Original Research Article

COMBINING ABILITY AND HETEROSIS FOR YIELD AND YIELD ATTRIBUTING TRAITS IN BITTER GOURD (*Momordica charantia* L.)

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 RCBD and Alpha lattice design, respectively for yield and yield attributing traits. The combining ability analysis revealed that among 14 parents, PusaRasdar, Pusa Do Mausami, PusaVishesh, Hirkani and Pant Karela 4 were identified as best general combiners for most of the studied traits. The estimates of heterosis revealed that the hybrids, Konkan Karali × Pant Karela 4 (45.45 %), Konkan Tara × Pusa Do Mausami (23.48 %), PusaRasdar × 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, PusaRasdar × Pant Karela 4 (127.06 %), Priya × Pusa Do Mausami (101.05 %), Punjab 14 × Pusa Do Mausami (100.53 %) and PusaRasdar × 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.

Comment [EC1]: There is for further reflection and improvement to make abstract comprehensive

Key words: Combining ability; gca; sca; Heterosis; Bitter gourd; yield

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. The genus *Momordica* encompasses several other species including *M. balsamina*, *M. cochinchinesis, M. dioca, M. denudate, M. macrocarpa, M. subangulata and M. tuberosa*. 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 (Gopalan et al., 1993).

Comment [EC2]: Prove citation to these sentences

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 (Jeffrey, 1980; Okabe *et al*., 1982). 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 (Yeh *et al*., 2003).

The traditional approaches to parent selection in breeding programmes, based solely on individual performance, often fall short of achieving desirable outcomes (Allard, 1960). 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 (Sekar *et al*., 2014). 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. Heterosis and combining ability studies are thus crucial for providing insights into crop improvement strategies (Hallauer and Miranda, 1981). 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.

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. 49 F_1 hybrids were developed by crossing 7 lines [Punjab 14 (L1), Hirkani (L2), PusaRasdar (L3), PusaPurvi (L4), Priya (L5), Konkan Tara (L6), and Konkan Karali (L7)] and 7 testers [Pant Karela 3 (T1), Pant Karela 4 (T2), CO 1 (T3), Preethi (T4), Phule Green Gold (T5), Pusa Do Mausami (T6), and PusaVishesh (T7)] in line × tester mating design (Kempthorne,

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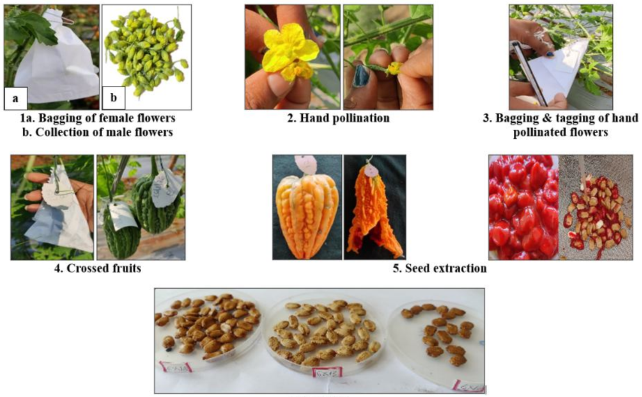
1957) (Fig 1) during *Rabi* 2022. All the parents with their respective hybrids and the check variety Pusa Hybrid 6, were planted during *Kharif* 2023 using a randomized complete block design (RCBD) for the parents and an Alpha lattice design for the hybrids and check variety, with each treatment replicated 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.



1a. Bagging of female flowers
b. Collection of male flowers

2. Hand pollination

3. Bagging & tagging of hand pollinated flowers

4. Crossed fruits

5. Seed extraction

6. F_1 Seeds

Fig 1: Hybridization technique followed during the experiment

RESULTS AND DISCUSSION

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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.* (2019) in bitter gourd, Ene*et al.* (2019) in cucumber and Napolitano *et al*. (2020) 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 (-31.282 ***). 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 1. 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 exhibited the highest negative standard heterosis. Conversely, hybrids like L4 × T7 showcased maximum positive scaeffects 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 length and girth. Similar findings are reported by Hossain *et al.* (2016), Talekar*et al.* (2013), Singh *et al.* (2013), Singh *et al.* (2007) and Panda (2001) 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.

Table 1: 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 T4 T6	-0.815 -0.752 -0.653	L5 × T4 L7 × T3 L3 × T1	-0.934 -0.923 -0.726	L2 × T4 L2 × T5 L2 × T7	-34.47 -34.47 -34.47
Germination percentage	T1 T2 T3	10.178 7.178 5.748	L4 × T7 L1 × T6 L4 × T3	33.826 27.445 25.349	L4 × T3 L4 × T7 L5 × T1	21.58 21.58 21.58
Vinelength at 90 DAS (m)	T7 L5 T6	0.628 0.336 0.311	L3 × T5 L6 × T6 L7 × T3	1.131 1.089 0.840	L3 × T7 L5 × T6 L3 × T5	63.97 58.36 57.11
Number of leaves at 90 DAS	T7 L3 L5	23.395 20.680 20.347	L3 × T5 L7 × T3 L7 × T2	59.891 52.224 51.224	L3 × T7 L3 × T5 L5 × T6	26.72 26.62 25.13
Internodal length (cm)	L4 T3 T7	-0.725 -0.478 -0.320	L5 × T5 L7 × T1 L1 × T7	-2.284 -1.980 -1.499	L4 × T3 L5 × T5 L1 × T7	-33.33 -28.07 -26.32
Days to first male flower	L3 T7 L6	-3.422 -1.422 -1.136	L2 × T2 L6 × T6 L7 × T7	-4.483 -3.912 -3.769	L3 × T1 L3 × T7 L6 × T6	-14.53 -14.53 -14.53
Days to first female flower	L3 L5 L6	-4.095 -1.810 -1.762	L3 × T5 L7 × T3 L2 × T2	-7.905 -7.000 -6.381	L3 × T5 L5 × T6 L3 × T1	-26.98 -25.40 -20.63
Node of first male flower	T1 L3 L6	-1.177 -1.415 -0.891	L5 × T6 L1 × T3 L6 × T5	-2.537 -2.442 -2.204	L7 × T1 L3 × T3	-22.22 -16.67
Node of first female flower	T3 L5 L3	-2.401 -2.306 -2.068	L4 × T6 L3 × T2 L4 × T1	-5.075 -4.027 -3.980	L3 × T2 L7 × T3 L3 × T1	-55.56 -55.56 -50.00
Days to first harvest of fruits	L3 T3 T7	-3.870 -2.250 -2.108	L7 × T3 L2 × T2 L4 × T4	-6.771 -5.809 -5.306	L3 × T1 L7 × T3 L1 × T7	-21.42 -18.48 -17.02
Days to last harvest of fruits	L4 T2 T6	2.699 1.198 1.196	L1 × T3 L3 × T6 L5 × T2	6.794 6.201 5.261	L5 × T2 L7 × T4 L4 × T3	13.44 12.52 11.60
Fruiting period (days)	L5 L2 T7	1.744 1.446 1.302	L4 × T3 L7 × T7 L7 × T1	8.919 2.781 2.657	L4 × T3 L2 × T7 L2 × T6	46.95 34.39 33.28
Fruit length (cm)	T2	3.466	L7 × T2	5.591	L7 × T2	45.45

	T6 L7	2.552 1.371	L5 × T1 L2 × T4	4.448 3.344	L6 × T6 L5 × T1	24.18 23.64
Fruit diameter (cm)	L6 L3 T2	0.580 0.486 0.191	L7 × T7 L4 × T2 L5 × T5	1.408 0.949 0.904	L6 × T6 L3 × T7 L7 × T7	18.95 23.48 21.80
Average fruit weight (gm)	L3 T2 L1	30.522 8.065 6.974	L6 × T4 L5 × T6 L3 × T5	42.528 36.814 32.527	L3 × T5 L3 × T7 L3 × T2	126.87 99.02 88.60
Number of fruits vine^{-1}	L2 L4 T6	2.575 4.387 5.386	L2 × T5 L7 × T3 L3 × T1	6.430 6.316 6.251	L2 × T6 L4 × T5 L2 × T5	46.20 43.28 35.25
Yield vine^{-1} (kg)	L3 T6 L2	0.674 0.329 0.257	L5 × T6 L6 × T4 L1 × T6	0.861 0.804 0.795	L3 × T2 L5 × T6 L1 × T6	127.06 101.59 100.53

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.

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