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EVALUATION OF GENERAL AND SPECIFIC COMBINING ABILITY EFFECTS FOR YIELD AND ITS COMPONENT TRAITS IN OKRA (*ABELMOSCHUS ESCULENTUS (L.) MOENCH*)

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ABSTRACT
This study evaluated combining ability for yield and related traits in okra [*Abelmoschus esculentus* (L.) Moench]. Twenty-eight F_1 hybrids developed from an 8 × 8 half-diallel crossing system, along with their eight parents and one commercial check, were tested across three environments. Combining ability analysis showed that mean squares for general combining ability (GCA) and specific combining ability (SCA) were significant for most of the 11 traits evaluated. This showed that both additive and non-additive gene actions controlled these traits. Fruit yield per plant, number of fruits per plant, and fruit weight were mainly governed by non-additive gene action, which indicated good potential for hybrid breeding. Earliness and plant height displayed noticeable additive effects, which showed that simple parental selection would be effective for these characters. Parents AKOV-107, GJO-3, and Phule Utkarsha were identified as the best general combiners for yield and seed traits. Among the hybrids, Phule Utkarsha × GJO-3, Konkan Bhendi × GJO-3, and Phule Vimukta × GJO-3 showed high and stable SCA effects across environments for yield and its key components. Although the environments affected combining ability estimates, pooled analysis helped identify stable parents and high-performing hybrids with wide adaptation. The findings confirmed the need to use both additive and non-additive gene actions in okra breeding programs.

KEYWORDS: Okra, combining ability, GCA, SCA, heterosis, yield traits

1. INTRODUCTION

Food security was long viewed mainly as having enough daily calories, but modern nutritional science focuses heavily on balanced diets and overall health. Vegetables are essential in everyday human nutrition because they supply dietary fiber, vital vitamins, minerals, and bioactive substances like phenolics and flavonoids that help prevent lifestyle illnesses (18). Within the vegetable group, okra [*Abelmoschus esculentus* (L.) Moench], a member of the Malvaceae family, holds a key position because of its nutritional value, medicinal qualities, and capacity to grow across varied agro-climatic conditions. Okra serves multiple purposes, as nearly every part of the plant including immature fruits, leaves, floral parts, and seeds can be consumed or used. Fresh green pods provide good amounts of carbohydrates, dietary fiber, essential vitamins like folate and vitamin C, and key minerals such as calcium, potassium, and zinc (6). Okra mucilage is an acidic polysaccharide bound to proteins and minerals, which provides notable biological benefits including antioxidant, antimicrobial, blood-sugar lowering, cholesterol-reducing, and anti-cancer properties (4). India ranks as the largest producer of okra globally, yet national productivity has leveled off. This plateau exists largely because farmers continue to cultivate older open-pollinated varieties without fully utilizing available genetic diversity through hybrid programs (2). Pod yield in okra is a complex polygenic trait that interacts strongly with growing conditions. Because final yield depends directly on several contributing characters, raising yield levels requires a clear understanding of the genetic mechanisms controlling each yield-related trait. While estimates of variability, heritability, and genetic advance help breeders assess selection prospects, selecting parents based on visible plant

type alone often fails because both additive and non-additive gene effects operate simultaneously. To overcome this, combining ability analysis offers a practical biometrical method to evaluate the genetic worth of parents and predict the performance of their hybrids (7, 9). General combining ability (GCA) reflects the average breeding performance of a parent in crosses and points to additive gene action, while specific combining ability (SCA) measures instances where a specific cross performs better or worse than expected based on parental GCA, pointing to non-additive gene action (7). Diallel mating designs have been widely utilized to estimate these GCA and SCA components, helping breeders determine gene action and identify the most promising parents and cross combinations in okra breeding.

2. MATERIAL AND METHODS

2.1 Experimental site

The field experiment was carried out at the Research Farm of K. V. Patel College of Agriculture, Shahada, District Nandurbar, Maharashtra, India (21.5454° N, 74.4711° E), under representative monsoonal conditions. During the cropping season, afternoon maximum temperatures ranged from 30.6 to 31.0 °C and night minimums from 24.5 to 25.7 °C. The district receives most of its average annual rainfall 767 mm per year during the south-west monsoon (June–September).

2.2 Experimental units, design and evaluation

The experimental material comprised eight genetically diverse parental okra genotypes, their twenty-eight F1 hybrids developed through a half-diallel mating design (excluding reciprocals), and one standard check variety (‘Parbhani Kranti’). Hybridization was performed during the preceding season using manual emasculation and hand-pollination techniques. The resulting 37 genotypes (8 parents, 28 F1 hybrids, and 1 check) were evaluated across three distinct environments during the *kharif* season using a Randomized Block Design (RBD) with three replications.

2.3 Planting geometry

Each genotype was grown in a single 6 m long row with a spacing configuration of 60 × 45 cm. Guard rows were systematically provided around the experimental blocks to minimize border effects. Standard recommended agronomic practices and plant protection measures were uniformly adopted across all environments to ensure optimal crop growth.

2.4 Observations recorded

Observations were recorded from five randomly selected, competitive plants per plot for eleven morpho-physiological traits: days to 50% flowering, plant height (cm), number of branches per plant, number of fruits per plant, fruit length (cm), fruit diameter (cm), average fruit weight (g), fruit yield per plant (g), number of seeds per fruit, seed index (100-seed weight in g), and days to edible maturity.

2.5 Statistical analysis and combining ability estimation

Replication mean values were first subjected to standard analysis of variance to confirm genetic differences among the tested entries. Combining ability analysis was carried out using Method II, Model I (fixed effects) described by Griffing (7). This model was used to calculate general combining ability (GCA) effects representing additive gene action and specific combining ability (SCA) effects representing non-additive gene action. The statistical significance of both GCA and SCA estimates was tested using appropriate t-tests, and genetic variance components were calculated to assess the relative contribution of additive versus non-additive genetic control. To examine the stability of combining ability effects across environments, pooled analysis over the three environments was conducted following the statistical procedures outlined by Singh (14, 15).

3. RESULTS AND DISCUSSION

Across the three individual environments ($E_1, E_2,$ and E_3) and in the pooled analysis, combining ability analysis revealed significant mean squares for both general combining ability (GCA) and specific combining ability (SCA) for most of the 11 traits evaluated. These findings indicated the involvement of both additive and non-additive gene actions in the genetic control of the characters studied. Yield and its primary contributing traits, including number of fruits per plant, average fruit weight, and fruit yield per plant, were predominantly governed by non-additive gene effects, as indicated by larger SCA variance relative to GCA variance. This demonstrated that heterosis breeding is the most effective approach for raising fruit yield. On the other hand, characters such as days to 50% flowering and plant height showed notable additive genetic effects, indicating that direct parental selection would be effective. Although environmental differences influenced combining ability estimates, pooled analysis over environments successfully identified stable parental lines and superior cross combinations across seasons.

For days to 50% flowering, negative GCA effects are desirable as they reflect earliness. Based on pooled analysis, parental lines AKOV-107 (-0.642) and Phule Vimukta (-0.540) were identified as the most stable and effective donors for early flowering, maintaining negative GCA estimates across all three environments (AKOV-107: -0.628, -1.035, and -0.290; Phule Vimukta: -0.528, -0.638, and -0.475 in $E_1, E_2,$ and E_3, respectively). Phule Utkarsha also contributed to earlier flowering (-0.367). In contrast, parents GJO-3 (1.709) and GO-6 (0.667) consistently promoted late flowering, while GOA-5 (0.449) and GOA-8 (0.259) also leaned toward lateness. At the hybrid level, pooled SCA effects revealed that AKOV-107 × GO-6 (-1.728), Konkan Bhendi × GO-6 (-1.597), and GOA-5 × Konkan Bhendi (ranging from -1.62 to -4.24 across environments) were the most

reliable combinations for early harvest. This confirmed the role of non-additive gene action in shortening the flowering period, particularly under E_2 conditions. Comparable trends were documented in previous studies on okra combining ability (8, 10, 11, 17).

For number of branches per plant, pooled GCA estimates were positive and significant for AKOV-107 (0.120) and GJO-3 (0.098), with both lines showing stable performance across environments. Parent GOA-8 (0.065) also provided a small positive additive effect. Conversely, Phule Utkarsha (-0.082), GOA-5 (-0.023), and GO-6 (-0.020) reduced branch number. Pooled SCA effects were substantial, with crosses Konkan Bhendi × GO-6 (0.522), Phule Utkarsha × AKOV-107 (0.555), AKOV-107 × GO-6 (0.348), and GJO-3 × GO-6 (0.264) recording positive values for branch development, which indicated the predominance of non-additive gene action for this trait.

For number of fruits per plant, pooled GCA estimates highlighted AKOV-107 (4.524) as a superior, stable donor, maintaining high positive effects in E_1 (4.550), E_2 (4.302), and E_3 (4.667). Parents GOA-8 (0.400) and Phule Vimukta (0.207) also gave positive contributions, whereas GJO-3 (-3.568), GO-6 (-1.265), and Phule Utkarsha (-0.856) showed negative general combining ability. Pooled SCA evaluations showed that GOA-5 × GOA-8 (1.381), GOA-5 × Phule Vimukta (1.335), Phule Utkarsha × Konkan Bhendi (0.935), Phule Vimukta × AKOV-107 (0.906), and GOA-8 × Konkan Bhendi (0.769) were the top cross combinations for fruit count, verifying that specific hybrid combinations drive fruit set.

Plant height displayed notable additive genetic variation. Negative pooled GCA values were observed in GOA-5 (-8.544), GOA-8 (-5.646), GO-6 (-4.831), Phule Vimukta (-4.286), and Konkan Bhendi (-3.844), indicating their usefulness for developing shorter, lodging-resistant plants across environments. Conversely, GJO-3 (11.664) and Phule Utkarsha (10.452) served as strong donors for increasing plant height. Pooled SCA effects showed that crosses GOA-8 × AKOV-107 (-5.306) and GJO-3 × GO-6 (-3.453) were effective for reducing plant height, whereas Konkan Bhendi × GO-6 (3.957) increased plant stature. Similar observations were noted by earlier researchers (1, 5, 13).

Yield per plant was strongly influenced by additive effects, where parents GJO-3 (18.549) and Phule Utkarsha (36.568) displayed high, stable positive pooled GCA values across all three test environments. All remaining parents produced negative GCA values, particularly GO-6 (-11.818), GOA-8 (-11.203), and Konkan Bhendi (-9.101). In terms of hybrid performance, pooled SCA estimates identified Phule Utkarsha × GJO-3 (15.267), Konkan Bhendi × GJO-3 (11.048), and AKOV-107 × GO-6 (7.331) as the highest-yielding crosses. By contrast, GJO-3 × GO-6 displayed a strong negative effect (-13.189), illustrating that yield heterosis relies on specific parental combinations.

For fruit length, Phule Utkarsha was the only parent with a strong positive pooled GCA value (2.523), performing consistently across all environments, while other parents showed negative or negligible effects. Hybrids GJO-3 × GO-6 (0.667), GOA-5 × GOA-8 (0.608), and AKOV-107 × Konkan Bhendi (0.503) showed positive pooled SCA effects for longer fruits. Fruit diameter displayed minor variation in GCA values; parents GJO-3 (0.051), AKOV-107 (0.039), and GOA-8 (0.048) slightly raised pod thickness, whereas GOA-5 (-0.105) lowered it. Specific crosses showed moderate positive or negative pooled SCA values, providing avenues to select for preferred fruit girth.

Average fruit weight was supported by positive pooled GCA effects in AKOV-107 (1.684), GJO-3 (0.842), and Phule Vimukta (0.375), while Phule Utkarsha (-0.668) and Konkan Bhendi (-0.518) lowered fruit mass. The crosses AKOV-107 × Konkan Bhendi (2.478), GOA-8 × GO-6 (2.447), and Phule Utkarsha × GO-6 (2.325) produced high pooled SCA values. For days to edible maturity, all parental lines recorded negative pooled GCA values, led by Phule Utkarsha (-4.672) and Konkan Bhendi (-4.326), confirming broad additive genetic potential for earlier pod harvest, which was further supported by cross GJO-3 × GO-6 (-4.910).

Seed characters were largely regulated by additive gene effects. Parent GJO-3 showed high pooled GCA for number of seeds per fruit (10.279), followed by AKOV-107 (3.566), whereas other parents recorded negative effects. Crosses AKOV-107 × GJO-3 (6.846) and Konkan Bhendi × GJO-3 (6.759) produced the highest pooled SCA values for seed count. For 100-seed weight, GJO-3 (0.499) and AKOV-107 (0.201) were the best positive general combiners, while hybrids AKOV-107 × GJO-3 (0.330) and Phule Vimukta × GO-6 (0.191) consistently increased seed mass across environments, supporting their utility for seed quality improvement programs. These trends agreed with findings reported in related studies (3, 12, 16).

4. SUMMARY AND CONCLUSION

The present study evaluated the nature and magnitude of gene action for yield and its component traits in okra [*Abelmoschus esculentus* (L.) Moench] across three distinct environments using an 8 × 8 half-diallel crossing system. Combining ability analysis revealed that mean squares for both general combining ability (GCA) and specific combining ability (SCA) were significant for most of the 11 traits evaluated, demonstrating that both additive and non-additive gene actions regulated their inheritance. Non-additive gene action was predominant for key yield-related characters, namely number of fruits per plant, average fruit weight, and fruit yield per plant, as evidenced by higher SCA variance relative to GCA variance. In contrast, additive gene action largely governed days to 50% flowering, plant height, and seed-related attributes.

Among the parental genotypes, AKOV-107, GJO-3, and Phule Utkarsha were identified as the most effective and stable general combiners for yield, earliness, and seed characters across environments. At the hybrid level,

crosses including Phule Utkarsha × GJO-3, Konkan Bhendi × GJO-3, and AKOV-107 × GO-6 exhibited consistently high specific combining ability for total fruit yield and primary yield components. While environmental differences influenced combining ability estimates, pooled analysis successfully distinguished stable parents and promising cross combinations.

In conclusion, the predominance of non-additive genetic control for fruit yield and its primary components indicates that heterosis breeding and hybrid development offer the most effective pathway for increasing okra productivity. Concurrently, the presence of appreciable additive gene action for earliness, plant architecture, and seed characters suggests that recurrent selection and pedigree methods can be successfully used to isolate superior pure-line derivatives. The superior crosses and stable parents identified in this investigation represent valuable genetic resources for future okra breeding programs.

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Table 1: Estimates of general combining ability (GCA) and specific combining ability (SCA) effects in okra for days to 50 per cent flowering, no. of fruits per plant and no. of branches per plant in individual and pooled analyses over environments

Sr. No.	Genotypes	Days to 50% flowering				No. of branches per plant				No. of fruits per plant			
		E1	E2	E3	Pooled	E1	E2	E3	Pooled	E1	E2	E3	Pooled
Parents													
1.	GOA-5	0.427	0.631	0.334	0.449	-0.021	0.027	-0.08	-0.023	-0.247	-0.302	-0.174	-0.243
2.	GOA-8	0.269	0.635	-0.145	0.259	0.066	0.018	0.111	0.065	0.357	0.566	0.362	0.4
3.	Phule Utkarsha	-0.374	-0.506	-0.204	-0.367	-0.08	-0.081	-0.062	-0.082	-0.848	-1.048	-0.689	-0.856
4.	Phule Vimukta	-0.528	-0.638	-0.475	-0.54	0.016	-0.018	0.018	0.01	0.217	0.355	0.028	0.207
5.	AKOV-107	-0.628	-1.035	-0.29	-0.642	0.118	0.136	0.113	0.12	4.55	4.302	4.667	4.524
6.	Konkan Bhendi	-0.016	0.079	-0.074	-0.009	0.013	0.023	-0.011	0.01	0.175	0.297	0.079	0.181
7.	GJO-3	1.716	1.665	1.735	1.709	0.099	0.121	0.072	0.098	-3.561	-3.527	-3.63	-3.568
8.	GO-6	0.663	0.678	0.67	0.667	-0.02	-0.04	0.003	-0.02	-1.261	-1.196	-1.347	-1.265
	S.E.gi	0.278	0.285	0.296	0.272	1.463	2.172	0.962	1.346	0.083	0.146	0.060	0.078
Hybrids													
1.	GOA-5 × GOA-8	1.134	1.058	1.399	1.172	-0.193	-0.223	-0.147	-0.19	1.397	1.462	1.253	1.381
2.	GOA-5 × Phule Utkarsha	0.879	-0.311	1.974	0.86	-0.298	-0.28	-0.312	-0.297	-1.385	-1.284	-1.393	-1.366
3.	GOA-5 × Phule Vimukta	0.665	0.101	0.788	0.576	0.3	0.297	0.259	0.291	1.331	0.666	2.013	1.335
4.	GOA-5 × AKOV-107	-0.28	0.255	-0.697	-0.257	-0.311	-0.374	-0.273	-0.316	0.383	0.68	0.301	0.426
5.	GOA-5 × Konkan Bhendi	-2.726	-1.679	-4.243	-2.82	0.071	0.059	0.108	0.076	-0.477	0.167	-1.211	-0.495
6.	GOA-5 × GJO-3	-0.401	-0.745	-0.262	-0.442	0.113	0.188	0.035	0.112	-1.449	-1.142	-2.045	-1.507
7.	GOA-5 × GO-6	1.075	2.092	1.193	1.302	0.044	0.039	0.064	0.047	0.116	-0.453	0.795	0.138
8.	GOA-8 × Phule Utkarsha	-1.129	-0.635	-2.259	-1.256	0.414	0.299	0.601	0.428	0.399	0.568	0.644	0.482
9.	GOA-8 × Phule Vimukta	-0.772	-1.137	-0.342	-0.759	-0.062	-0.078	-0.082	-0.069	0.31	1.202	-0.357	0.355
10.	GOA-8 × AKOV-107	0.374	0.69	0.27	0.416	0.107	0.139	0.053	0.102	0.336	0.025	0.445	0.296
11.	GOA-8 × Konkan Bhendi	0.907	-0.2	1.496	0.803	0.137	0.248	0.047	0.141	0.819	0.44	0.949	0.769
12.	GOA-8 × GJO-3	-0.863	0.537	-2.779	-0.966	0.08	0.017	0.041	0.06	-1.412	-1.853	-1.218	-1.462
13.	GOA-8 × GO-6	-0.335	-0.126	0.53	-0.12	-0.241	-0.279	-0.2	-0.24	-0.722	-0.207	-0.678	-0.61
14.	Phule Utkarsha × Phule Vimukta	0.801	1.427	0.243	0.815	-0.016	-0.006	-0.056	-0.022	-1.317	-1.688	-1.046	-1.337
15.	Phule Utkarsha × AKOV-107	-1.433	-1.666	-1.528	-1.498	0.538	0.638	0.522	0.555	-0.223	-0.552	-0.004	-0.245
16.	Phule Utkarsha × Konkan Bhendi	0.626	1.844	0.022	0.749	-0.06	-0.11	-0.087	-0.076	0.897	1.22	0.763	0.935
17.	Phule Utkarsha × GJO-3	-0.484	-1.496	0.507	-0.488	-0.044	0.019	-0.043	-0.031	0.432	0.207	0.863	0.473
18.	Phule Utkarsha × GO-6	0.485	0.371	1.128	0.591	-0.275	-0.253	-0.351	-0.286	0.719	0.693	-0.067	0.556
19.	Phule Vimukta × AKOV-107	0.491	0.366	0.973	0.562	0.175	0.228	0.108	0.171	0.863	1.242	0.698	0.906
20.	Phule Vimukta × Konkan Bhendi	1.453	1.633	1.879	1.574	-0.098	-0.119	-0.047	-0.092	0.539	0.784	0.646	0.609
21.	Phule Vimukta × GJO-3	-1.5	-1.924	-0.859	-1.457	0.235	0.286	0.224	0.243	-0.565	-0.863	-0.335	-0.578
22.	Phule Vimukta × GO-6	0.003	0.437	-1.411	-0.193	-0.324	-0.413	-0.231	-0.323	-0.719	-0.503	-1.761	-0.884
23.	AKOV-107 × Konkan Bhendi	0.711	0.346	1.205	0.736	-0.225	-0.263	-0.218	-0.231	0.158	-0.49	0.288	0.054
24.	AKOV-107 × GJO-3	1.404	1.03	2.089	1.466	-0.527	-0.604	-0.481	-0.533	-1.423	-1.016	-1.647	-1.386
25.	AKOV-107 × GO-6	-1.52	-2.246	-1.836	-1.728	0.34	0.364	0.358	0.348	0.09	-0.266	0.297	0.06
26.	Konkan Bhendi × GJO-3	0.86	1.303	0.623	0.901	-0.295	-0.328	-0.247	-0.292	-1.951	-1.822	-2.326	-2.
27.	Konkan Bhendi × GO-6	-1.488	-2.797	-0.726	-1.597	0.523	0.543	0.498	0.522	0.325	0.358	0.858	0.438
28.	GJO-3 × GO-6	1.451	1.721	1.079	1.43	0.262	0.319	0.216	0.264	-0.631	-0.268	-0.539	-0.54
	S.E.sij	0.855	0.873	0.907	0.835	4.486	6.658	2.949	4.125	0.253	0.448	0.184	0.241

*,** Significant at 5 % and 1 % level, respectively

Table 2: Estimates of general combining ability (GCA) and specific combining ability (SCA) effects in okra for plant height (cm), yield per plant (g) and fruit length (cm) in individual and pooled analyses over environments

Sr. No.	Genotypes	Plant height (cm)				Yield per plant (g)				Fruit length (cm)			
		E1	E2	E3	Pooled	E1	E2	E3	Pooled	E1	E2	E3	Pooled
Parents													
1.	GOA-5	-8.527	-8.527	-8.618	-8.544	-6.768	-7.815	-5.903	-6.806	-0.721	-0.839	-0.65	-0.731
2.	GOA-8	-5.527	-6.546	-5.112	-5.646	-11.154	-10.807	-11.736	-11.203	-0.48	-0.395	-0.469	-0.462
3.	Phule Utkarsha	10.587	11.825	8.666	10.452	36.537	36.444	36.791	36.568	2.532	2.432	2.591	2.523
4.	Phule Vimukta	-4.458	-3.895	-4.168	-4.286	-7.913	-6.561	-9.171	-7.896	-0.512	-0.471	-0.559	-0.514
5.	AKOV-107	-2.508	-3.499	-2.323	-2.668	-2.403	-2.11	-2.987	-2.463	-0.691	-0.579	-0.844	-0.7
6.	Konkan Bhendi	-4.08	-4.525	-2.462	-3.844	-9.012	-9.152	-9.307	-9.101	-0.403	-0.442	-0.322	-0.396
7.	GJO-3	11.538	11.424	12.276	11.664	18.467	18.307	19.046	18.549	-0.057	-0.023	-0.094	-0.059
8.	GO-6	-4.748	-4.122	-5.795	-4.831	-11.919	-12.287	-11.036	-11.818	-0.476	-0.379	-0.553	-0.473
	S.E.gi	0.166	0.198	0.113	0.147	0.079	2.118	2.866	1.172	2.012	1.064	0.067	0.081
Hybrids													
1.	GOA-5 × GOA-8	2.042	2.29	1.562	1.996	3.015	3.711	3.042	3.159	0.58	0.563	0.74	0.608
2.	GOA-5 × Phule Utkarsha	-5.107	-0.424	-10.703	-5.289	1.381	5.983	-1.665	1.692	-0.205	-0.584	-0.216	-0.283
3.	GOA-5 × Phule Vimukta	2.46	1.802	3.998	2.637	2.245	1.132	3.564	2.286	0.061	-0.338	0.493	0.067
4.	GOA-5 × AKOV-107	2.428	2.083	1.819	2.238	1.302	-0.383	2.676	1.239	0.267	-0.046	0.462	0.243
5.	GOA-5 × Konkan Bhendi	-3.127	-7.248	-0.679	-3.461	7.126	6.286	6.282	6.789	-0.339	0.067	-0.601	-0.31
6.	GOA-5 × GJO-3	-1.671	-1.453	-2.244	-1.742	-14.012	-14.956	-13.96	-14.191	0.011	0.158	-0.075	0.023
7.	GOA-5 × GO-6	-0.073	-0.444	3.361	0.54	6.261	3.241	9.562	6.317	-0.55	-0.193	-0.926	-0.554
8.	GOA-8 × Phule Utkarsha	-0.782	-1.398	0.261	-0.696	-5.557	-4.551	-6.575	-5.56	0.497	0.569	0.472	0.506
9.	GOA-8 × Phule Vimukta	-0.101	-4.242	4.805	0.053	-6.504	-8.465	-5.306	-6.657	0.187	0.019	0.384	0.192
10.	GOA-8 × AKOV-107	-4.259	-7.154	-6.6	-5.306	-2.138	-2.197	-1.351	-1.993	-0.617	-0.08	-1.034	-0.593
11.	GOA-8 × Konkan Bhendi	-3.078	-2.902	-3.685	-3.164	9.211	8.182	10.455	9.253	-0.307	-0.36	-0.439	-0.345
12.	GOA-8 × GJO-3	8.281	11.987	8.01	8.968	5.117	6.52	1.99	4.771	0.191	-0.142	0.52	0.19
13.	GOA-8 × GO-6	-1.668	-0.981	-2.468	-1.69	1.396	3.017	0.069	1.454	-0.35	-0.136	-0.562	-0.35
14.	Phule Utkarsha × Phule Vimukta	3.226	1.128	4.937	3.149	-1.399	-7.064	0.18	-2.216	0.192	0.188	0.202	0.193
15.	Phule Utkarsha × AKOV-107	-2.259	-1.905	-1.059	-1.947	3.896	3.931	3.812	3.886	-0.447	-0.39	-0.52	-0.45
16.	Phule Utkarsha × Konkan Bhendi	2.84	2.921	6.153	3.519	-1.278	-4.333	1.835	-1.267	0.139	-0.034	0.242	0.125
17.	Phule Utkarsha × GJO-3	-1.148	-4.177	-0.398	-1.603	14.424	16.025	17.043	15.267	0.288	0.501	0.294	0.331
18.	Phule Utkarsha × GO-6	-0.813	2.289	-7.376	-1.505	-3.843	-2.788	-6.156	-4.095	-0.109	-0.137	0.009	-0.091
19.	Phule Vimukta × AKOV-107	0.712	3.915	-2.034	0.803	3.288	8.753	-1.403	3.442	0.056	0.283	0.07	0.104
20.	Phule Vimukta × Konkan Bhendi	0.212	2.95	-0.226	0.673	-12.16	-5.364	-16.446	-11.658	0.189	0.163	0.194	0.185
21.	Phule Vimukta × GJO-3	-2.937	-2.461	-4.854	-3.225	10.555	9.884	11.338	10.577	-0.098	-0.093	-0.28	-0.133

22.	Phule Vimukta × GO-6	0.915	2.301	-1.065	0.797	9.498	10.044	10.827	9.873	-0.047	0.363	-0.568	-0.069
23.	AKOV-107 × Konkan Bhendi	-1.094	-0.512	-1.434	-1.045	-0.371	-2.776	1.809	-0.416	0.488	0.568	0.483	0.503
24.	AKOV-107 × GJO-3	4.458	2.167	6.854	4.479	0.53	-0.768	1.6	0.484	-0.492	-0.258	-1.041	-0.555
25.	AKOV-107 × GO-6	3.702	2.402	6.976	4.098	7.601	7.262	6.592	7.331	0.381	-0.179	0.824	0.357
26.	Konkan Bhendi × GJO-3	1.936	2.889	2.423	2.224	11.351	11.814	9.377	11.048	-0.01	-0.228	0.273	0.003
27.	Konkan Bhendi × GO-6	4.451	2.665	3.765	3.957	-0.694	-0.405	-1.211	-0.74	0.372	0.291	0.488	0.379
28.	GJO-3 × GO-6	-3.575	-4.164	-2.38	-3.453	-13.368	-12.408	-13.433	-13.189	0.64	0.619	0.798	0.667
	S.E.sij	0.508	0.609	0.347	0.453	0.244	6.491	8.785	3.592	6.169	3.262	0.204	0.249

*,** Significant at 5 % and 1 % level, respectively

Table 3: Estimates of general combining ability (GCA) and specific combining ability (SCA) effects in okra for fruit weight (g), fruit diameter (cm) and days to edible maturity in individual and pooled analyses over environments

Sr. No.	Genotypes	Fruit weight (g)				Fruit diameter (cm)				Days to edible maturity			
		E1	E2	E3	Pooled	E1	E2	E3	Pooled	E1	E2	E3	Pooled
Parents													
1.	GOA-5	0.034	-0.06	-0.024	0.003	-0.104	-0.085	-0.127	-0.105	-3.077	-2.773	-3.241	-3.049
2.	GOA-8	-0.221	-0.106	-0.246	-0.203	0.047	0.058	0.043	0.048	-1.615	-1.552	-1.722	-1.624
3.	Phule Utkarsha	-0.647	-0.807	-0.592	-0.668	-0.008	0.02	-0.04	-0.009	-4.669	-4.643	-4.71	-4.672
4.	Phule Vimukta	0.367	0.355	0.419	0.375	0.01	-0.045	0.045	0.006	-1.354	-1.631	-0.935	-1.325
5.	AKOV-107	1.685	1.661	1.704	1.684	0.041	0.022	0.049	0.039	-1.704	-1.795	-1.408	-1.663
6.	Konkan Bhendi	-0.548	-0.46	-0.483	-0.518	-0.024	-0.006	-0.024	-0.02	-4.348	-4.463	-4.125	-4.326
7.	GJO-3	0.84	1.052	0.638	0.842	0.052	0.049	0.051	0.051	-2.3	-2.259	-2.697	-2.371
8.	GO-6	-0.249	-0.378	-0.174	-0.26	0.011	0.	0.021	0.01	-1.702	-1.766	-1.92	-1.758
	S.E.gi	0.0531	0.063	0.043	0.053	0.027	0.096	0.139	0.091	0.105	0.055	0.347	0.453
Hybrids													
1.	GOA-5 × GOA-8	1.434	0.911	2.047	1.452	-0.299	-0.329	-0.274	-0.3	-0.825	-1.309	0.03	-0.751
2.	GOA-5 × Phule Utkarsha	-1.118	-2.298	-0.873	-1.305	-0.044	-0.077	-0.015	-0.045	-1.618	-1.712	-1.869	-1.687
3.	GOA-5 × Phule Vimukta	1.51	1.577	1.579	1.537	-0.213	-0.192	-0.224	-0.211	-0.585	-2.061	1.016	-0.56
4.	GOA-5 × AKOV-107	0.809	1.425	0.298	0.83	0.161	0.221	0.047	0.15	1.302	2.393	-0.658	1.128
5.	GOA-5 × Konkan Bhendi	0.165	0.288	0.232	0.203	-0.22	-0.195	-0.231	-0.217	-0.784	-0.492	-0.731	-0.715
6.	GOA-5 × GJO-3	-0.751	-0.4	-1.347	-0.8	0.337	0.374	0.37	0.351	0.574	1.351	-0.299	0.555
7.	GOA-5 × GO-6	-0.235	0.157	-0.374	-0.184	0.28	0.227	0.297	0.273	3.408	3.058	4.178	3.492
8.	GOA-8 × Phule Utkarsha	-1.228	-0.432	-1.645	-1.152	0.283	0.279	0.342	0.294	1.373	1.714	1.269	1.421
9.	GOA-8 × Phule Vimukta	-0.13	-0.267	0.254	-0.131	0.324	0.348	0.297	0.323	-0.639	-0.801	-0.663	-0.676
10.	GOA-8 × AKOV-107	-0.796	-0.909	-0.82	-0.824	-0.118	-0.109	-0.136	-0.12	0.43	1.233	-0.717	0.362
11.	GOA-8 × Konkan Bhendi	-0.739	-0.583	-0.734	-0.707	0.31	0.345	0.273	0.31	0.564	0.777	-0.513	0.391
12.	GOA-8 × GJO-3	-0.826	-0.618	-1.335	-0.886	-0.342	-0.353	-0.319	-0.339	-1.339	-1.516	-0.514	-1.21
13.	GOA-8 × GO-6	2.459	2.316	2.541	2.447	0.183	0.163	0.225	0.187	-0.015	0.021	0.576	0.11
14.	Phule Utkarsha × Phule Vimukta	1.443	1.438	1.573	1.468	-0.197	-0.134	-0.257	-0.196	-0.989	-0.701	-1.355	-1.004
15.	Phule Utkarsha × AKOV-107	-0.203	0.149	-0.551	-0.203	0.295	0.282	0.326	0.299	0.901	-0.953	4.735	1.297
16.	Phule Utkarsha × Konkan Bhendi	-1.052	-1.258	-0.931	-1.069	-0.18	-0.184	-0.171	-0.179	-0.853	-0.365	-0.598	-0.705
17.	Phule Utkarsha × GJO-3	1.069	1.084	1.241	1.106	0.229	0.245	0.11	0.209	-2.55	-3.462	-2.276	-2.678
18.	Phule Utkarsha × GO-6	2.32	2.177	2.487	2.325	0.057	0.018	0.097	0.057	0.819	2.895	-3.169	0.436
19.	Phule Vimukta × AKOV-107	0.986	1.097	0.845	0.98	-0.149	-0.359	-0.032	-0.167	-0.824	-1.286	-0.927	-0.937
20.	Phule Vimukta × Konkan Bhendi	-0.685	-0.677	-0.889	-0.724	0.193	0.132	0.29	0.2	1.06	1.399	0.873	1.091
21.	Phule Vimukta × GJO-3	-0.733	-0.878	-0.46	-0.708	0.066	0.024	0.085	0.061	2.551	3.962	1.468	2.617
22.	Phule Vimukta × GO-6	-1.022	-0.818	-1.218	-1.02	0.083	0.15	0.042	0.088	-3.488	-4.068	-2.428	-3.392
23.	AKOV-107 × Konkan Bhendi	2.444	2.261	2.797	2.478	-0.072	-0.032	-0.11	-0.072	-2.042	-2.33	-1.924	-2.076
24.	AKOV-107 × GJO-3	1.737	1.633	1.979	1.765	-0.212	-0.197	-0.178	-0.202	2.391	2.753	2.295	2.444
25.	AKOV-107 × GO-6	-1.441	-2.114	-1.068	-1.501	0.096	0.14	0.082	0.102	-2.515	-1.987	-2.822	-2.471
26.	Konkan Bhendi × GJO-3	1.476	1.603	1.482	1.503	0.358	0.358	0.367	0.36	-1.927	-3.189	-1.068	-2.007
27.	Konkan Bhendi × GO-6	-1.235	-1.127	-1.458	-1.258	-0.121	-0.143	-0.119	-0.125	3.522	3.761	3.842	3.634
28.	GJO-3 × GO-6	0.722	0.671	0.763	0.72	-0.235	-0.251	-0.234	-0.238	-4.671	-7.439	-3.096	-4.91
	S.E.sij	0.162	0.193	0.133	0.162	0.0821	0.296	0.426	0.278	0.321	0.167	0.085	0.301

*,** Significant at 5 % and 1 % level, respectively

Table 4: Estimates of general combining ability (GCA) and specific combining ability (SCA) effects in okra for number of seeds per fruit and 100-seed weight (g) in individual and pooled analyses over environments

Sr. No.	Genotypes	Number of seeds per fruit				100-seed weight (g)			
		E1	E2	E3	Pooled	E1	E2	E3	Pooled
Parent									
1.	GOA-5	-2.925	-3.736	-2.088	-2.921	-0.303	-0.286	-0.33	-0.305
2.	GOA-8	-0.825	-0.804	-0.378	-0.732	-0.348	-0.365	-0.297	-0.341
3.	Phule Utkarsha	-5. 325	-5.755	-4.463	-5.045	-0.072	-0.088	-0.078	-0.076
4.	Phule Vimukta	-3.044	-3.635	-2.732	-3.101	0.001	0.066	-0.052	0.004
5.	AKOV-107	3.492	4.579	2.78	3.566	0.198	0.176	0.232	0.201
6.	Konkan Bhendi	-3.264	-2.97	-3.16	-3.186	-0.17	-0.21	-0.155	-0.175
7.	GJO-3	10.311	10.274	10.192	10.279	0.506	0.502	0.473	0.499
8.	GO-6	-4.464	-3.571	-5.82	-4.558	-0.081	-0.055	-0.075	-0.074
	S.E.gi	0.133	0.123	0.082	0.118	0.058	0.114	0.136	0.106
Hybrids									
1.	GOA-5 × GOA-8	3.387	1.171	5.483	3.362	-0.214	-0.457	-0.125	-0.245
2.	GOA-5 × Phule Utkarsha	-0.179	-0.468	0.794	-0.043	0.321	0.193	0.48	0.327
3.	GOA-5 × Phule Vimukta	0.756	0.866	0.25	0.676	-0.272	-0.057	-0.45	-0.265
4.	GOA-5 × AKOV-107	5.836	9.668	4.555	6.345	0.127	0.156	0.113	0.13
5.	GOA-5 × Konkan Bhendi	-1.724	-0.139	-4.992	-2.061	-0.255	-0.209	-0.244	-0.244
6.	GOA-5 × GJO-3	-3.428	-5.304	-2.891	-3.696	-0.135	-0.06	-0.341	-0.161
7.	GOA-5 × GO-6	0.943	-0.889	3.131	1.014	0.567	0.624	0.523	0.569
8.	GOA-8 × Phule Utkarsha	-0.528	1.196	-2.896	-0.657	0.192	0.238	0.213	0.205
9.	GOA-8 × Phule Vimukta	3.074	4.757	1.343	3.064	0.087	0.065	0.09	0.083
10.	GOA-8 × AKOV-107	-5.26	-5.031	-6.056	-5.374	0.065	0.111	0.113	0.084
11.	GOA-8 × Konkan Bhendi	-0.845	1.905	-1.296	-0.386	0.296	0.33	0.263	0.296
12.	GOA-8 × GJO-3	1.057	-1.509	3.342	1.	-0.085	-0.095	0.009	-0.068
13.	GOA-8 × GO-6	4.378	3.276	5.621	4.406	-0.149	-0.095	-0.221	-0.152
14.	Phule Utkarsha × Phule Vimukta	3.37	4.415	2.298	3.364	0.109	0.098	0.135	0.112
15.	Phule Utkarsha × AKOV-107	1.726	0.424	2.983	1.716	-0.22	-0.083	-0.342	-0.217
16.	Phule Utkarsha × Konkan Bhendi	-3.903	-6.097	-3.158	-4.193	0.109	0.173	0.012	0.103
17.	Phule Utkarsha × GJO-3	-1.014	-0.668	-0.98	-0.939	0.317	0.282	0.42	0.331
18.	Phule Utkarsha × GO-6	5.124	4.87	6.262	5.3	-0.161	-0.142	-0.209	-0.167
19.	Phule Vimukta × AKOV-107	4.044	3.714	4.335	4.036	-0.29	-0.3	-0.312	-0.296
20.	Phule Vimukta × Konkan Bhendi	-1.643	-3.773	0.878	-1.565	0.215	0.136	0.315	0.22
21.	Phule Vimukta × GJO-3	-4.017	-3.124	-4.694	-3.974	0.222	0.165	0.287	0.224
22.	Phule Vimukta × GO-6	1.023	-0.823	2.965	1.042	0.192	0.098	0.281	0.191
23.	AKOV-107 × Konkan Bhendi	5.094	1.456	9.296	5.206	0.099	0.136	0.055	0.097
24.	AKOV-107 × GJO-3	6.724	6.445	7.614	6.846	0.349	0.191	0.414	0.33
5.	AKOV-107 × GO-6	-7.89	-3.11	-14.647	-8.286	0.151	0.011	0.324	0.157
26.	Konkan Bhendi × GJO-3	6.588	8.844	5.191	6.759	-0.221	-0.357	-0.053	-0.214
27.	Konkan Bhendi × GO-6	-1.584	0.069	-3.374	-1.612	0.131	0.104	0.125	0.124
28.	GJO-3 × GO-6	2.772	3.448	1.378	2.628	-0.236	-0.071	-0.413	-0.238
	S.E.sij	0.408	0.378	0.251	0.362	0.177	0.351	0.418	0.325

*,** Significant at 5 % and 1 % level, respectively