Heterosis and Combining Abilities Studies in Okra [*Abelmoschus esculentus* (L.) Moench]

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Aim: Genetically complementary parents and amount of heritability of economic traits determines the successful development of breeding population, hybrids and varieties. The studies on heterosis and combining ability are useful in formulating effective breeding strategies and selection of suitable parents for crosses in breeding program.
Study Design: During the study period 24 F_1 hybrids and their 10 parents were evaluated along with commercial check ('Shakthi') in a randomized block design (RBD) with three replication.
Place and Duration of the Study: The present study was conducted at Adhiparasakthi Agricultural College farm, Kalavai, Vellore district of Tamil Nadu state during summer 2014.
Methodology: The experimental material consist of 24 F_1 hybrids developed from six lines (EC755648, EC755653, EC 755654, IC52303, IC755652 IC111515) and three tester (Arakka Anamika, Parbhani, Pusa Sawani VRO 22). These were evaluated along with commercial check ('Shakthi') in a randomized block design with three replication. The observation were recorded for 14 yield and yield contributing characters.
Results: The results inferred that the predominance of non-additive gene action was observed for all the traits. Among the parents, the overall study of gca effects suggested that parent EC 755648 and Parbhanikranti were significant general combiner for yield, these can be used to improve hybrids with desirable traits in future. Significant positive SCA effects were found for all the studied traits.

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Conclusion: Among the hybrids, EC755653 x ArakkaAnamikaand IC111515 x ParbhaniKrantishowed desirable standard heterosis percentage over the check Shakthi along with good sca effects and per se performance for yield and other important yield contributing traits, thus it can be effectively be exploited in hybrid breeding programme.

1. INTRODUCTION

Globally okra (*Abelmoschus esculentus*) produced in 2 million hectares and with production of 10 million tones of fresh fruit [1]. India is the largest producer and consumer of Okra with production of 6.5 million tones of fresh pods covering an area of 5 lakhs hectares and contributes 73 % of world production tons [2]. It is essential to breed high yielding variety which can be suitably grown in diverse agro ecological conditions. Genetically complementary parents and amount of heritability of economic traits determines the successful development of breeding population, hybrids and varieties. The studies on heterosis and combining ability are useful in formulating effective breeding strategies and selection of suitable parents for crosses in breeding program. The present investigation has been undertaken to study gene action and selection of best parents and crosses in a line x tester crosses of Okra.

2. MATERIALS AND METHODS

The experimental material consist of 24 F_1 hybrids developed from six lines (EC755648, EC755653, EC 755654, IC52303, IC755652 IC111515) and three tester (Arakka Anamika, Parbhani, Pusa Sawani VRO 22). The 24 F_1 hybrids and their 10 parents were evaluated along with commercial check ('Shakthi') in a randomized block design (RBD) with three replication at spacing of 60 X 45 cm at Adhiparasakthi Agricultural College farm, Kalavai, Vellore district of Tamil Nadu state during summer 2014. The observation were recorded for 14 yield and yield contributing characters *viz.,* plant height (cm), node at which first flowering (No's), days to first flowering, days to 50% flowering, inter nodal length (cm), number of branches per plant, number of fruits per plant, yield per plant (g), yield per plot (kg), fruit length (cm), fruit girth (cm), individual fruit weight (g), number of ridges per fruit and number of seeds per fruit. The data were subjected to Line x Testers (variance) analysis. The general

combining abilities of parents and specific combining ability (sca) of hybrids were estimated as per the model suggested by [3].

3. RESULTS AND DISCUSSION

3.1 Analysis of Variance

The analysis of variance revealed significant variation among the parents and cross combination for all the traits except nodes at which first flowering, inter node length, number of branched per plant, fruit girth. The variance due to lines, tester and line x tester interaction was significant for most of the traits studied (Table 1). This indicated that there was a good level of genetic difference present among lines and testers. The variance due to general and specific combining ability were highly significant for most of the traits indicating the importance of both additive and non-additive type of gene action. The additive and dominance genetic variances and their relative proportions to be useful for identify the yield and yield related characters. The estimate of genetic variance revealed that the dominance genetic variation (σ^2SCA) was higher in magnitude than the additive genetic variance (σ^2GCA) for all the traits indicating greater importance of non-additive gene action for the traits. The same results also reported by [4-7].

3.2 General Combining Ability (GCA) and Specific Combining Ability (SCA) Effects

The contribution lines and testers to crosses were not consistent across traits with a few crosses. Among the lines viz., EC 755648 had positive gca for plant height, fruit length, number of fruits per plant, individual fruit weight, yield per plant and yield per plot. Among the tester Parbhanikranti had positive gca for number of fruits per plant and yield per plant. Among all parental lines, EC 755648 had positive gca effect for most of the yield contributing traits (Table 2).

Table 1. Analysis of variance for combing ability in yield and yield related traits

Source	Df	D1st F	NFF	DFF	PH (cm)	INL (cm)	NBPP	FL (cm)	FG (cm)	NRPF	NFPP	NSPF	IFW (g)	YPP (g)	YPPL (Kg)
Replication	1	0.01	0.13	0.665	34.919	0.74	0.101	0	0.231	0.213	0.706	1.268	0.295	3.836	0.003
Crosses	23	2.726**	0.451	15.984**	266.712**	0.652	0.535	10.106**	0.604	0.933	10.683**	60.264**	29.943**	15497.995**	2.232*
Lines	5	2.556	0.558	34.083**	499.418**	1.183	0.978	18.132**	1.039	2.495*	26.507**	95.186**	37.276**	37113.354**	0.449
Testers	3	6.267**	0.38	14.394**	103.318**	0.536	0.29	11.963**	0.208	1.331	1.544	17.207**	20.931**	3135.119**	0.449
L x T (C)	15	2.074*	0.429	10.269**	221.817**	0.49	0.437	7.058**	0.539	0.332	7.236**	57.234**	29.302**	10765.451**	1.549
Error	23	0.877	0.166	1.54	6.681	0.115	0.123	0.892	0.107	0.104	0.233	2.991	2.418	765.76	0.091
σ^2GCA		0.025	0.001	0.216	1.408	0.006	0.004	0.115	0.003	0.023	0.130	0.115	0.024	179.027	0.026
σ^2SCA		0.599	0.132	4.364	71.828	0.192	0.157	3.083	0.216	0.114	3.502	27.122	13.442	4999.84	0.720
σ^2GCA/ σ^2SCA		0.041	0.006	0.050	0.020	0.030	0.024	0.037	0.012	0.199	0.037	0.004	0.002	0.036	0.036

*and** indicate significant at 5 and 1 percent level respectively

σ^2gca- variance general combining ability σ^2sca- variance scaspecific combining ability

D1st F- Days to first flowering, NFF- Node at which first flowering, DFF- Days to 50 % flowering, PH- Plant height, INL- Inter nodal length (cm), NBPP- Number of branches per Plant, FL- Fruit length, FG- Fruit girth, NRPF- Number of ridges per fruits, NFPP- Number of fruits per plant, NSPF- Number of seeds per fruit, IFW- Individual fruit weight, YPP- Yield per plant, YPPL- Yield per plot

Table 2. Estimation of general combing ability (GCA) effect of parents for fourteen characters of okra

Parents	D1st F	NFF	DFF	PH (cm)	INL (cm)	NBPP	FL (cm)	FG (cm)	NRPF	NFPP	NSPF	IFW (g)	YPP (g)	YPPL (Kg)
EC755648	-0.90*	-0.22	3.69**	10.32**	0.72**	0.61**	2.37**	0.54**	1.03**	3.15**	-0.02	3.66**	128.35**	1.54**
EC755653	-0.06	0.13	-2.44**	-1.21	0.01	0.01	0.72*	0.09	-0.47**	0.27	1.78**	-1.9**	-26.33*	-0.32*
EC 755654	-0.02	0.33*	0.28	7.21**	-0.37**	-0.16	-0.87*	0.03	-0.19	-1.48**	0.48**	1.28*	-16.02	-0.19
IC52303	0.43	-0.07	-1.07*	-4.73	0.05	-0.41**	-1.64**	-0.55**	-0.04	-1.68**	2.06**	-1.57**	-58.8**	-0.71**
IC755652	0.75*	0.2	0.19	-0.20	-0.17	0.11	-1.19**	0.1	0.47**	-1.01**	-0.49	-1.48*	-44.79**	-0.54**
IC111515	-0.2	-0.36*	-0.66	-11.39**	-0.24	-0.16	0.6	-0.2	0.13	0.75**	3.15**	0.02	17.58	0.21
SED	0.4682	0.2036	0.6025	1.2922	0.1697	0.1757	0.4722	0.1632	0.1614	0.2412	0.8647	0.7775	13.8362	0.166
CD5%	0.9691	0.4215	1.2843	2.6749	0.3514	0.3636	0.9774	0.3379	0.3341	0.4993	1.7898	1.6094	28.6409	0.3437
CD1%	1.3156	0.5722	1.7435	3.6314	0.477	0.4936	1.3268	0.4586	0.4535	0.6778	2.4297	2.1847	38.8797	0.4666
ArakkaAnamika	-0.3	0.09	-1.31**	0.27	-0.13	0.2	-1.23**	-0.17	-0.27**	0.04	-0.78	-0.06	2.40	0.03
ParbhaniKranti	-0.43	-0.26*	0.43	4.03**	0.23*	-0.16	-0.24	0.01	0.26*	0.27	-0.42	0.55	15.17	0.18
PusaSawani	1.08**	0.06	1.25**	-2.56**	0.14	-0.06	0.31	0.15	-0.30**	-0.52**	-0.58	1.31**	5.24	0.09
VRO 22	-0.35	0.12	-0.38	-1.74	0.21*	0.02	1.15**	0	0.32**	0.26	1.78**	-1.79**	-22.81**	-0.27**
SED	0.3823	0.1663	0.5066	1.0551	0.1386	0.1434	0.3855	0.1333	0.1318	0.1969	0.706	0.6348	11.2972	0.1356
CD5%	0.7913	0.3442	1.0487	2.1841	0.2869	0.2969	0.7981	0.28	0.2728	0.4077	1.4614	1.3141	23.3852	0.2806
CD1%	1.0741	0.4672	1.4235	2.9648	0.3895	0.4031	1.0834	0.3745	0.3703	0.5534	1.9838	1.7838	31.7451	0.381

Table 3. Estimation of specific combing ability (SCA) of hybrids in respect of 14 characters of okra

Parents	D1st F	NFF	DFF	PH (cm)	INL (cm)	NBPP	FL (cm)	FG (cm)	NRPF	NFPP	NSPF	IFW (g)	YPP (g)	YPPL
EC755648 x ArakkaAnamika	-0.61	0.04	0.33	1.99	0.49	-0.28	1.38	0.09	-0.90**	-0.54	-5.18**	2.77*	35.03	0.42
EC755648 x ParbhaniKranti	1.16	-0.11	1.20	2.93	-0.45	-0.41	-1.94**	0.07	0.37	0.12	0.08	-2.43*	-46.60*	-0.56*
EC755648 x PusaSawani	-1.19	0.06	-0.58	-17.39**	0.13	0.19	-0.12	-0.24	0.22	1.42**	7.33**	-2.22	-1.24	-0.02
EC755648 x VRO 22	0.64	0.01	-0.95	12.47**	0.81**	0.50	0.69	0.09	0.31	-0.76*	-2.23	1.87	12.8	0.16
EC755653 x ArakkaAnamika	-1.55*	0.49	0.02	-4.88*	0.15	0.02	1.16	0.82**	-0.20	3.09**	4.22**	2.21	94.93**	1.14**
EC755653 x ParbhaniKranti	0.28	-0.26	-0.27	-5.25**	-0.02	-0.31	0.81	-0.36	0.27	0.60	6.18**	-3.11**	-42.40*	-0.51*
EC755653 x PusaSawani	1.37	0.11	1.16	10.21**	-0.49	0.39	-0.23	-0.15	0.03	-2.21**	-7.97**	0.83	-27.70	-0.33
EC755653 x VRO 22	-0.10	-0.34	-0.91	-0.07	0.35	0.10	-1.74	0.30	-0.09	-1.48**	-2.43	0.07	-24.80	-0.30
EC 755654 x ArakkaAnamika	0.41	0.51	0.3	15.74	0.51*	-0.70**	0.38	-0.09	0.22	1.29**	4.38**	-3.64**	-28.23	-0.34
EC 755654 x ParbhaniKranti	0.14	0.24	-1.63	10.09**	0.13	0.16	-2.81**	0.10	-0.01	-1.10**	0.13	-2.31*	-55.15**	-0.66**
EC 755654 x PusaSawani	-0.12	-0.39	0.24	-11.20**	-0.19	0.36	3.16**	0.24	0.05	0.04	-0.62	8.28**	115.61**	1.39**
EC 755654 x VRO 22	-0.44	0.66*	1.09	-14.63**	-0.20	0.18	-0.73	-0.26	-0.27	-0.23	-3.88**	-2.34*	-32.24	-0.39
IC52303 x ArakkaAnamika	1.41*	0.49	2.09*	-5.35**	0.08	-0.05	-0.87	-0.64	0.48**	-0.31	0.54	0.72	2.39	0.03
IC52303 x ParbhaniKranti	-0.91	-0.46	0.61	2.32	0.06	0.01	0.82	-0.41	-0.26	-1.60**	-6.71**	0.12	-31.33	-0.38
IC52303 x PusaSawani	-0.72	0.01	-2.27*	1.47	0.26	-0.09	-1.1	0.62*	-0.20	-0.86*	1.95	-1.41	-30.96	-0.37
IC52303 x VRO 22	0.21	-0.04	-0.44	1.55	-0.39	0.13	1.15	0.43	-0.02	2.77**	4.23**	0.57	59.91**	0.72*
IC755652 x ArakkaAnamika	-0.46	-0.49	-3.52	-2.98	-0.75**	0.32	0.27	0.52	0.50*	-1.88**	-3.81**	-1.22	-52.31	-0.63*
IC755652 x ParbhaniKranti	-0.59	0.86**	1.50	-0.29	0.40	0.59*	0.77	0.27	-0.13	-0.26	2.74*	1.25	10.52	0.13
IC755652 x PusaSawani	1.41*	0.14	4.17**	7.31**	0.62*	-0.71**	-2.29**	-0.21	-0.53	0.48	-5.15**	0.81	25.03	0.30
IC755652 x VRO 22	-0.36	-0.52	-2.15	-4.05	-0.28	-0.20	1.25	-0.57*	-0.16	1.66**	6.23**	-0.83	16.66	0.20
IC111515 x ArakkaAnamika	0.79	-0.02	0.78	-4.52*	0.50*	0.70*	-2.31**	-0.69**	-0.10	-1.64**	-0.40	-0.85	-51.91	-0.62*
IC111515 x ParbhaniKranti	-0.09	-0.27	-1.40	-9.80**	0.13	-0.04	2.36**	0.33	-0.23	2.48**	-2.40	6.48**	164.95**	1.98**
IC111515 x PusaSawani	-0.74	0.05	-2.73**	9.95**	-0.34	-0.14	0.58	-0.26	0.42	1.12**	4.46**	-6.29**	-80.73**	-0.91**
IC111515 x VRO 22	0.04	0.24	3.35**	4.72*	-0.29	-0.52*	-0.62	0.62*	-0.09	-1.96**	-1.91	0.66	-32.31	-0.39
SED	0.9199	0.9363	0.4073	2.5845	2.4968	0.3395	0.3513	0.9444	0.3264	0.3228	0.4824	1.7293	1.5550	27.6724
CD 5%	1.9042	1.9382	0.8403	5.3498	5.1683	0.7027	0.7273	1.9549	0.6757	0.6682	0.9986	3.5797	3.2188	57.2818
CD1%	2.5849	2.6311	1.1444	7.2623	7.0159	0.954	0.9873	2.6537	0.9173	0.9071	1.3556	4.8594	4.3694	77.7593

Table 4. Standard heterosis for fourteen yield and yield related traits in okra hybrid

		D1st F	NFF	DFF	PH (cm)	INL (cm)	NBPP	FL (cm)	FG (cm)	NRPF	NFPP	NSPF	IFW (g)	YPP (g)	YPPL
1	EC755648 x ArakkaAnamika	-12.33**	-22.81**	-14.11**	-5.79	-18.49**	9.37	2.92	16.79**	-7.14	37.40**	-1.72	11.10-	52.88**	47.39**
2	EC755648 x ParbhaniKranti	-8.63**	-31.58**	-9.79**	-1.38	-19.66**	-6.25	-10.81	19.81**	25.00**	41.98**	10.32**	-8.07	30.87**	27.71**
3	EC755648 x PusaSawani	-10.54**	-22.81**	-11.37**	-24.01**	-3.70	15.63	3.18	16.60*	12.50*	48.09**	25.59**	-4.03	42.20**	37.84**
4	EC755648 x VRO 22	-9.64**	-22.81**	-14.69**	-4.82	9.08	28.13*	3.77	20.00**	25.00**	37.40**	10.11**	0.08	37.72**	33.83**
5	EC755653 x ArakkaAnamika	-12.56**	-8.77**	-24.81**	-20.81**	-19.66**	0.00	-8.07	22.08**	-21.43**	43.13**	22.37**	-14.51*	22.59**	20.31*
6	EC755653 x ParbhaniKranti	-8.74**	-28.07**	-22.41**	-19.46**	-24.20**	-21.88*	-4.33	3.21	-3.57	25.57**	27.31**	-34.16**	-17.22	-15.28
7	EC755653 x PusaSawani	-2.91	-15.79**	-18.67**	-10.49**	-25.88**	3.12	-7.22	9.81	-17.86**	-1.53	-3.44	-14.55**	-15.69	-13.92
8	EC755653 x VRO 22	-9.42**	-22.81**	-24.81**	-18.45**	-10.59	-9.38	-11.17	4.15	-8.93	9.92*	13.55**	-30.69**	-23.74*	-11.94
9	EC 755654 x ArakkaAnamika	-8.07**	-.22.81**	-19.83**	3.62	-20.00**	-28.13*	-22.04**	3.87	-8.93	16.03**	4.95	-25.63**	-13.48	-24.13
10	EC 755654 x ParbhaniKranti	-8.97**	-15.79**	-20.17**	2.03	-32.44**	-12.50	-35.00**	10.75	-3.57	-0.76	-3.44	-17.52	-18.00*	-15.98*
11	EC 755654 x PusaSawani	-6.17**	-21.05**	-15.68**	-21.41**	-27.23**	-3.13	3.48	16.23*	-12.50*	2.29	-5.38	29.93**	33.40**	29.97**
12	EC 755654 x VRO 22	-10.09**	-22.82**	-16.97**	-23.60**	-26.22**	-6.25	-14.53*	3.96	-7.14	6.11	-7.31*	-27.42**	-22.82*	-20.29*
13	IC52303 x ArakkaAnamika	-4.82*	-12.28**	-19.09**	-24.16**	-20.34**	-15.63	-33.94**	-17.55**	-1.79	2.29	15.05**	-19.34**	-17.36	-15.41
14	IC52303 x ParbhaniKranti	-10.31**	-35.09**	-18.67**	-14.55**	-22.35**	-25.00*	-18.12**	-9.81	-5.36	-6.11	0.22	-19.27**	-24.06*	-21.40*
15	IC52303 x PusaSawani	-6.50**	-21.05**	-22.07**	-20.80**	-12.77*	-25.00*	-26.16**	12.45*	-14.29*	-6.11	18.49**	-22.53**	-27.11**	-24.13**
16	IC52303 x VRO 22	-7.62**	-21.05**	-21.74**	-19.46**	-22.52**	-15.63	-7.98	5.94	-0.00	24.05**	28.49**	-27.19**	-7.04	-6.18

		D1st F	NFF	DFF	PH (cm)	INL (cm)	NBPP	FL (cm)	FG (cm)	NRPF	NFPP	NSPF	IFW (g)	YPP (g)	YPPL
17	IC755652 x ArakkaAnamika	-8.30**	-24.56**	-26.31**	-18.36**	-37.82**	12.50	-24.57**	16.60*	-8.93	-4.58	0.22	-27.09**	-30.34**	-27.01**
18	IC755652 x ParbhaniKranti	-8.86**	-7.02**	-15.10**	-12.93**	-20.17**	9.37	-15.79**	15.28*	-10.71	9.16*	15.05**	-14.17*	-6.21	-5.44
19	IC755652 x PusaSawani	-1.01	-14.04**	-9.29**	-12.08**	-10.25	-28.13*	-30.55**	8.87	-27.68**	9.16*	-2.26	-12.88	-4.74	-4.12
20	IC755652 x VRO 22	-8.18**	-24.56**	-22.49**	-18.94**	-24.20**	-9.37	-4.77	-0.75	-4.46	24.05**	27.31**	-32.69**	-16.39	-14.53
21	IC111515 x ArakkaAnamika	-7.62**	-26.32**	-20.58**	-29.06**	-17.98**	15.63	-29.23**	-11.70	-8.93	10.69**	15.91**	-19.23**	-10.31**	-9.10
22	IC111515 x ParbhaniKranti	-9.87**	-36.84**	-21.33**	-30.34**	-25.88**	-18.75	4.15	10.75	-1.79	43.51**	11.83**	13.96*	63.08**	56.51**
23	IC111515 x PusaSawani	-7.96**	-25.44**	-22.16**	-19.46**	-27.56**	-18.75	-3.09	2.55	0.00	27.48**	26.24**	-36.25**	-18.61*	-16.52*
24	IC111515 x VRO 22	-9.42**	-21.05**	-14.77**	-22.97**	-25.55**	-28.13*	-5.24	16.23*	1.79	9.92*	17.63**	-20.15**	-12.10	-10.47

A critical evaluation of the results with respect to specific combing ability effects showed that none of the hybrids exhibited desirable significant sca effects for all the characters (Table 3). The crosses EC755653 X ArakkaAnamika and IC 52303 X VRO22 exhibited desirable significant positive sca for number of fruits per plant, number of seeds per fruit, yield per plant and yield per plot. Significant and positive sca effects for number of fruits per plant, individual fruit weight, yield per plant and yield per plot was recorded by cross IC 111515 X ParbhaniKranti. The hybrid namely EC755654 X PusaSawani manifested desirable sca effects for fruit length, individual fruit weight, yield per plant and yield per plot (Table 3).

3.3 Heterosis

The standard heterosis expressed by 24 crosses for all the quantitative traits are presented in the Table 4. The levels of heterosis differed from crosses to crosses and from character to character. Heterosis ranged from -6.11 to 48.09, -34.16 to 29.93, -27.11 to 63.08 and -27.01 to 56.51 for number fruits per plant, individual fruit weight, yield per plant and yield per plot respectively. Positive heterosis desirable for the number fruits per plant, individual fruit weight, yield per plant. Sixteen crosses manifested highly significant positive heterosis for number of fruits per plant over the standard check shakthi. Two crosses exhibited significant positive standard heterosis for individual fruit weight. Seven crosses expressed highly significant positive standard heterosis for yield per plant. In the present study, we studied the combining ability and heterosis for yield and yield related traits**.** Hence, it is inferred that the parents EC 755648 among the lines and Parbhanikranti among the tester were found to be the best general combiners, they exhibited high gca effect for yield per plant. Our study was in agreement with previous studies [6-10].

Consequently, few cross combination were recorded high sca effect for the most of the traits. In this regards, hybrids viz.,EC755653 x ArakkaAnamika, IC52303 x VRO 22 and IC111515 x ParbhaniKranti were the best experimental hybrids recorded significant sca effects for major yield contributing traits. These hybrids were considered as good specific combiners and can be effectively utilized for heterosis breeding programme. Results of the current study supported by [11,7,8].

4. CONCLUSION

Significant heterosis over the standard check Shakthi was observed for five traits by cross combination EC755648 x ArakkaAnamika, EC755648 x ParbhaniKranti, EC755648 x PusaSawani, EC755648 x VRO 22, EC755653 x ArakkaAnamika, EC 755654 x PusaSawani, IC111515 x ParbhaniKranti. Hence, these hybrids were adjusted as the best cross suited for heterosis breeding. Based on results, it can be concluded that parents having good general combing ability for number of fruits per plant (EC755648 and ParbhaniKranti) could be utilized as donor parents for obtaining high fruit yield per plant and desirable traits. For quantitative traits parents EC755648 and ParbhaniKranti was found as good general combines. The cross combination EC755653 x ArakkaAnamika, IC52303 x VRO 22 and IC111515 x ParbhaniKranti had maintained high sca coupled with high and desirable heterosis for most of the traits could effectively be exploited in hybrid breeding programme.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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