Journal of Advances in Biology & Biotechnology

Volume 27, Issue 9, Page 63-70, 2024; Article no.JABB.121956
ISSN: 2394-1081

Combining Ability and Heterosis for Yield and Yield Attributing Traits in Bitter Gourd

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Authors' contributions

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

Article Information

DOI: https://doi.org/10.9734/jabb/2024/v27i91274

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/121956

Original Research Article

Received: 14/06/2024
Accepted: 17/08/2024
Published: 19/08/2024

ABSTRACT

A study was conducted during *Rabi* 2022 and *Kharif* 2023 at the Department of Horticulture, University of Agricultural Sciences, Bangalore to develop 49 F_1 hybrids through the utilization of line × tester mating design. The parents and developed hybrids along with standard check (Pusa Hybrid 6) were evaluated in Randomized Complete Block Design) and Alpha lattice design, respectively,

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Cite as: *R., Tejaswini, Kavita Kandpal, Chikkalingaiah, T. S. Manjunatha Swamy, Mohan Kumar, T. L., Pooja Rajendra Dhange, Chandan Manjunath Gunaga, and Ashika, S. 2024. "Combining Ability and Heterosis for Yield and Yield Attributing Traits in Bitter Gourd". Journal of Advances in Biology & Biotechnology 27 (9):63-70. https://doi.org/10.9734/jabb/2024/v27i91274.*

for yield and yield attributing traits. The combining ability analysis revealed that among 14 parents, Pusa Rasdar, Pusa Do Mausami, Pusa Vishesh, Hirkani and Pant Karela 4 were identified as best general combiners for most of the studied yield and yield attributing traits. The estimates of heterosis revealed that the hybrids, Konkan Karali × Pant Karela 4 (45.45%), Konkan Tara × Pusa Do Mausami (23.48%), Pusa Rasdar × Phule Green Gold (126.87%) and Hirkani × Pusa Do Mausami (46.20%) were top performing hybrids over standard check for fruit length, diameter, average weight and number of fruits per vine, respectively. Similarly, Pusa Rasdar × Pant Karela 4 (127.06%), Priya × Pusa Do Mausami (101.05%), Punjab 14 × Pusa Do Mausami (100.53%) and Pusa Rasdar × Pant Karela 3 (97.61%) were top performing hybrids over standard check for yield per vine. These hybrids also recorded highest significant *sca* effects hence, considered as good specific combiners.

Keywords: Combining ability; gca; sca; heterosis; bitter gourd; yield.

1. INTRODUCTION

Bitter gourd (*Momordica charantia* L.) known by various names such as Balsam pear, bitter cucumber or bitter melon is a member of the cucurbitaceous vegetable family Cucurbitaceae. Bitter gourd is diploid having chromosome number 2n=2x=22 and has its origin in the Indo-Burma region. Bitter gourd is cultivated primarily for its bitter and tender fruits, which are renowned for their rich nutritional compositions, vitamin A and C [1].

The characteristic bitter taste of bitter melon is attributed to specific compounds, including the cucurbitacin-like alkaloid momordicine and triterpene glycosides such as momordicoside K and L [2,3]. Beyond its culinary appeal, bitter melon has garnered attention for its potential health benefits, particularly in managing diabetes. Studies have revealed the presence of a hypoglycemic compound named ‘charantin’ in bitter melon, suggesting its efficacy in regulating blood sugar levels [4].

The traditional approaches to parent selection in breeding programmes, based solely on individual performance, often fall short of achieving desirable outcomes [5]. Hence, it is imperative to consider the genetic architecture and combining ability of potential parent genotypes in addition to their inherent traits. Combining ability is the measure of a genotypes relative capacity to pass on its desirable traits to its offspring. The enhancement of yield and correlated traits in bitter gourd has been extensively recorded, with improvement achieved through heterosis breeding techniques [6]. Hybrids offer opportunities for improvement in productivity, quality, earliness, uniformity, wider adaptability and the rapid development of dominant genes for resistance to diseases and pests. The predominance of dominant gene action coupled with low heritability observed for most of yield traits indicating the importance of heterosis breeding for improvement of yield and yield attributing traits in bitter gourd [7]. Heterosis and combining ability studies are thus crucial for providing insights into crop improvement strategies [8]. Therefore, this research aims to explore the genetic mechanisms underlying yield and yield attributing traits in bitter gourd and develop superior varieties through line × tester mating designs contributing to sustainable agriculture and human health.

2. MATERIALS AND METHODS

The study on combining ability and heterosis in bitter gourd was conducted during *Rabi* 2022 and *Kharif* 2023 at the Department of Horticulture, University of Agricultural Sciences, Bangalore. Twelve genotypes were crossed in line × tester mating design [9] (Fig. 1) during *Rabi* 2022 to develop 49 F_1 hybrids. The important features of the parents along with their source of collection used in this study are presented in Table 1. All the parents with their respective hybrids and the check variety Pusa Hybrid 6, were planted during *Kharif* 2023 using a Randomized Complete Block Design (RCBD) for the parents and an Alpha Lattice design for the hybrids and check variety, with each treatment replicated three times, to assess the combining ability effects, magnitude and direction of heterosis among them. To prevent any interference between parents and their crosses, they were assessed separately in two distinct experimental designs. The observations were recorded for 17 parameters such as growth, flowering and yield traits and the data was collected from 5 randomly selected plants in each replication. The statistical analysis was done using Microsoft excel for RCBD, R studio for alpha lattice and Indostat version 9.1 for the combining ability analysis and heterosis.

Table 1. Details of parents taken for hybridization along with their salient features and source of collection

Code	Genotypes	Salient features	Source of collection
Lines			
L_1	Punjab 14	Plants are bushy and bear light green fruits with average weight of 35 g. Yield 14 t ha^{-1}.	NSC, New Delhi
L_2	Hirkani)	Fruits dark green, 15-20 cm long, spindle shaped with warts and prickles, yield t ha^{-1} in 160 days.	MPKV, Rahuri
L_3	Pusa Rasdar	Fruits juicy, smooth, non-prickled with tender skin, fleshy and dark green colour. Average fruit weight is 110 g with an average yield of 0.5 t/ 100 sqm in insect proof net-house.	IARI, New Delhi
L_4	Pusa Purvi	First small fruited variety, dark green colour fruits, small size (4-5 cm long and 3-4 diameter) and crispy flesh with high dry matter. Average yield is 8.78 t ha^{-1}.	IARI, New Delhi
L_5	Priya)	Extra long green spiny fruits with white tinge at stylar end, average fruit length 39 cm. Average fruit weight 235 g with a productivity of 24.5 t ha^{-1}.	KAU, Thrissur
L_6	Konkan Tara	Fruits green, prickly, medium long (15-16 cm) and spindle shaped.) Yield 24 t ha^{-1}.	KKV, Dapoli
L_7	Konkan Karali	Long attractive sharp prickled, dark shiny green colour fruits suitable for high rainfall areas with a yield of 16-18 t ha^{-1}.	KKV, Dapoli
Testers			
T_1	Pant Karela 3	Cylindrical dark green fruits with a length of 24 cm, suitable for plain and hilly areas with a yield of 15-16 t ha^{-1}.	GBPUAT, Pantnagar
T_2	Pant Karela 4	Dark green fruits with a length of 30-35 cm. Yield 12.5-15) t ha^{-1}.	GBPUAT, Pantnagar
T_3	CO 1	Dark green fruits with medium length (20-25 cm) and weight (100-120 g). Yield 14 t ha^{-1}.	TNAU, Coimbatore
T_4	Preethi	Medium sized white fruits with spines, average fruit length 30 cm, average fruit girth 24 cm, average fruit weight 0.31 kg with a productivity 15 t ha^{-1}.	KAU, Thrissur
T_5	Phule Green Gold	Fruits dark green, 25-30 cm long, prickled, tolerant to downy mildew, yield 23 t ha^{-1} in 160-180 days.	MPKV, Rahuri
T_6	Pusa Do Mausami	Fruits are dark green, club like shape with 7-8 continuous ribs.) Fruit weight is 100-120 g with a yield 12-15 t ha^{-1}.	IARI, New Delhi
T_7	Pusa Vishesh	Selection from a local collection and suitable for growing during summer.) Fruits are glossy green in colour, medium long and thick.	IARI, New Delhi

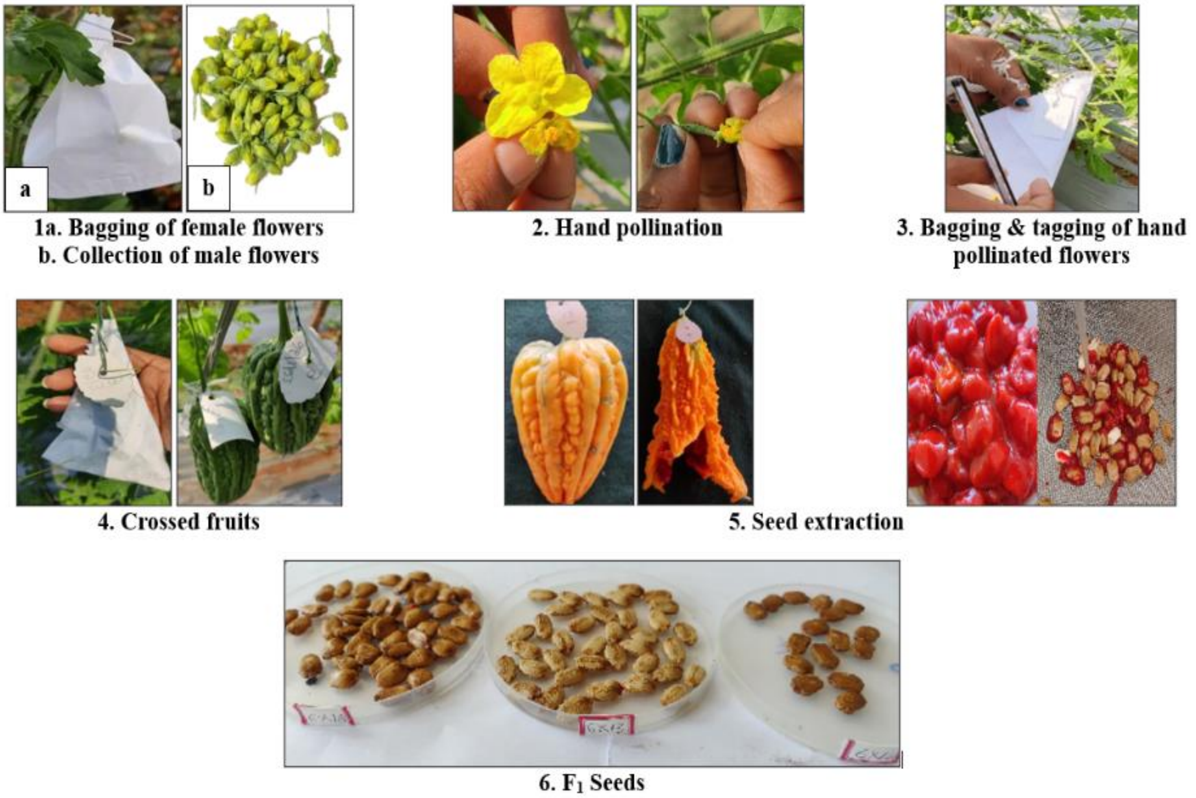

Fig. 1. Hybridization technique followed during the experiment

3. RESULTS AND DISCUSSION

Analysis of Variance and Gene Action: The analysis of variance performed for enhancing the quality of crop is contingent upon the availability of genetic diversity among the parents and their offspring for the desired characteristics. The ANOVA indicated that mean sum of squares of all the treatments were highly significant at p=0.001. Similarly, variance owing to lines, testers and crosses was substantial (P<0.05) for majority of the traits.) Results of the investigation revealed that all the characters studied exhibited higher sca variance indicating the preponderance of non-additive genes in control of the characters studied. The ratio of GCA/SCA variance was not found near to unity for any of the trait under study which showed the involvement of additive and non- additive gene action in their expression. The results are in harmony with earlier findings of Acharya et al*.* [10] in bitter gourd, Ene et al*.* [11] in cucumber and Napolitano et al. [12] in melons.

Combining Ability and Heterosis: The analysis of general combining ability effects among parental lines in bitter gourd reveals significant variations in estimates of GCA both among different parents for specific traits and within a parent across various traits (Table 2). For instance, among 17 traits, genotype L3 exhibited the maximum *gca* effects for 12 traits, followed by T7 for 11 traits, T6 and L5 for 9 traits each. The parent L2 displayed positive *gca* effects specifically for the number of fruits per vine and fruit yield per vine. Notably, L4 exhibited significant *gca* effects for the number of fruits per vine, with the smallest fruit size having the maximum negative *gca* effects on average fruit weight. These findings underscore the importance of specific parental lines in influencing reproductive development and yield-related characteristics in bitter gourd, providing valuable insights for breeding programs*.*

The top three best crosses, identified for their significant and desirable specific combining ability effects and heterosis over standard check, for all the yield and yield attributing traits are presented in Table 3. The results of the study unveil significant insights into the *sca* effects and heterosis in bitter gourd hybrids, particularly focusing on essential fruit-related traits. Among the 49 hybrid combinations assessed, notable findings emerged across various parameters. For instance, the hybrid L2 ×T6 displayed the minimum number of days for germination and

Table 2. General combining ability effects for yield and yield attributing parameters in bitter gourd

Parents	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
L1	-0.574 ***	4.939 ***	0.174 *	-0.891	-0.001	0.721 ***	1.476 ***	0.490 ***	-0.925 ***	0.742 ***	-3.172 ***	-3.915 ***	0.095	-0.057	6.974 **	-1.844 ***	0.006
L2	-0.815 ***	-1.587 ***	0.009	-1.129	0.261 *	0.912 ***	-0.143	1.395 ***	1.884 ***	-0.913 ***	0.533 ***	1.446 ***	-0.072	0.016	1.930	2.575 ***	0.257 ***
L3	0.512 ***	1.129 **	0.282 ***	20.680 ***	0.608 ***	-3.422 ***	-4.095 ***	-1.415 ***	-2.068 ***	-3.870 ***	-3.978 ***	-0.109	1.337 ***	0.486 ***	30.522 ***	0.429	0.674 ***
L4	-0.126	-4.060 ***	-0.449 ***	-19.463 ***	-0.725 ***	0.245	2.524 ***	0.156	2.837 ***	1.618 ***	2.699 ***	1.080 ***	-4.358 ***	-0.574 ***	-31.282 ***	4.387 ***	-0.451 ***
L5	0.679 ***	2.129 ***	0.336 ***	20.347 ***	-0.130	0.673 ***	-1.810 ***	0.347 **	-2.306 ***	-0.783 ***	0.960 ***	1.744 ***	0.799 *	0.058	1.246	-1.989 ***	-0.048
L6	-0.312 *	0.700	-0.417 ***	-18.415 ***	-0.225	-1.136 ***	0.714 ***	-0.891 ***	-0.163	1.224 ***	1.179 ***	-0.044	0.828 *	0.580 ***	-0.940	-2.564 ***	-0.204 ***
L7	0.636 ***	-3.250 ***	0.066	-1.129	0.213	2.007 ***	1.333 ***	-0.082	0.741 ***	1.982 ***	1.779 ***	-0.202	1.371 ***	-0.509 ***	-8.450 **	-0.996 **	-0.234 ***
T1	-0.293 *	10.178 ***	-0.271 ***	-9.510 ***	0.513 ***	1.054 ***	0.000	-1.177 ***	-1.259 ***	0.105	-1.232 ***	-1.337 ***	1.180 **	-0.163	-3.879 ***	-3.621 ***	-0.265 ***
T2	1.251 ***	7.178 ***	0.059	6.014 ***	0.118	-0.279	0.381 *	0.061	0.694 ***	1.679 ***	1.198 ***	-0.482 ***	3.466 ***	0.191 *	8.065 ***	-1.253 ***	0.123 **
T3	0.780 ***	5.748 ***	-0.163 *	-10.320 ***	-0.478 ***	0.007	-1.143 ***	-0.082	-2.401 ***	-2.250 ***	-0.992 ***	1.259 ***	-2.591 ***	-0.085	-7.666 ***	0.536	-0.125 **
T4	-0.752 ***	-6.253 ***	-0.461 ***	-23.224 ***	-0.178	-0.517 ***	1.619 ***	-0.415 **	0.884 ***	0.665 ***	0.026	-0.639 ***	-2.810 ***	-0.049	-3.581 ***	-0.771 *	-0.110 **
T5	-0.278 *	-7.774 ***	-0.104	-4.129 ***	0.427 ***	1.293 ***	2.190 ***	1.395 ***	1.408 ***	1.861 ***	0.610 ***	-1.250 ***	0.495	-0.026	6.759 ***	-1.649 ***	-0.042
T6	-0.653 ***	-6.347 ***	0.311 ***	17.776 ***	-0.082	-0.136	-1.286 ***	0.823 ***	0.170	0.047	1.196 ***	1.149 ***	2.552 ***	0.075	-3.052 ***	5.386 ***	0.329 ***
T7	-0.055	-2.730 ***	0.628 ***	23.395 ***	-0.320 *	-1.422 ***	-1.762 ***	-0.605 ***	0.503 **	-2.108 ***	-0.805 ***	1.302 ***	-2.291 ***	0.056	3.355 ***	1.371 ***	0.090 *
S.Em ±	0.12	0.41	0.07	1.03	0.13	0.14	0.16	0.12	0.19	0.13	0.12	0.10	0.36	0.09	0.71	0.36	0.04
C.D @ 5%	0.25	0.81	0.15	2.03	0.25	0.28	0.33	0.25	0.38	0.26	0.24	0.20	0.71	0.18	1.42	0.72	0.08
C.D @ 1%	0.33	1.07	0.19	2.69	0.33	0.37	0.43	0.33	0.50	0.34	0.32	0.27	0.94	0.24	1.88	0.95	0.10

Significance at P = 0.05, ** Significance at P = 0.01, * Significance at P = 0.001*

1. Days taken for germination (No.) 2. Germination percentage 3. Vine length 90 DAS (m) 4. Number of leaves per vine (90 DAS) 5. Internodal length (cm) 6. Days to first male flower appearance 7. Days to first female flower appearance 8. Node of first male flower appearance 9. Node of first female flower appearance 10. Days to first harvest of fruits 11. Days to final harvest of fruits 12. Fruiting period (days) 13. Fruit length (cm) 14. Fruit diameter (cm) 15. Average fruit weight (g) 16. Number of fruits per vine 17. Fruit yield per vine (kg) exhibited the highest negative standard heterosis. Conversely, hybrids like L4 × T7 showcased maximum positive *sca* effects for germination percentage while L4 × T3 demonstrated the highest heterosis over the standard check. In terms of fruit morphology, significant *sca* effects and heterosis were observed for traits such as fruit length, diameter and average fruit weight. Hybrids such as L7 × T2 exhibited the highest positive *sca* effects for fruit length, while L7 × T6 displayed the highest negative *sca* effects. Moreover, maximum standard heterosis was observed in the cross L7 × T2, indicating its potential for enhancing fruit length significantly. Similar trends were observed for fruit diameter with hybrids showing contrasting *sca* effects and heterosis values. Notably, hybrids like L6 × T4 displayed the highest positive *sca* effects for average fruit weight whereas, L3 × T4 showcased the highest negative *sca* effects. Furthermore, the study revealed significant findings concerning yield-related traits, particularly yield per vine. Hybrids such as L5 × T6 exhibited substantial *sca* effects for yield per vine, followed by L6 × T4 and L1 × T6. These hybrids demonstrated considerable heterosis over the standard check, highlighting their potential for yield enhancement. The total yield per vine primarily relies on the number of fruits per vine and the average fruit weight. The quantity of fruits per vine is influenced by factors such as the size of the fruit, including its

Table 3. List of top three Parents with *gca* effects, F_1 hybrids with their *sca* effects and standard heterosis for yield and yield attributing traits

Traits	Parents	*gca* effects	F_1 hybrids	*sca* effects	F_1 hybrids	Standard Check (%)
Number of days taken for germination	L2	-0.815	L5 × T4	-0.934	L2 × T4	-34.47
	T4	-0.752	L7 × T3	-0.923	L2 × T5	-34.47
	T6	-0.653	L3 × T1	-0.726	L2 × T7	-34.47
Germination percentage	T1	10.178	L4 × T7	33.826	L4 × T3	21.58
	T2	7.178	L1 × T6	27.445	L4 × T7	21.58
	T3	5.748	L4 × T3	25.349	L5 × T1	21.58
Vine length at 90 DAS (m)	T7	0.628	L3 × T5	1.131	L3 × T7	63.97
	L5	0.336	L6 × T6	1.089	L5 × T6	58.36
	T6	0.311	L7 × T3	0.840	L3 × T5	57.11
Number of leaves at 90 DAS	T7	23.395	L3 × T5	59.891	L3 × T7	26.72
	L3	20.680	L7 × T3	52.224	L3 × T5	26.62
	L5	20.347	L7 × T2	51.224	L5 × T6	25.13
Internodal length (cm)	L4	-0.725	L5 × T5	-2.284	L4 × T3	-33.33
	T3	-0.478	L7 × T1	-1.980	L5 × T5	-28.07
	T7	-0.320	L1 × T7	-1.499	L1 × T7	-26.32
Days to first male flower	L3	-3.422	L2 × T2	-4.483	L3 × T1	-14.53
	T7	-1.422	L6 × T6	-3.912	L3 × T7	-14.53
	L6	-1.136	L7 × T7	-3.769	L6 × T6	-14.53
Days to first female flower	L3	-4.095	L3 × T5	-7.905	L3 × T5	-26.98
	L5	-1.810	L7 × T3	-7.000	L5 × T6	-25.40
	L6	-1.762	L2 × T2	-6.381	L3 × T1	-20.63
Node of first male flower	T1	-1.177	L5 × T6	-2.537	L7 × T1	-22.22
	L3	-1.415	L1 × T3	-2.442	L3 × T3	-16.67
	L6	-0.891	L6 × T5	-2.204		
Node of first female flower	T3	-2.401	L4 × T6	-5.075	L3 × T2	-55.56
	L5	-2.306	L3 × T2	-4.027	L7 × T3	-55.56
	L3	-2.068	L4 × T1	-3.980	L3 × T1	-50.00
Days to first harvest of fruits	L3	-3.870	L7 × T3	-6.771	L3 × T1	-21.42
	T3	-2.250	L2 × T2	-5.809	L7 × T3	-18.48
	T7	-2.108	L4 × T4	-5.306	L1 × T7	-17.02
Days to last harvest of fruits	L4	2.699	L1 × T3	6.794	L5 × T2	13.44
	T2	1.198	L3 × T6	6.201	L7 × T4	12.52
	T6	1.196	L5 × T2	5.261	L4 × T3	11.60
Fruiting period (days)	L5	1.744	L4 × T3	8.919	L4 × T3	46.95
	L2	1.446	L7 × T7	2.781	L2 × T7	34.39
	T7	1.302	L7 × T1	2.657	L2 × T6	33.28
Fruit length (cm)	T2	3.466	L7 × T2	5.591	L7 × T2	45.45
	T6	2.552	L5 × T1	4.448	L6 × T6	24.18
	L7	1.371	L2 × T4	3.344	L5 × T1	23.64
Fruit diameter (cm)	L6	0.580	L7 × T7	1.408	L6 × T6	18.95
	L3	0.486	L4 × T2	0.949	L3 × T7	23.48
	T2	0.191	L5 × T5	0.904	L7 × T7	21.80
Average fruit weight (gm)	L3	30.522	L6 × T4	42.528	L3 × T5	126.87
	T2	8.065	L5 × T6	36.814	L3 × T7	99.02
	L1	6.974	L3 × T5	32.527	L3 × T2	88.60
Number of fruits vine^{-1}	L2	2.575	L2 × T5	6.430	L2 × T6	46.20
	L4	4.387	L7 × T3	6.316	L4 × T5	43.28
	T6	5.386	L3 × T1	6.251	L2 × T5	35.25
Yield vine^{-1} (kg)	L3	0.674	L5 × T6	0.861	L3 × T2	127.06
	T6	0.329	L6 × T4	0.804	L5 × T6	101.59
	L2	0.257	L1 × T6	0.795	L1 × T6	100.53

length and girth.) Similar findings are reported by Hossain et al. [13], Talekar et al. [14], Singh et al. [15], Singh et al. [16] and Panda [17] in bitter gourd. Overall, these findings shed light on the genetic mechanisms underlying fruit-related traits in bitter gourd hybrids and provide promising avenues for breeding programs aimed at improving yield and yield attributing traits.

4. CONCLUSION

Among the parents, L3, T6, T7 and L2 exhibited significant *gca* effects for yield and yield attributing traits. The hybrids that exhibited substantial heterosis involved one of these parents, demonstrating high heterosis for yield and yield contributing characters. Therefore, selecting these genotypes as parents for developing hybrids could be an effective strategy for exploiting heterosis in fruit yield per vine. In such a scenario, heterosis breeding would be a rewarding approach for crop improvement in bitter gourd. Based on the overall performance, significant *sca* effects and desirable heterosis, the top high-yielding crosses identified are L3 × T2, L5 × T6, L1 × T6, L3 × T1 and L3 × T7. These crosses exhibited potential for commercial exploitation of hybrid vigour in terms of fruit yield per plant. This comprehensive evaluation shall provide valuable insights into the stability and adaptability of these high-yielding hybrid combinations, ultimately contributing to the advancement of bitter gourd cultivation practices and the improvement of crop productivity in agricultural environment.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Gopalan C, Rama Sastri B V, Balasubramanian S C. Nutritive value of Indian foods. National Institute of Nutrition, IGMR Hyderabad; 1971.
2. Jeffrey C. A review of the cucurbitaceae. Botanical Journal of the Linnean Society. 1980;81(3):233-247.
3. Okabe H, Miyahara Y, Yamauchi T. Studies on the constituents of Momordica charantia L. IV. Characterization of the new cucurbitacin glycosides of the immature fruits. (2) Structures of the bitter glycosides, momordicosides K and L. Chemical and Pharmaceutical Bulletin. 1982;30(12):4334-4340.
4. Yeh G Y, Eisenberg D M, Kaptchuk T J, Phillips R S. Systematic review of herbs and dietary supplements for glycemic control in diabetes. Diabetes Care. 2003;26(4):1277-1294.
5. Allard R W. Principles of Plant Breeding. John Wiley and Sons, New York. 1960;485.
6. Sekar S, Sathish S, Parthiban K T, Rangasamy S R. Heterosis for yield and its component characters in bitter gourd (*Momordica charantia* L.). Electronic Journal of Plant Breeding. 2014;5(2):351-357.
7. Rani KR, Raju CS, Reddy KR. A study on heterosis for yield and earliness in bitter gourd. Ind. J. Sci. Res. Technol. 2014; 2(3):89-97.
8. Hallauer A R, Miranda J B. Quantitative genetics in maize breeding, pp.124-126. Iowa State University Press; 1981.
9. Kempthorne O. An Introduction to Genetic Statistics, pp.545. John Wiley and Sons, New York; 1957.
10. Acharya S K, Kaushik R A, Ameta K D, Dubey R B, Upadhya B. Heterosis and combining ability in bitter gourd (*Momordica charantia* L.). International Journal of Bioassays. 2019;8(1):5692-5711.
11. Ene CO, Ogbonna PE, Agbo CU, Chukwudi UP. Heterosis and combining ability in cucumber (*Cucumis sativus* L.). Information Processing in Agriculture. 2019;6(19):150-157.
12. Napolitano M, Terzaroli N, Kashyap S, Russi L, Evans E, Albertini E. Exploring heterosis in melon (*Cucumis melo* L.). Plants. 2020;9:282-298.
13. Hossain Al-Mamun M, Harunur Rashid M, Nazim Uddin M, Rabiul Islam M, Asaduzzaman M. Heterosis studies in bitter gourd. International Journal of Vegetable Science. 2016;22(5): 442-450.

14. Talekar N S, Vaddoria M A, Kalkaran G V. Heterosis studies for quantitative traits in bitter gourd (*Momordica charantia* L.). Progressive Research. 2013;8:650-653.
15. Singh A K, Pan R S, Bhavana P. Heterosis and combining ability analysis in bitter gourd (*Momordica charantia* L.). The Bioscan. 2013;8(4):1533-1536.
16. Singh SK, Singh B, Kumar U, Rai M. Heterosis analysis in bitter gourd through Line x Tester design. Vegetable Science. 2007;34(1):95.
17. Panda A, Singh DK, Bairagi SK. Study of combining ability for the production of bitter gourd hybrids. Progressive Horticulture. 2008;40(1):33-37.

Peer-review history:
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