General and Specific Combining Ability for Quantitative Characters in Sunflower

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Abstract

Seven sunflower (*Helianthus annuus* L.) inbred lines were crossed in 7×7 half diallel to obtain 21 F_1 hybrids. These lines were used to estimate general combining ability (GCA) and specific combining ability (SCA) effects for yield, head diameter, 1,000-seed weight, plant height and oil content in order to select suitable parents for hybridization and to identify the promising hybrids. The 7 inbred lines and 21 hybrids were planted in a randomized complete block design with three replications at Nakhon Ratchasima, Thailand during 2008-2009. General combining ability and specific combining ability were estimated for seed yield, head diameter, 1,000-seed weight, plant height and oil content. The results revealed that mean squares for GCA were highly significant for head diameter and significant for yield and oil content. Mean squares for SCA were highly significant for 1,000-seed weight and plant height, while those of yield, head diameter and oil content were non-significant. Components of variance showed that the GCA variance was higher than the SCA variance for yield, head diameter and oil content. These results indicated that additive gene action was more important than non-additive gene action for these traits. Inbred line 5A exhibited the highest GCA effects for yield and oil content, followed by the line 2A. Among all the crosses, 5A×2A showed the greatest positive SCA effects for 1,000-seed weight and oil content. Thus, the two inbred lines (2A and 5A) revealed good potential to be used as parents for hybrid.

Keywords: *Helianthus annuus* L., Diallel cross, GCA, SCA

1. Introduction

Hybrids, due to their high yield potential, are being used throughout the world for increasing the productivity of sunflower. In the breeding program, it is very important to know the combining abilities of inbred lines that are used as parents in hybrids. Plant breeders can take advantage from such information on combining ability for developing high yielding lines and hybrids. Therefore, knowledge of combining ability is essential for selection of suitable parents for hybridization and identification of promising hybrids in breeding program. The diallel method of genetic analysis has been widely used to assess the combining ability of parents in hybrids (Miller *et al.,* 1980; Kadkol *et al.,* 1984; Sherrif *et al.,* 1985). The analysis of diallel cross by the method proposed by Griffing (1956) which partition the total genetic variation into general combining ability (GCA) of the parents and specific combining ability (SCA) of the crosses have been widely used. The GCA is the average performance of a particular inbred in a series of hybrid combinations, whereas SCA refers to the performance of a combination of specific inbred in a particular cross (Sprague and Tatum, 1942). The GCA and SCA variances

provide an estimation for additive and non-additive gene actions, respectively (Falconer, 1967). Also, combining ability is used in understanding the nature of gene action involved in the expression of quantitative traits and to predict the performance of the progenies. In corn, Bello and Olaoye (2009) found that additive gene action was primarily involved in determining yield and other agronomic traits. In sunflower, various reports indicated the importance of both additive and non-additive genetic variances for yield and other characters (Kaya, 2004; Kaya and Atakisi, 2004; Mijic et al., 2008). Mijic et al. (2008) reported that both GCA and SCA were significant for yield, oil content and oil yield, and estimates of GCA were greater than SCA in magnitude. Marinkovic (1993) reported that GCA effect was more important than SCA for oil content and he found that lines with high GCA gave higher yielding hybrids than lines with low GCA. However, Putt (1966) has reported for his materials that SCA was more important than GCA for seed yield, head diameter and 1,000-seed weight and he reported that generally the higher yielding lines produced the higher yielding hybrid.

This experiment was conducted to estimate GCA and SCA for seed yield, head diameter, 1,000-seed weight, plant height and oil content in 7 inbred lines and to determine perspective parental lines and hybrids of sunflower.

2. Materials and Methods

The materials for the present study were seven inbred lines of sunflower developed by Sunflower Breeding Program of Suranaree University of Technology (SUT), Thailand. These inbred lines were designated as 2A, 5A, 7A, 8A, 10A, 11A and 12A. All the inbred lines are of medium to high oil content. A half diallel cross of 7×7 without reciprocals proposed by Griffing (1956) was used to produce F_1 hybrids, in 2008. The seven inbred lines and their 21 hybrids were evaluated at two locations during 2008-2009. The first location was at the experimental farm of the Suranaree University of Technology (SUT farm). The soil type at the site was a Chatturat series (Typic Haplustalfs). The second location was at the National Corn and Sorghum Research Center, Pak Chong. The soil type of this site was Pak Chong series (Oxic Paleustults). The experiment in each site was conducted in a randomized complete block design with three replications. Each plot consisted of 4 rows of 5 m long and spacing of 0.75 m between rows and 0.30 m between plants within row. Two seeds were planted per hill and later thinned to one plant per hill. Fertilizer was applied at the rate of 120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1}. Recommended herbicides were used to suppress weeds. Diseases and insects were controlled by regular application of fungicides and insecticides. Data were recorded for seed yield, head diameter, 1,000-seed weight, plant height and oil content. Analyses of variance were computed for all characters over 2 locations. Griffing Method IV was used to estimate combining ability (Griffing, 1956). The analysis was based on the model by Griffing as:

$$X_{ij} = \mu + g_i + g_j + s_{ij}$$

where X_{ij} = the mean phenotypic value; μ = the general mean; g_i, g_j = GCA effects of the ith and jth parents, respectively; s_{ij} = SCA effect of the cross i × j.

The estimates of GCA and SCA of parents and hybrids were obtained as:

GCA effects $g_i = \dfrac{1}{n(n-2)}[nX_{i.} - 2X_{..}]$

SCA effects $s_{ij} = X_{ij} - \dfrac{1}{n-2}(X_{i.} + X_{j}) + \dfrac{2}{(n-1)(n-2)}X_{..}$

where $X_{i.}$, $X_{.j}$ = means of the ith and jth parents, respectively; $X_{..}$ = grand mean; n = number of parent lines.

3. Results and Discussion

There was no interaction between location × hybrid and the significant difference between locations was not found for all characters (data not shown). Thus, combined ANOVA of combining ability for yield, head diameter, 1,000-seed weight, oil content and plant height over two locations (SUT farm and National Corn and Sorghum Research Center) are presented in Table 1. The mean square for GCA was highly significant for head diameter and significant for seed yield and oil content, indicating the importance of additive gene effect for these traits. The components of variance showed that GCA variance was higher than SCA variance for yield, head diameter and oil content. Furthermore, the ratio of GCA to SCA variance for these traits were higher than 1. The result indicated for these lines that additive gene action is important for yield, head diameter and oil content. Similar results were reported by others who also found that GCA variance was larger than SCA variance for these traits (Kaya and Atakisi, 2004; Mijic et al., 2008). On the other hand, GCA mean squares were not significant for plant height and 1,000-seed weight. Mean squares for SCA were highly significant for plant height and 1,000-seed weight, while

other characters were non-significant. This was similar to other reports (Jan *et al.,* 2005; Khan *et al.,* 2008) which found highly significant SCA effect for 1,000-seed weight. In addition, Khan *et al.* (2008) reported that SCA variance was greater than GCA variance for 1,000-seed weight, which showed greater manifestation of non-additive gene effect.

The GCA effects for yield and other characters of 7 inbred lines are presented in Table 2. The results revealed that the parents 5A and 2A were good combiners for yield and oil content. The highest GCA effect for yield was observed for line 5A (8.54), followed by lines 2A (5.26) and 7A (3.44), whereas the lowest GCA value was observed for line 8A (-7.97), followed by lines 10A (-4.96). Significant additive genetic variance for seed yield exists in sunflower (Miller *et al.,* 1980), suggesting that selecting lines on the basis of yield should be useful in developing lines with good combining ability. The lines 5A showed the highest GCA (1.11) for oil content followed by lines 2A (1.08), whereas the lowest GCA value was observed for line 7A (-0.76). The highest GCA effects for head diameter was observed for line 10A (0.60), followed by lines 5A (0.56) and 11A (0.50). Previous research (Sawargaonkar and Ghodke, 2008) also reported positive GCA for yield, head diameter and oil content. In addition, the lines 5A appeared to be good combiners for seed weight (1.01). The preponderance of additive gene action observed for yield, head diameter and oil content indicates that there will be progress in selection form crosses involving inbred 2A and 5A.

The usefulness of a particular cross in exploiting heterosis is judged by the SCA effect of component lines. According to Sprague and Tatum (1942) the SCA is controlled by non-additive gene action. The SCA effect is an important criterion for the evaluation of hybrids. Mean squares for SCA were highly significant for 1,000-seed weight and plant height. The results indicated that non-additive effects were important for these traits. The SCA effects for 1,000-seed weight, plant height, yield and other characters of crosses are presented in Table 3. The cross of 5A×2A showed the highest SCA effect for 1,000-seed weight (2.67), followed by the crosses of 12A×5A (1.94) and 7A×2A (1.31). In this research, increasing plant height was considered to be undesirable but increasing yield, oil content, 1,000-seed weight and head diameter were desirable. Also, the highest negative SCA effect for plant height was observed for the cross 12A×2A (-8.80). The importance in SCA effect was not found for yield, head diameter and oil content. However, the highest specific combination for seed yield was 12A×2A (12.32), followed by 10A×5A (8.96). Among the crosses, 8A×7A showed the greatest positive SCA effect for head diameter (1.22), followed by 5A×2A (0.98). The best specific combinations for oil content were 10A×8A (1.94), followed by 5A×2A (1.45) and 8A×7A (1.22).

4. Conclusion

Seed yield, head diameter and oil content are important traits in sunflower. The results showed that for this set of inbred lines GCA effect gave greater proportion of variance than SCA effect, suggesting that additive gene effects were found governing the inheritance of yield, head diameter and oil content. Among the lines, 2A and 5A were found to be good general combiners for yield, oil content and 1,000-seed weight and also involved in promising cross combinations. The lines 5A and 10A exhibited maximum GCA effect for head diameter. Therefore, the performances of a single cross progeny can be predicted on the basis of GCA, because SCA mean squares were not significant. Among the crosses, 5A×2A had positive significant SCA value for seed yield, oil content, 1,000-seed weight and head diameter, which are the desired traits for better population. Therefore, the lines 2A and 5A have desirable agronomic traits and could be used as parents for hybrid due to their high performance and their hybrid having one of the highest SCA effect in yield, 1,000-seed weight and oil content.

Acknowledgement

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Table 1. Mean squares for general (GCA) and specific combining ability (SCA) of 21 hybrids for yield and other characters

Sources	df	Yield	Head diameter	1,000-seed weight	Plant height	Oil content
GCA	6	11,064.12*	2.78**	2.25	14.97	4.98*
SCA	14	3,833.36	0.59	2.58**	39.94**	1.58
error	80	4,405.02	0.37	0.81	15.13	2.18
GCA/SCA		3:1	5:1	1:1	0.4:1	3:1

*, ** Significant at 0.05 and 0.01 probability levels, respectively.

Table 2. General combining ability (GCA) for yield and other characters of 7 inbred lines

Lines	Yield	Head diameter	1,000-seed weight	Plant height	Oil content
2A	5.26**	-0.66**	0.06	1.35*	1.08**
5A	8.54**	0.56**	1.01**	-0.65	1.11**
7A	3.44*	-0.56**	-0.13	-1.62**	-0.76**
8A	-7.97**	-0.75**	-0.10	-0.29	-0.69**
10A	-4.96**	0.60**	0.29*	2.07**	0.34
11A	-3.71*	0.50**	-0.60**	-1.62**	-0.61**
12A	-0.59	0.30*	-0.62**	0.77	-0.47*

*, ** Significant at 0.05 and 0.01 probability levels, respectively.

Table 3. Specific combining ability (SCA) for yield and other characters of 21 hybrids

Hybrids	Yield	Head diameter	1,000-seed weight	Plant height	Oil content
5A×2A	6.91	0.98**	2.67**	-6.60**	1.45**
7A×2A	5.64	-0.28	1.31**	0.57	1.08*
8A×2A	-7.69	0.38	-0.37	9.80**	-1.74**
10A×2A	-16.67**	0.09	-0.98**	-0.53	-0.77
11A×2A	-0.51	-0.91**	0.56	5.57**	0.43
12A×2A	12.32**	-0.25	-3.19**	-8.80**	-0.44
7A×5A	-4.05	-0.02	-2.56**	-2.20	-0.06
8A×5A	6.87	-0.73**	-0.33	3.20*	-1.06*
10A×5A	8.96	0.34	-0.39	-1.47	-0.11
11A×5A	-6.32	0.62**	-1.34**	-0.87	-0.62
12A×5A	-12.36**	-1.18**	1.94**	7.93**	0.40
8A×7A	-13.37**	1.22**	0.17	-0.13	1.22*
10A×7A	3.83	-0.89**	0.79*	9.70**	-0.63
11A×7A	1.77	0.01	0.84*	-4.20*	-1.17*
12A×7A	6.17	-0.04	-0.57	-3.73*	-0.45
10A×8A	6.31	-0.41	-0.09	-8.40**	1.94**
11A×8A	1.29	-0.51*	-0.35	-2.97*	-0.96
12A×8A	6.59	0.05	0.97*	-1.50	0.59
11A×10A	5.53	0.13	0.05	-1.47	0.99
12A×10A	-10.95*	0.76**	0.62	2.17	-1.43**
12A×11A	-3.26	0.66**	0.23	3.93*	1.32*

*, ** Significant at 0.05 and 0.01 probability levels, respectively.