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SELECTION OF TESTERS FOR COMBINING ABILITY ANALYSIS AND RELATIONSHIP BETWEEN *PER SE* PERFORMANCE AND GCA IN SUNFLOWER (*Helianthus annuus*.L)

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SUMMARY

Studies were conducted to determine the optimum number of testers required to rank lines according to their GCA and to understand the quantitative relationship between *per se* performance and combining ability of the lines in sunflower. Forty-eight lines were crossed to 3 types of testers; an inbred, an open pollinated population and a single cross hybrid. The hybrids were evaluated during summer 1994. Spearman's rank correlation coefficient indicated that the 3 testers as well as 2 tester combinations ranked the lines similarly for GCA. The correlations between *per se* performance and GCA were not significant for the studied characters except for days to 50 per cent flowering, days to maturity, plant height and oil content. Hence *per se* performance cannot be taken as a criterion for high GCA for yield and means of its components.

Key words: GCA effect, line x tester analysis, rank correlation.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) has become a very important oilseed crop in India because of its wide adaptability, high yielding potential, short duration (85-100 days), less photosensitivity and remunerative market price. Extension of the crop to various cropping systems and crop growing situations necessitated the development of hybrids with high yield, oil content and suitability to different agro-ecological situations. One crucial step in hybrid development is testing of inbred lines for their general combining ability (GCA). The line x tester analysis is one of the simple and efficient methods of evaluating large number of inbreds. However, the problem confronting breeders is the number of testers required for a most economic and effective evaluation of lines for GCA. Different workers (Federer and Sprague, 1947; Akthar *et al.*, 1985 and Charcosset *et al.*, 1990) suggested different numbers of testers for the estimation of general combining ability of inbred lines. Therefore, there is a need for investigating the type and number of testers required

Table 1: List of inbred lines (females) and testers (males) selected for the study in sunflower

Sl. No.	Pedigree	Sl No.	Pedigree
	Lines (females)		
1	M 787-5-4	28	IB-2
2	M 787-9-5	29	IB-4
3	M 733-10-1	30	IB-14
4	M 733-2-2	31	IB-19-1R
5	M 733-3-3	32	IB-19-2R
6	M 733-10-3	33	IB-21
7	M 49-8-5	34	IB-24
8	M 787-5-2	35	IB-28
9	M 174-6-1	36	IB-29
10	M 787-7-2	37	IB-43-1R
11	M 787-6-2	38	IB-49
12	M 733-10-4	39	BLC 5R-8-3-4
13	M 733-4-1-1	40	BLC 5R-8-1-4
14	M 733-3-7	41	BLC 5R-8-1-1
15	M 733-3-7-5	42	BLC 5R-8-1-2
16	M 733-3-4	43	BLC 5R-2-7-2
17	M 787-8-4	44	BLC 15-7-1-1
18	M 68-4-4	45	Per 157-3-6-7
19	M 174-6-2	46	Per 157-3-6-6
20	M 446-3-2	47	Per 96-6-2
21	M 223-10-1	48	Arm 60-1-3-1
22	M 733-8-4		Testers (males)
23	M 733-4-2	1	KBSH-1 (single cross hybrid)
24	M 716-2-4	2	HA-234B (inbred line)
25	M 658-7-2	3	No.61 (population)
26	M 658-4-6		
27	M 16-10-3-6		

Note:
M = Inbred line derived from Morden
BLC = Inbred line derived from 'B' line composite
Per = Inbred line derived from Peredovik (EC 68414)
Arm = Inbred line derived from Armavirski-3497 (EC 68415)

for better estimation of combining ability of inbred lines in sunflower. Hence, the present study was undertaken with the twin objectives of (1) determining the number of testers required for estimating GCA and (2) to quantify the relationship between *per se* performance and GCA of the lines.

MATERIALS AND METHODS

The material used in the experiment consisted of 48 inbred lines and 3 testers namely, KBSH-1, HA-234B and No.61 (Table 1). The testers KBSH-1, HA-234B and No.61 were designated as A, B and C, respectively. The inbred and testers were raised during the rainy season of 1993-94 at Main Research Station, Hebbal, UAS, Bangalore. Male sterility was induced in all 48 inbred lines by applying gibberellic acid (GA3) at starbud stage at 100 ppm concentration and crossed to 3 testers. Care was taken to avoid undesirable outcrossing by bagging the female lines.

During summer 1994, 144 crosses and 51 parents were grown in a randomized block design with two replications. Each entry was planted in a row of 5m. Spacing of 60 cm between rows and 30 cm within row was maintained. Fertilizers were given at the rate of 60:90:60 kg/ha of N:P:K; 50 per cent of nitrogen and the entire dose of phosphorus and potassium were applied during sowing and the remaining 50 per cent of nitrogen were top dressed 35 days after sowing. The crop was grown under protective irrigated condition. Thirteen agronomic characters were selected for study and observations were recorded on ten randomly selected plants in each row. The data were subjected to combining ability analysis (Kempthorne,1957).

The GCA effects of each line were calculated as the deviation of its average performance in hybrid combination from the general mean. The GCA effects of the lines were estimated on the basis of the individual testers as well as two and three tester combinations as given below:

i) The GCA effects of the lines on the basis of individual testers,

ii) The GCA effects of the lines on the basis of combination of two testers (i.e., single cross + inbred, single cross + population and inbred + population),

iii) The GCA effects of the lines on the basis of combination of all three testers.

The GCA effects were ranked and Spearman's rank correlation was calculated among the GCA values obtained in different tester combinations. Association between *per se* performance and general combining ability of the lines (means of the crosses involving the lines) were worked out for different tester combinations for each character to know the nature and degree of relationship between them by simple correlation coefficients.

Table 2: Spearman's rank correlation coefficents of GCA values in different testers and tester combinations for different characters

Tester combination	Days to 50% flowering	Days to maturity	No of leaves per plant	Plant height	Head diameter	Stem girth	Seed yield per plant	Seed filling percent	No of seeds per plant	Test weight	Oil content	Volume weight	Oil yield per plant	Mean
ABC vs AB	0.9144**	0.9011**	0.8869**	0.8959**	0.8556**	0.8870**	0.8872**	0.7851**	0.7948**	0.8790**	0.8412**	0.9015**	0.8822**	0.8704
ABC vs AC	0.9363**	0.9491**	0.8825**	0.9251**	0.8524**	0.8999**	0.8865**	0.8956**	0.8255**	0.8460**	0.8728**	0.8482**	0.8819**	0.8847
ABC vs BC	0.9566**	0.9365**	0.8952**	0.9409**	0.8521**	0.8930**	0.8572**	0.8540**	0.8685**	0.8253**	0.9322**	0.8136**	0.8764**	0.8847
ABC vs A	0.7785**	0.7872**	0.6686**	0.7010**	0.5453**	0.7350**	0.6286**	0.6224**	0.4000**	0.6416**	0.6674**	0.7680**	0.5871**	0.6562
ABC vs B	0.7933**	0.7774**	0.7960**	0.8085**	0.6979**	0.7432**	0.7530**	0.6611**	0.7209**	0.6289**	0.6933**	0.7056**	0.7749**	0.7349
ABC vs C	0.8866**	0.8358**	0.7273**	0.8121**	0.5707**	0.6838**	0.6548**	0.7045**	0.6787**	0.6745**	0.7134**	0.5657**	0.6705**	0.7060
AB vs AC	0.8031**	0.8118**	0.7315**	0.7712**	0.6638**	0.7204**	0.7231**	0.5756**	0.5375**	0.6665**	0.5980**	0.6689**	0.7038**	0.6907
AB vs BC	0.8092**	0.7714**	0.6879**	0.7568**	0.6035**	0.6914**	0.6419**	0.6006**	0.5900**	0.6089**	0.7319**	0.6673**	0.6767**	0.6798
AB vs A	0.8538**	0.8609**	0.7864**	0.8337**	0.6723**	0.8353**	0.7559**	0.7770**	0.5968**	0.7391**	0.7285**	0.7854**	0.7076**	0.7655
AB vs B	0.8471**	0.7866**	0.8347**	0.8507**	0.7204**	0.8210**	0.7854**	0.8375**	0.8029**	0.6938**	0.8459**	0.7874**	0.8186**	0.8024
AB vs C	0.6646**	0.5506**	0.3858**	0.4924**	0.1838	0.3190*	0.3191*	0.2524	0.2045	0.3021*	0.3092*	0.2233	0.3157*	0.3478
AC vs BC	0.8666**	0.8516**	0.7061**	0.8291**	0.6146**	0.7471**	0.6615**	0.7434**	0.6256**	0.5820**	0.8143**	0.5677**	0.6824**	0.7147
AC vs A	0.8148**	0.8133**	0.7843**	0.7360**	0.6654**	0.7745**	0.7201**	0.6089**	0.5557**	0.7784**	0.6960**	0.8464**	0.7018**	0.7307
AC vs B	0.5918**	0.5789**	0.4617**	0.5921**	0.2792	0.4298**	0.4005**	0.3486*	0.2909*	0.1803	0.3292*	0.2795	0.4469**	0.4007
AC vs C	0.9016**	0.8773**	0.7546**	0.8257**	0.6646**	0.7678**	0.6998**	0.7950**	0.7272**	0.7627**	0.8739**	0.6899**	0.6826**	0.7709
BC vs A	0.5851**	0.5668**	0.3397*	0.4507**	0.1261	0.3863**	0.1941	0.2192	0.0102	0.1522	0.4552**	0.3577*	0.1833	0.3097
BC vs B	0.8151**	0.8199**	0.8220**	0.7973**	0.7783**	0.7785**	0.8076**	0.7186**	0.7763**	0.7474**	0.7247**	0.8196**	0.8427**	0.7875
BC vs C	0.9231**	0.8700**	0.8363**	0.8904**	0.7021**	0.8046**	0.8144**	0.8324**	0.8173**	0.7559**	0.7907**	0.7068**	0.8248**	0.8129
A vs B	0.5212**	0.5098**	0.3226*	0.4627**	0.1410	0.4047**	0.2471	0.3469*	0.0786	0.0912	0.3537*	0.3341*	0.5212**	0.3334
A vs C	0.5606**	0.4979**	0.2518	0.3227*	0.1056	0.2337	0.0992	0.0928	-0.0351	0.2310	0.3132*	0.2734	0.0480	0.2524
B vs C	0.6055**	0.5118**	0.4298**	0.4847**	0.1773	0.3135*	0.3777**	0.2991*	0.3111*	0.1668	0.1828	0.2096	0.4404**	0.3469
Mean	-0.7283	0.7564	0.6662	0.7218	0.5462	0.6604	0.6149	0.5986	0.5606	0.5692	0.6496	0.6104	0.6218	0.6420

* Significant at 5% level
** Significant at 1% level

RESULTS

Correlations between GCA effects of different tester combinations were statistically significant (Table 2) for all the studied characters except head diameter, seed filling per cent, number of seeds per head and volume weight in the AB vs C combination; for test weight, volume weight in the AC vs B combination; for head diameter, seed yield, seed filling per cent, test weight and oil yield in the BC vs A combination; for number of leaves per plant, head diameter, stem girth, seed yield, seed filling per cent, number of seeds per head, test weight and volume weight in the A vs C combination; and for head diameter, test weight, oil content and volume weight in the B vs C combination.

The correlations between GCA effects obtained from the three testers and two tester combinations were very high for all the characters, ranging from 0.7851 (ABC vs AB for seed filling per cent) to 0.9566 (ABC vs BC for days to 50 per cent flowering). The values obtained for three tester vs single tester combinations were lower compared with those obtained for three tester vs two tester combinations although 'r' values were highly significant for all the characters in all the combinations. The values ranged from 0.4000 (ABC vs A in case of number of seeds per head) to 0.8866 (ABC vs C in case of days to 50 per cent flowering). Similarly, two tester combinations also showed significant correlations, ranging from 0.5375 (AB vs AC for seed number per head) to 0.8666 (AC vs BC for days to 50 per cent flowering). In the case of two tester vs single tester combination 'r' values were still lower and ranged between 0.1261 (BC vs A for head diameter) and 0.9231 (BC vs C for days to 50 per cent flowering). The 'r' values for single vs single testers were lowest.

The average correlation values obtained in different tester combinations are presented in Table 4. In general, the values were highest in 3 tester vs 2 tester combinations followed by 2 tester vs 2 tester combination, 3 tester vs single tester, 2 tester vs single tester and single tester vs single tester for all characters except stem girth, seed yield per plant, seed filling per cent, number of seeds per head and test weight.

Relationship between *per se* performance and general combining ability for different characters

The correlations between *per se* performance and general combining ability were significant only for days to 50 per cent flowering, days to maturity, plant height and oil content. The correlation coefficients were not significant for other characters. For yield the 'r' value was negative and non significant (Table 3).

DISCUSSION

The correlations between GCA values of 3 tester vs 2 tester combinations were high for all the characters. The highest 'r' values were obtained for days to 50 per

Table 3: Correlations coefficients between *per se* performance and general combining ability in different tester combinations

Tester combination	Days to 50% flowering	Days to maturity	No of leaves per plant	Plant height	Head diameter	Stem girth	Seed yield per plant	Seed filling per cent	No of seeds per head	Test weight	Oil content	Volume weight	Oil yield per plant
ABC	0.3768**	0.3702**	0.2408	0.4142**	0.0300	0.2031	-0.0360	-0.0181	-0.0455	0.2027	0.3359**	0.1401	-0.1407
AB	0.2984*	0.3040*	0.1572	0.3597**	0.0321	0.2697	0.0447	-0.0267	0.0363	0.1880	0.3286**	0.1619	-0.0437
AC	0.3790**	0.3760**	0.2814	0.4300	-0.0124	0.1745	-0.0821	-0.0163	-0.1225	0.1210	0.3507**	0.1466	-0.2104
BC	0.3883**	0.3614**	0.2314	0.3633	0.0588	0.2074	-0.0622	-0.0081	-0.0398	0.2298	0.2328	0.0682	-0.1432

* Significant at 5% level
** Significant at 1% level

Note: A: KBSH-1
B: HA-234B
C: No.61

Table 4: Average correlation coefficients in different tester combinations for different characters

Tester combination	Days to 50% flowering	Days to maturity	No of leaves per plant	Plant height	Head diameter	Stem girth	Seed yield per plant	Seed filling per cent	No of seeds per head	Test weight	Oil content	Volume weight	Oil yield per plant	**Mean**
3 vs 2	0.9538**	0.9289**	0.8882**	0.9206**	0.8535**	0.8930**	0.8769**	0.8449**	0.8295**	0.8501**	0.8820**	0.8533**	0.8802**	0.8798
3 vs 1	0.8195**	0.8001**	0.7306**	0.7739**	0.6046**	0.7206**	0.6788**	0.6627**	0.5998**	0.6483**	0.6914**	0.6798**	0.6775**	0.6990
2 vs 2	0.8263**	0.8116**	0.7085**	0.7857**	0.6273**	0.7163**	0.6748**	0.6399**	0.5844**	0.6190**	0.7147**	0.6347**	0.6876**	0.6946
2 vs 1	0.7466**	0.7493**	0.6673**	0.7188**	0.5329**	0.6574**	0.6084**	0.5988**	0.5313**	0.5680**	0.6381**	0.6107**	0.6138**	0.6339
1 vs 1	0.5624**	0.5065**	0.4493**	0.4234**	0.1413	0.3195*	0.2413	0.2463	0.1182	0.1630	0.2832	0.2724	0.3365*	0.3125

* Significant at 5% level
** Significant at 1% level

cent flowering and days to maturity followed by plant height. For seed yield the correlation values were highest in case of ABC vs AB (0.8872) followed by ABC vs AC (0.8865) and ABC vs BC (0.8572). This clearly indicated that both the 3 tester and 2 tester combinations ranked the lines almost similarly with respect to their GCA values. No substantial difference was observed among the correlation values of ABC vs AB, ABC vs BC and ABC vs AC for each character. The correlations for three testers vs single tester were lower.

From the present study it is inferred that two testers are as good as three testers in ranking the lines for GCA but a single tester is not sufficient to estimate the GCA values. Thus a combination of two testers can be more economical and efficient in evaluating the GCA effect of lines. Sprague and Tatum (1942), Federer and Sprague (1947), Singh (1958) and Charcossett *et al.*,(1990) advocated the use of more than one tester for reliable estimates of GCA effects of lines. Keller (1949), Matzinger(1953), Kempthorne and Curnow (1961) and Nawar (1985) reported that the combination of two testers was more economical and efficient in maize.

The correlation coefficients between 2 tester vs 2 tester combinations were high for days to 50 per cent flowering, days to maturity and plant height (ranging from 0.7568 to 0.8666) whereas for other characters 'r' values were between 0.6 and 0.7. Thus it may be concluded that the correlation values between 2 tester vs 2 tester combination were not high indicating that 2 different tester combinations ranked the lines differently for their GCA.

The correlation in 2 tester vs single tester combinations were high where single tester was a component of the tester combination, but it was low when the single tester was not a component. A similar trend in maize was reported by Charcosset *et al.*, (1990). The correlations of single tester vs single tester were lowest. This clearly indicates that each tester ranks the lines differently.

Correlation coefficient between *per se* performance and gca

The correlation between *per se* performance and GCA was for the first time quantified in sunflower. The correlations were significant only for days to 50 per cent flowering, days to maturity, plant height and oil content in all the combinations except for BC combination for oil content. These traits have high heritability and additive genetic variance (Fick, 1975; Lakshmanaiah, 1978 and Reddy and Reddy, 1979).

There was no correspondence between *per se* performance and GCA for seed yield, seed filling percentage, number of seed per head, test weight, volume weight, number of leaves per plant, head diameter and stem girth suggesting these traits are predominantly governed by non-additive gene action (Dua and Yadav, 1983; Gupta and Singh, 1988; Bindu Madhava, 1990; Naresh, 1993). Lack of relationship between *per se* performance and GCA with respect to these characters have also been reported by several workers in sunflower (Furedi and Frank, 1981; Harini, 1992). However the relationship was not quantified by these authors as done in the present study.

CONCLUSIONS

Three tester and any of the two tester combinations ranked the GCA values of the lines almost similarly, implying that two testers are sufficient for estimating combining ability of the lines.

There was no correlation between *per se* performance and general combining ability except for the characters with high heritability and additive genetic variance such as days to 50 per cent flowering, days to maturity, plant height and oil content. Hence the *per se* performance can not be taken as a criterion for high GCA for yield and other agronomic characters.

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SELECCIÓN DE PROBADORES PARA ANÁLISIS DE LA APTITUD COMBINATORIA Y RELACIÓN ENTRE COMPORTAMIENTO PER SE Y ACG EN GIRASOL (*Helianthus annuus* L.)

RESUMEN

Se llevaron a cabo estudios para determinar el número óptimo de probadores requeridos para clasificar las líneas de acuerdo a su ACG y comprender la relación cuantitativa entre comportamiento per se y aptitud combinatoria de las líneas en girasol. 48 líneas fueron cruzadas con tres tipos de probadores, línea pura, población de polinización abierta y un híbrido simple. Los híbridos fueron evaluados durante el verano de 1994. Los coeficientes de correlación de Spearman indicaron que la combinación de tres probadores así como la combinación de dos probadores clasificaron las líneas similarmente para ACG. Las correlaciones entre comportamiento per se y ACG no fueron significativas para los caracteres estudiados excepto para días a 50% floración; días a maduración, altura de planta y contenido de aceite. Por tanto el comportamiento per se no puede ser tomado como criterio para alta ACG para rendimiento y medias de sus componentes.

SÉLECTION DE TESTEURS POUR L'ANALYSE DE L'APTITUDE À LA COMBINAISON ET RELATIONS ENTRE LA VALEUR PROPRE ET L'AGC CHEZ LE TOURNESOL (*Helianthus annuus* L.)

RÉSUMÉ

Des études ont été menées pour déterminer le nombre optimal de testeurs nécessaires pour classer les lignées en fonction de leur AGC et comprendre la relation quantitative entre la valeur propre et la valeur en combinaison de lignées chez le tournesol. 48 lignées ont été croisées avec 3 types de testeurs: lignée, population et hybride simple. Les hybrides ont été évalués durant l'été 1994. Le coefficient de rang de Spearman indique que 3 ou 2 combinaisons de testeurs classent de manière similaire les lignées pour leur AGC. Les corrélations entre la valeur propre et l'AGC ne sont pas différentes pour les caractères étudies excepté pour le nombre de jours à 50% de floraison, le nombre de jours à maturité, la taille des plantes et la teneur en huile. En conséquence, la valeur propre ne peut pas être considérée comme un critère valable pour estimer les AGC élevées pour le rendement et ses composantes.