previous ones were possibly because different parents were used. Thus, the cross is suitable for breeding shallot hybrid for high yielding capacity considering the high yield genes are dominant genes. Heritability value is used as a guide in selection and prediction of selection (Verma and Srivasta, 2004; Topal *et al.*, 2004).

Table 4. Estimate of SCA of the parental genotypes based on the observed characters of the diallel cross F_1 hybrids

Half diallel cross	Characters						
	Plant height (cm)	Number of bulblets	Number of bulbs	Bulb diameter (cm)	Bulb fresh weight/ hill (g)	Bulb dry weight/ hill (g)	Observed of bulb dry weight/hill (g)*
Kuning/Bima	-3.17	-0.67	-0.67	0.34	-7.51	-5.93	10.64 a
Kuning/Tiron	0.46	-0.34	-0.34	0.14	16.66	15.47	37.24 e
Kuning/Timor	-2.64	-0.19	-0.19	0.47	-1.82	-0.90	20.20 bc
Kuning/Sibolangit	6.83	1.92	1.92	-0.11	18.94	13.61	30.43 de
Kuning/Maja	1.08	-0.80	-0.80	0.09	-6.79	-5.65	11.16 a
Kuning/Bima Juna	4.22	-1.43	-1.43	-0.04	-13.52	-12.63	6.87 a
Bima/Tiron	-1.49	-1.26	-1.26	-0.16	-3.79	-4.08	16.23 b
Bima/Timor	-0.32	-0.62	-0.62	0.06	-1.86	-3.68	15.95 b
Bima/Sibolangit	2.19	0.33	0.33	-0.46	-6.42	-4.26	11.09 a
Bima/Maja	-3.15	0.27	0.27	-0.43	5.61	1.36	16.69 b
Bima/Bima Juna	-0.26	-0.19	-0.19	0.42	1.92	2.18	20.20 bc
Tiron/Timor	4.99	1.38	1.38	0.08	7.48	7.73	32.56 de
Tiron/Sibolangit	0.87	-1.00	-1.00	0.09	-17.23	-14.07	6.48 a
Tiron/Maja	-0.98	1.44	1.44	0.27	8.50	7.95	28.49 cd
Tiron/Bima Juna	0.83	1.31	1.31	-0.11	5.61	2.70	25.93 cd
Timor/Sibolangit	-0.99	-0.52	-0.52	0.03	0.43	-0.29	19.58 bc
Timor/Maja	3.02	-0.75	-0.75	-0.30	-3.26	-3.70	16.16 b
Timor/Bima Juna	3.95	-0.38	-0.38	0.06	9.46	10.78	33.33 de
Sibolangit/Maja	-6.28	0.37	0.37	-0.55	-4.32	-2.38	13.21 b
Sibolangit/Bima Juna	-1.60	-0.26	-0.26	-0.25	-4.82	-4.44	13.83 b
Maja/Bima Juna	-6.14	-0.49	-0.49	-0.02	-14.17	-11.68	6.58 a

Remarks: * means in the same column followed by the same letter are not different at P<0.05 of Duncan Multiple Range Test.

Table 5. Heterosis effect (%) of the observed characters of the diallel cross F_1 hybrids and the measurement results of the bulb dry weight per hill (g)

Half diallel cross	**Characters**						
	Plant height (cm)	**Number of bulblets**	**Number of bulbs**	**Bulb diameter (cm)**	**Bulb fresh weight/ hill (g)**	**Bulb dry weight/ hill (g)**	**Observed of bulb dry weight/hill (g)***
Kuning/Bima	-17.87	0.00	0.00	-25.07	-50.38	-52.30	10.64 a
Kuning/Tiron	-15.99	-65.22	-65.22	15.11	94.57	111.01	37.24 e
Kuning/Timor	4.65	-21.74	-21.74	25.74	0.29	5.30	20.20 bc
Kuning/Sibolangit	5.36	-34.78	-34.78	-5.00	53.35	61.99	30.43 de
Kuning/Maja	-14.42	13.04	13.04	-25.09	-49.92	-50.66	11.16 a

Table 5. continued

Half diallel cross	Characters						
	Plant height (cm)	Number of bulblets	Number of bulbs	Bulb diameter (cm)	Bulb fresh weight/ hill (g)	Bulb dry weight/ hill (g)	Observed of bulb dry weight/hill (g)*
Kuning/Bima Juna	-8.92	-65.22	-65.22	11.16	-73.27	-75.02	6.87 a
Bima/Tiron	-4.33	-64.71	-64.71	-9.15	-17.24	-27.27	16.23 b
Bima/Timor	-2.56	-64.71	-64.71	18.53	-15.18	-28.50	15.95 b
Bima/Sibolangit	-5.01	-16.67	-16.67	-31.06	-50.77	-50.28	11.09 a
Bima/Maja	-23.07	-33.33	-33.33	-28.32	-8.27	-26.20	16.69 b
Bima/Bima Juna	-7.98	-52.63	-52.63	22.46	-24.08	-26.52	20.20 bc
Tiron/Timor	15.10	52.94	52.94	2.49	63.25	69.72	32.56 de
Tiron/Sibolangit	-2.07	-41.18	-41.18	-12.93	-71.53	-69.87	6.48 a
Tiron/Maja	-13.93	35.29	35.29	-6.31	21.25	25.98	28.49 cd
Tiron/Bima Juna	-0.13	36.84	36.84	1.47	6.31	-5.70	25.93 cd
Timor/Sibolangit	-1.42	-47.06	-47.06	-20.27	-6.95	-8.99	19.58 bc
Timor/Maja	-7.55	-64.71	-64.71	-29.09	-25.52	-28.56	16.16 b
Timor/Bima Juna	5.07	-36.84	-36.84	2.01	14.42	21.25	33.33 de
Sibolangit/Maja	-31.33	37.50	37.50	-35.81	-45.34	-41.60	13.21 b
Sibolangit/Bima Juna	-13.38	-42.11	-42.11	-27.93	-48.23	-49.69	13.83 b
Maja/Bima Juna	-20.83	-57.89	-57.89	-19.14	-75.29	-76.05	6.58 a

Remarks: * means in the same column followed by same letter are not different at P<0.01 of DMRT

Table 6. estimates of broad and narrow sense heritability of yield related characters in shallot

Characters	Broad sense heritability	Narrow sense heritability
Plant height (cm)	0.71	0.29
Number of bulblets	0.93	0.20
Number of bulbs	0.93	0.20
Bulb diameter	0.73	0.12
Bulb fresh weight per hill (g)	0.95	0.11
Bulb dry weight per hill (g)	0.97	0.09

CONCLUSSIONS AND SUGGESTIONS

CONCLUSIONS

Shallot genotypes that had a high GCA was Tiron and Timor. Crosses between shallot genotypes with SC-A high and high yield were Kuning/Tiron, Timor/Bima Juna, Tiron/Timor and Kuning/Sibolangit, so that can be selected for high yield. Heterosis on characters observed from these crosses varied, there was a low value of (-76) to high (111 percent). Crossing of Kuning/Tiron had high heterosis and high yield and consequently is potential to be used for new hybrid cultivar development.

Value of broad sense heritability estimates for the observed character was high but the narrow sense heritability was low, except for plant height that was moderate. The dominant gene action observed on all yield-related characters suggests that the evaluated genotypes are potential to be used in breeding for high yielding hybrid varieties.

SUGGESTIONS

Crosses with other genotypes of shallot are required. The combination of shallot cross between Kuning/Tiron, Timor/Bima Juna, Tiron/Timor and Kuning/Sibolangit can be used for plant breeding.

ACKNOWLEDGMENT

The authors would like to thank Higher Education Competitive Grant Program in 2009-2010, the Ministry of National Education, Indonesia for funding the research.

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