Plant Archives Vol. 24, No. 2, 2024 pp. 1251-1256 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2024.v24.no.2.176

ASSESSMENT OF GENERAL COMBINING ABILITY EFFECTS IN BITTER GOURD (*MOMORDICA CHARANTIA* L.) FOR ENHANCING HYBRID BREEDING EFFICIENCY

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(Date of Receiving-11-04-2024; Date of Acceptance-14-06-2024)

ABSTRACT

The study investigates the General Combining Ability (GCA) effects of six parental lines of bitter gourd (*Momordica charantia* L.) BG-1, BG-2, BG-6, BG-7, BG-8 and BG-15 to identify their potential for hybrid breeding programs. Bitter gourd, a widely cultivated crop in the Cucurbitaceae family, exhibits significant variability in fruit traits and regional preferences across India. The research, conducted at the Crop Research Centre -3, School of Agriculture, ITM University, Gwalior, followed a randomized complete block design (RCBD) with three replications. Data were collected on key agronomic and morphological traits, including flowering time, vine characteristics, fruit morphology, and yield components.

GCA effects were estimated using Griffing's method 2, model 1 (fixed model) for diallel analysis. Results indicated that BG-7 exhibited consistently positive GCA effects for several yield-related traits, such as the number of fruits per vine, fruit weight and marketable yield per hectare, making it a superior parent for hybrid breeding. Conversely, BG-1 showed negative GCA effects for traits like vine length and number of fruits per vine, which might be advantageous for specific breeding goals such as early maturity and compact plant structure.

The findings underscore the importance of GCA in selecting parental lines for developing high-yielding hybrids. Parental lines with positive GCA effects for key traits can enhance hybrid performance, contributing to improved productivity and quality in bitter gourd cultivation. These insights are crucial for optimizing breeding strategies and achieving sustainable agricultural practices.

Key words : Bitter gourd, *Momordica charantia*, Mean performance, Combining ability, GCA effect.

Introduction

Bitter gourd (*Momordica charantia* L.) is a delicate, edible fruit belonging to the Momordica genus, a group of climbing vines in the Cucurbitaceae family. The Momordica genus comprises approximately 80 species, with *Momordica charantia* L. being the most widely cultivated. This species has a chromosome number of 2n = 22. Momordica is a Latin word meaning –to bite pertaining to the toothed leaf margin (Taylor, 2002).

In India, bitter gourd exhibits a significant range of variability in terms of both quantitative and qualitative traits. This vegetable, when cultivated across various tropical regions, demonstrates considerable differences in fruit color, seed color and fruit size (Behera *et al*, 2008a). Consequently, regional preferences for bitter gourd vary significantly (Dey *et al*., 2010). For instance, in North India, dark green fruits that are long (ranging from 15 to 40 cm) are favored. Conversely, in South India, white fruits and those that are medium-long (12 to 20 cm) are more popular. In East India, however, people tend to prefer short, green-fruited varieties, such as the Muricata type. These diverse regional preferences, combined with the nutritional benefits of bitter gourd, drive the need for the development of new varieties through various breeding methods.

Bitter gourd is a crop that undergoes extensive cross-pollination and is monoecious in nature, which accounts large variability. Yield potential of bitter gourd needs to be improved and heterosis breeding is one among the best way for augmenting yield and quality of bitter gourd. Heterosis breeding is useful for improvement of yield and other economic traits. F_1 hybrids offer numerous benefits, including early maturity, high yield, enhanced postharvest quality, uniformity, greater adaptability and resistance to diseases and pests (Riggs, 1988). Given that bitter gourd is monoecious, it can be effectively utilized to produce F_1 hybrid seeds at a lower cost. Each successful cross produces a substantial number of hybrid seeds, enhancing cost-effectiveness. Additionally, the crop's wide spacing reduces the number of seeds needed per hectare, making it economically viable for commercial farming. Consequently, bitter gourd presents a promising opportunity for harnessing hybrid vigor at a commercial scale, significantly boosting both productivity and production.

Understanding the importance of general combining ability (GCA) and specific combining ability (SCA) for quantitative traits influencing yield and its components is crucial when selecting parents to produce superior hybrids. GCA effects aid in identifying superior parents, while SCA effects assist in choosing superior hybrids (Singh and Narayanan, 1993). These insights are instrumental in assessing the extent of heterosis in F_1 hybrids. Heterosis and combining ability shed light on the type of gene action involved, thereby guiding the selection of appropriate breeding methods and parameters for crop improvement.

Materials and Methods

The study was conducted to evaluate the General Combining Ability (GCA) effects of six parental lines of Bitter Gourd (*Momordica charantia* L.), designated as BG-1, BG-2, BG-6, BG-7, BG-8 and BG-15. These lines were selected based on their diverse phenotypic traits and potential for hybrid breeding programs.

Field experiment and management

The experiment was conducted at Crop Research Centre -3, School of Agriculture, ITM University, Gwalior, M.P., India. The research farm is situated at 26° 13' North latitude and 76° 14' East longitude with an altitude of 211.52 meters above Mean Sea Level. The field of research farm having homogenous fertility and uniform textural make-up was selected for the field experimentation.

Technical Programme

Design	-	RBD
Replications	-	03
Treatments	-	6
Net plot Size	-	19 m × 10 m
Spacing	-	90cm × 40cm

Season of Sowing: Summer

Layout of the Experimental Design

The design of the experiment was randomized block design (RBD) and there were three replications. Seeds were sown on hills of the channels and spacing of 90cm between rows and 40 cm between plants was maintained. The three plants were randomly selected for recording the observations. All the recommended packages of practices were followed to raise the crop.

Data collection

Data were collected on various agronomic and morphological traits that are critical for hybrid breeding programs. The traits evaluated included:

Flowering Traits: Days to first flowering and days to 50% flowering.

Vine Characteristics: Vine length, number of primary branches, and internode length.

Fruit Morphology: Fruit length, fruit diameter, and fruit weight.

Yield Components: Number of fruits per plant and total fruit yield per plant.

Each trait was measured according to standard procedures at appropriate growth stages.

Statistical analysis

The GCA effects were estimated using Griffing's method 2, model 1 (fixed model) for diallel analysis. The statistical model for GCA effects is represented as:

$$Y_{ij} = \mu + g_i + g_j + s_{ij} + e_{ij}$$

where, Y_{ij} is the observed value of the cross between the i-th and j-th parent, μ is the overall mean, g_i and g_j are the GCA effects of the i-th and j-th parent, s_{ij} is the specific combining ability (SCA) effect and e_{ij} is the experimental error.

Data analysis was performed using the statistical software [Datapine], which provided estimates of GCA effects for each parent across the various traits. The significance of GCA effects was tested using analysis of variance (ANOVA), and means were compared using the least significant difference (LSD) test at the 0.05 probability level.

This analysis enabled the identification of parental lines with superior GCA effects, indicating their potential to contribute beneficial traits to their progeny in hybrid combinations.

Results and Discussion

Detailed analysis of General Combining Ability (GCA) effects in parental lines

The analysis of the General Combining Ability (GCA) effects is crucial in understanding the genetic potential of parental lines in hybrid breeding programs. GCA effects highlight the average performance of parents and their ability to pass on beneficial traits to their progeny. This analysis examines various traits, including those related to flowering, vine characteristics, fruit morphology and yield components, in six parental lines (BG-1, BG-2, BG-6, BG-7, BG-8 and BG-15). The data is outlined in the Table 1.

Number of Nodes for First male flower

In terms of the number of nodes for the first male flower, BG-1 exhibits a significantly negative GCA effect (-1.773), indicating it promotes early male flowering by reducing the number of nodes required for the first male flower to appear. This early flowering trait is advantageous in synchronizing flowering time and ensuring a shorter crop cycle. Conversely, BG-7 shows a positive GCA effect (+1.803), suggesting it contributes to a higher number of nodes for the first male flower, potentially leading to delayed flowering. This trait can be valuable in breeding programs aiming for staggered flowering and extended harvesting periods.

Number of Nodes for First Female flower

For the number of nodes for the first female flower, BG-1 again shows a strong negative GCA effect (-2.693), suggesting early female flowering. Early female flowering is critical for enhancing fruit set and ensuring timely harvests. In contrast, BG-7 displays a positive GCA effect (+1.984), indicating later development of female flowers. This delay might be useful in breeding programs that require a prolonged flowering phase for continuous fruit production.

Days to First Male flower anthesis

When examining the days to the first male flower anthesis, BG-1 has a notable negative GCA effect (-2.767), indicating a reduction in the number of days to reach anthesis. Early anthesis is often associated with early maturing varieties, which are beneficial in regions with short growing seasons or in multiple cropping systems. BG-7, with a positive GCA effect (+0.720), suggests a longer period to reach anthesis, which might be useful for extending the flowering period and ensuring a longer harvest window.

Days to First Female flower Anthesis

In terms of days to first female flower anthesis, BG-1 continues to show a negative GCA effect (-0.623), promoting earlier female flower anthesis. Early female anthesis is crucial for synchronizing fruit sets and maximizing yield potential. On the other hand, BG-8, with a positive GCA effect (+0.387), indicates later female anthesis, which can be advantageous for breeding programs that aim to extend the fruiting period and ensure a steady supply of fruits over time.

Days to 50% flowering

Regarding the days to 50% flowering, BG-1 demonstrates a significant negative GCA effect (-2.020), indicating it accelerates the flowering process, leading to earlier 50% flowering. Early flowering is advantageous for early-season varieties and can help in avoiding biotic and abiotic stresses that occur later in the season. BG-7, with a positive GCA effect (+1.156), suggests it delays the attainment of 50% flowering, which can be beneficial in breeding programs aiming for extended flowering periods.

Internodal length

In terms of internodal length, BG-1 shows a negative GCA effect (-0.327), indicating it contributes to shorter internodes. Shorter internodes can result in more compact plant architecture, which is advantageous in high-density planting systems and controlled environments. Conversely, BG-7 exhibits a positive GCA effect (+0.688), suggesting longer internodes, which could be beneficial for climbing varieties or those that require more spacing.

Number of primary branches per vine

For the number of primary branches per vine, BG-7 shows a positive GCA effect (+1.552), indicating it promotes the development of more branches, leading to a bushier plant structure. A higher number of branches can enhance the plant's ability to bear more fruits, thereby increasing yield potential. In contrast, BG-1 has a negative GCA effect (-0.679), suggesting it contributes to fewer branches, which might be beneficial for single-stem cultivation methods where space and resources are limited.

Vine length

Examining vine length, BG-1 exhibits a highly negative GCA effect (-29.219), indicating it promotes shorter vine length. Shorter vines are beneficial for controlled growth environments and can reduce the need for extensive staking or trellising. BG-7, with a positive GCA effect (+25.460), indicates it contributes to longer vines, which could be advantageous in sprawling cultivation systems where longer vines can maximize ground coverage and fruit production.

Number of fruits per vine

In terms of the number of fruits per vine, BG-7 shows a significant positive GCA effect (+3.334), indicating it enhances the number of fruits produced per vine. This trait is crucial for increasing overall yield and improving the efficiency of fruit production. In contrast, BG-1 has a negative GCA effect (-3.050), suggesting it contributes to fewer fruits per vine, which might be balanced by other favourable traits such as fruit size or quality.

Fruit length

Regarding fruit length, BG-7 exhibits a positive GCA effect (+1.722), indicating it contributes to longer fruits. Longer fruits are often preferred in markets where size is a key quality attribute. BG-1, with a negative GCA effect (-0.481), suggests a shorter fruit length, which might be desirable in markets that prefer compact fruits.

Fruit diameter

For fruit diameter, BG-7 again shows a positive GCA effect (+0.481), indicating it enhances fruit diameter, leading to larger fruits. Larger fruits are often associated with higher market value and consumer preference. Conversely, BG-6 exhibits a negative GCA effect (-0.908), suggesting it contributes to smaller-diameter fruits, which might be suitable for specific niche markets.

Fruit weight

In terms of fruit weight, BG-7 shows a significant positive GCA effect (+11.940), indicating it promotes heavier fruits. Heavier fruits can translate to higher yield per vine and improved marketability. BG-15, with a negative GCA effect (-5.579), suggests lighter fruits, which might be preferred in markets that favour smaller, snack-sized fruits.

Fruit yield per vine

Regarding fruit yield per vine, BG-7 shows a highly positive GCA effect (+185.818), indicating it significantly enhances the overall yield per vine. High yield per vine is a critical trait for maximizing productivity and profitability in commercial cultivation. BG-1, with a negative GCA effect (-74.630), suggests lower yields, which might be balanced by other desirable traits such as early maturity or fruit quality.

Number of seeds per fruit

For the number of seeds per fruit, BG-7 has a positive GCA effect (+2.975), indicating it promotes a higher seed count per fruit. A higher seed count can be beneficial for seed production programs. BG-8, with a negative GCA effect (-1.286), suggests fewer seeds per fruit, which might be desirable in markets that prefer seedless or low-seed varieties.

Yield of Marketable produce per hectare

In terms of yield of marketable produce per hectare, BG-7 shows a highly positive GCA effect (+29.990), indicating it significantly enhances marketable yield per hectare. High marketable yield is essential for ensuring the economic viability of crop production. BG-15, with a negative GCA effect (-9.705), suggests lower marketable yield, which might be offset by other traits such as disease resistance or stress tolerance.

Eliminating undesirable genotypes is crucial in any crop breeding program. The analysis of GCA effects provides invaluable insights into the genetic potential of parental lines in hybrid breeding programs. Parental lines like BG-7, which exhibit consistently positive GCA effects for key yield components and fruit characteristics, are prime candidates for hybrid breeding. The positive GCA effects in BG-7 suggest it possesses favourable alleles that enhance productivity traits, making it a superior parent for developing high-yielding hybrids. The genetic control of these traits is often polygenic, meaning multiple genes influence these characteristics. Significant GCA effects for these characters were also recorded by Karuppaiah *et al*. (2002), Panday *et al*. (2005), Tiwari *et al*. (2009), Verma and Singh (2014) as well as Suhanshu Mishra *et al*. (2019) as they confirmed that positive GCA effects play a major role in yield and yield attributing characters.

Understanding the GCA effects allows breeders to make informed decisions on parent selection to combine the best traits in their breeding programs. For example, the integration of molecular breeding techniques, such as marker-assisted selection (MAS), can further enhance the efficiency of breeding programs. By identifying genetic markers associated with favourable GCA effects, breeders can select parents with greater precision, accelerating the development of high-performing hybrids. This approach not only improves yield and quality traits but also enhances the adaptability and resilience of new cultivars to various environmental conditions, contributing to sustainable agricultural practices

Summary and Conclusion

The study aimed to evaluate the General Combining Ability (GCA) effects of six parental lines of bitter gourd (*Momordica charantia* L.), specifically designated as BG-1, BG-2, BG-6, BG-7, BG-8 and BG-15. The primary objective was to identify parental lines with superior genetic potential for use in hybrid breeding programs.

Table 1 : Analysis of General Combining Ability (GCA) effects in Parental Lines.

Parents	No. of node for 1st male flower	No. of node for 1st female flower	Days to 1st male flower anthesis	Days to 1st female flower anthesis	Days to 50 % flowering	Inter-nodal length (cm)	No. of primary branches per vines	Vine length (cm)	No. of fruits per vine	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Fruit yield per vine (g)	No. of seeds per fruit	Yield of market-able (q/ha)
BG-1	-1.77	-2.69	-2.77	-0.62	-2.02	-0.33	-0.68	-29.22	-3.05	-0.48	-0.21	-2.05	-74.63	-0.40	-4.19
BG-2	0.35	1.28	-0.24	-0.25	1.08	0.04	0.19	7.07	0.81	0.70	0.17	1.58	-12.01	0.55	5.96
BG-6	0.08	-0.75	-0.23	-0.04	-0.07	-0.11	-0.07	-4.49	1.36	-0.91	-0.16	-4.76	-38.35	-0.88	-8.69
BG-7	1.80	1.98	0.72	0.68	1.16	0.69	1.55	25.46	3.33	1.72	0.48	11.94	185.82	2.98	29.99
BG-8	-0.81	0.13	1.29	0.39	0.29	-0.05	-0.24	8.16	-1.31	-0.55	-0.10	-1.14	30.70	-1.29	-13.36
BG-15	0.35	0.06	1.23	-0.15	-0.44	-0.24	-0.75	-6.98	-1.14	-0.48	-0.17	-5.58	-91.53	-0.96	-9.70
CD 5%	1.12	1.46	0.27	0.23	0.23	0.31	0.29	0.25	0.23	0.25	0.27	0.22	19.85	0.20	1.38
CD 1%	1.75	2.29	0.42	0.36	0.36	0.49	0.45	0.40	0.36	0.39	0.42	0.35	31.13	0.32	2.16

The research was conducted at the Crop Research Centre -3, School of Agriculture, ITM University, Gwalior, M.P., using a randomized block design (RBD) with three replications. Data were collected on key agronomic and morphological traits, including flowering traits, vine characteristics, fruit morphology and yield components.

The analysis employed Griffing's method 2, model 1, for estimating GCA effects. Results revealed significant variations among the parental lines in their ability to pass on beneficial traits to their progeny. Notably, BG-7 demonstrated consistently positive GCA effects for critical traits such as number of fruits per vine, fruit length, fruit diameter, fruit weight and overall fruit yield per vine. Conversely, BG-1 showed positive GCA effects for early flowering and shorter vine length, which are advantageous for early maturity and compact growth.

The findings of this study underscore the importance of GCA effects in identifying parental lines with superior genetic potential for hybrid breeding in bitter gourd. Parental line BG-7 emerged as a prime candidate for breeding programs aimed at enhancing yield and fruit quality, given its positive GCA effects across several key traits. BG-1 also showed potential due to its traits associated with early maturity and compact growth, which can be beneficial in specific breeding objectives.

Understanding GCA effects enables breeders to make informed decisions when selecting parents to combine the best traits in hybrid offspring. This knowledge is instrumental in improving yield, quality and adaptability of bitter gourd cultivars. The integration of molecular breeding techniques, such as marker-assisted selection (MAS), can further enhance the efficiency and precision of breeding programs, accelerating the development of high-performing hybrids. This approach supports sustainable agricultural practices by creating cultivars that are resilient to various environmental conditions while maximizing productivity and profitability.

Overall, the study highlights the critical role of GCA effects in hybrid breeding and provides valuable insights for the development of superior bitter gourd hybrids. Future research should continue to explore the genetic basis of these traits and incorporate advanced breeding technologies to further optimize breeding strategies for bitter gourd and other important crops.

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