



Genetical Contributions and Combining Ability Analysis in Bitter gourd (*Momordica charantia* L.)

D. R. Bhardwaj^{a*} and Akhilesh Kumar Singh^a

^a ICAR-Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh, India.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The present study was undertaken to estimate the general and specific combining ability in 10 x 10 diallel set of crosses (excluding reciprocals) in bitter gourd to get 45 hybrids using 10 parents (DVBTG-1, VRBT-94, VRBT-39, VRBT-41, VRBT-49, VRBT-50, VRBT-103, VRBT-63, VRBT-32 and VRBT-6). These 45 F₁ along with 10 parents were evaluated in Randomized Block Design with three replications considering 10 characters (days to first male flower anthesis, days to first female flower anthesis, days to first harvest, number of branches/plant, plant height, fruit length, fruit diameter, number of fruits/plant, fruit weight and fruit yield/plant) in bitter gourd. Analysis of variance due to treatment was highly significant for all the traits. The combining ability analysis revealed highly significant differences among the treatments for all the parameters studied. The variances due to sca were higher than the gca for all the characters indicating the predominance of non-additive gene effects. Out of 10 parents' four parents DVBTG-1, VRBT-49, VRBT-103 and VRBT-32 exhibited significant and negative g.c.a effects for early female flowering and days to first harvest. Similarly, positive and significant g.c.a effects were shown by DVBTG-1, VRBT-50, VRBT-49, VRBT-103 and VRBT-6 for number of fruits/plant. DVBTG-1 and VRBT-49 showed negative gca effects for the characters except days to 1st harvesting. How VRBT-49 was identified as one of the best general combiners. The cross combinations VRBT-94 x VRBT-32, DVBTG-1 x VRBT-50, VRBT-49 x VRBT-103, VRBT-49 x VRBT-32, VRBT-94 x VRBT-32 and VRBT-41 x VRBT-103 exhibited positive and significant s.c.a effects for first female flower anthesis and days to first harvest. The finding of experiments confirmed the potentiality of DVBTG-1 x VRBT-6, VRBT-94 x VRBT-103, VRBT-41 x VRBT-6, VRBT-94 x VRBT-49, VRBT-39 x VRBT-49 and VRBT-94 x VRBT-

*Corresponding author: E-mail: dram_iivr@yahoo.com;

39 combination based hybrids for yield/plant. The results of this study also suggest that for improvement of a desirable character, the selected parental line should be of high gca value and their F₁s should express high specific combining ability. Significant estimates of additive component (d) along with significance of additive x additive (i) gene interaction-with positive sign pod yield per plant which indicated the presence of increase alleles and associated pair of genes.

Keywords: Bitter gourd; diallel analysis; genetical contributions; GCA; SCA; quantitative traits.

1. INTRODUCTION

Bitter gourd (*Momordica charantia* L.) is an important cucurbit, which is grown throughout the country for its nutritious vegetable. Reader's Digest UK recently featured bitter gourd as one of the "Five Foods that Will Save the World" along with scuba rice, mung bean, disease-resistant banana, and drought-hardy maize. Bitter gourd is well known for nutritional, medicinal (antidiabetic) and other curative properties and due to these properties, tender green fruits have captured a prominent position among vegetables. It is now an export oriented vegetable which is generally marketed in fresh but sometimes in dehydrated or osmo-drying form. It is one of the most popular vegetables in China, Taiwan, Vietnam, Thailand, India and the Philippines [1]. Occurrence and distribution of both wild and cultivated forms of bitter gourd indicates its rich diversity in India [2]. The predominant sex form in bitter gourd is monoecious, however gynoeceous sex form (only female flower bearing plant) has been reported from India, Japan and China [3-7]. In the past few years, due to several factors such as incidence of viral diseases like leaf mosaic virus and unavailability of good quality and pure seeds of desired types, there is drastic reduction in yield potential, even in some popular varieties like PDM, Arka Harit, MC-84 etc. are worse affected. Choice of parents is considered an important aspect in any breeding programme aimed in improving yield and its related attributes because the high yielding parent may not necessarily transfer its superiority to the progenies in the crosses. Commonly, gca and sca effects have been extensively used in breeding programme to identify the desirable parents and crosses. Hence the present study was undertaken to assess the combining ability and to determine the nature and magnitude of genetic variances for yield and yield contributing traits in bitter gourd.

2. MATERIALS AND METHODS

The experiment was conducted at ICAR-Indian Institute of Vegetable Research, Varanasi (U.P.).

In the present investigation, the experimental materials used for the study comprised of 10 genetically diverse inbred lines viz. DVBTG-1, VRBT-94, VRBT-39, VRBT-41, VRBT-49, VRBT-50, VRBT-103, VRBT-63, VRBT-32 and VRBT-6 and 45 hybrids (F₁s) developed through half-diallel mating design. The experiment was laid down with 10 parents and 45 F₁s hybrids in a Randomized Block Design (RBD) with three replications. In each row seeds were sown keeping row to row and plant to plant spacing of 60 cm x 45 cm., respectively. All the recommended agronomic and cultural practices were adopted to ensure a good crop. Observations were recorded on 5 randomly selected plants from each of parents and crosses in each replication on 10 characters (days to first male flower anthesis, days to first female flower anthesis, days to first harvest, number of branches/plant, plant height, fruit length, fruit diameter, number of fruits/plant, fruit weight and fruit yield/plant) in bitter gourd. The estimates of combining ability variances and effects were obtained using method 2 of model-1 Griffing [8].

3. RESULTS AND DISCUSSION

With the advancement in biometrical genetics, several techniques are now available which permit quantitative genetic analysis and selection of promising parents crosses for further exploitation. The parents who produced good progenies upon crossing are of immense value to the plant breeder. In a crop improvement programme, success depends upon the isolation of valuable cross combinations as determined in the form of parents with high combining ability. The emphasis is on the importance of testing the combining ability of parents because many times the high yielding parents may not combine well to give good segregates. Combining ability analysis is a powerful tool to identify inbreds having good potential to transmit the desirable traits to their off-springs and also helps in sorting out promising crosses for fruit yield and its attributes. At the same time, it also elucidates the nature of gene action (additive and non-additive) involved in the inheritance.

Table 1. Analysis of variances for diallel progenies for 10 characters in bitter gourd

| Source | df | 1 st male flower anthesis | 1 st female flower anthesis | Days to 1 st harvesting | Plant height (m) | No. of branches/ plant | Fruit length (cm) | Fruit diameter (cm) | No. of fruits/ plant | Av. fruit wt. (g) | Yield/plant (g) |
|------------------|-----|--|--|---------------------------------------|---------------------|------------------------------|----------------------|---------------------------|----------------------------|----------------------|-----------------|
| Treatment | 99 | 68.94** | 68.44** | 65.51** | 2.84** | 62.42** | 23.73** | 1.11** | 104.88** | 505.18** | 938626.43** |
| Parent | 9 | 92.63** | 86.30** | 86.92** | 1.51** | 21.75** | 14.01** | 1.05** | 22.51** | 256.67** | 179377.18** |
| F ₁ | 44 | 57.14** | 54.78** | 57.22** | 2.01** | 45.71** | 12.62** | 0.99** | 54.79** | 752.51** | 669459.71** |
| PVF ₁ | 1 | 439.88** | 677.97** | 762.63** | 33.99** | 844.38** | 616.28** | 8.78** | 2822.09** | 9209.69** | 264280.46** |
| Replication | 2 | 50.57 | 58.71 | 62.41 | 0.43 | 1.48 | 0.09 | 0.03 | 0.56 | 5.34 | 2918.74 |
| Error | 198 | 1.11 | 1.27 | 1.82 | 0.06 | 0.75 | 0.11 | 0.05 | 0.35 | 2.92 | 2523.69 |

*, ** = Significant at 5% and 1% level of probability, respectively

Table 2. Genetical contribution in F₁ progenies under diallel for 10 characters in bitter gourd

| Components | 1 st male flower anthesis | 1 st female flower anthesis | Days to 1 st harvesting | Plant height (m) | No. of branches / plant | Fruit length (cm) | Fruit diameter (cm) | No. of fruits/ plant | Av. fruit wt. (g) | Yield/plant (g) |
|--|--|--|---------------------------------------|--------------------|-------------------------------|----------------------|---------------------------|----------------------------|------------------------|------------------------------|
| D | 30.5 (+7.03) | 28.34 (+5.44) | 28.37 (+6.05) | 0.48 (+0.21) | 7.00 (+4.52) | 4.63 (+0.38) | 0.33 (+0.09) | 7.39 (+6.81) | 84.58 (+30.94) | 59040.70 (56158.86) |
| H ₁ | 314.63** (+59.81) | 294.68** (+46.29) | 309.4** (+51.50) | 11.00** (+1.77) | 288.09** (+38.47) | 56.93** (+3.20) | 6.03** (+0.78) | 386.27** (+58.00) | 1671.50** (+263.40) | 2039345.10** (+478157.52) |
| H ₂ | 362.84** (+50.59) | 260.56** (+39.34) | 280.2** (+43.77) | 9.53** (+1.50) | 271.19** (+32.70) | 54.01** (+2.72) | 4.75** (+0.66) | 367.69** (+49.30) | 1361.71** (+223.86) | 1824487.08** (+406380.84) |
| h ² | 57.93** (+8.52) | 89.34** (+6.58) | 100.45** (+7.32) | 4.48** (+0.25) | 111.37** (+5.47) | 81.34** (+0.45) | 1.15** (+0.11) | 372.47** (+8.25) | 1215.33** (+37.46) | 618343.65** (+68003.89) |
| F | 59.24 (+32.46) | 45.93 (25.09) | 44.23 (+27.91) | 0.64 (+0.96) | 14.60 (+20.85) | -4.05 (1.73) | 0.96 (0.42) | -4.15 (+31.44) | -107.42 (142.76) | -95487.01 (+259150.77) |
| E | 0.37 (+2.12) | 0.42 (+1.64) | 0.61 (+1.82) | 0.020 (+0.06) | 0.25 (1.36) | 0.04 (+0.11) | 0.02 (+0.03) | 0.12 (+2.05) | 0.98 (+9.33) | 751.45 (+16932.53) |
| (H ₁ /D) ^{1/2} =F ₁ | 3.21 | 3.22 | 3.30 | 4.77 | 6.42 | 3.51 | 4.25 | 7.23 | 4.45 | 5.88 |
| H ₂ /4H ₁ | 0.21 | 0.22 | 0.23 | 0.22 | 0.24 | 0.24 | 0.20 | 0.24 | 0.20 | 0.22 |
| KD/KR | 1.87 | 1.67 | 1.62 | 1.32 | 1.39 | 0.78 | 2.02 | 0.93 | 0.75 | 0.76 |
| h ² /H ₂ | 0.22 | 0.34 | 0.36 | 0.47 | 0.41 | 1.51 | 0.24 | 1.01 | 0.89 | 0.34 |
| r | 0.6794* | 0.7336* | 0.7863* | -0.5518 | -0.5400 | +0.9598* | +0.3179 | +0.7514* | -0.5090 | 0.2164 |
| t ² | 0.4286 | 0.5134 | 0.6413 | 0.2503 | 0.3833 | 0.5379 | 0.3113 | 3.4106** | 0.9548 | 21.4566** |
| Heritability (NS) | 37.65 | 35.11 | 32.97 | 16.17 | 9.62 | 22.01 | 23.45 | 6.94 | 15.01 | 9.53 |

*, ** = Significant at 5% and 1% level of probability, respectively

Table 3. The analysis of variance for GCA and SCA under diallel mating design for 10 characters

| Characters | df | GCA | | SCA | | Error | | GCA/ SCA | |
|------------------------------|----|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| | | F ₁ | F ₂ | F ₁ | F ₂ | F ₁ | F ₂ | F ₁ | F ₂ |
| First male flower anthesis | 45 | 44.167** | 32.03** | 19.227** | 23.461** | 0.371 | 0.313 | 2.297 | 1.365 |
| First female flower anthesis | 45 | 45.679** | 31.167** | 19.494** | 24.085** | 0.422 | 0.408 | 2.343 | 1.294 |
| Days to first harvesting | 45 | 45.420** | 29.502** | 21.008** | 24.285** | 0.607 | 0.609 | 2.162 | 1.215 |
| Plant height (m) | 45 | 1.431** | 0.923** | 0.751** | 0.849** | 0.020 | 0.019 | 1.905 | 1.087 |
| No. of branches/plant | 45 | 11.723** | 31.659** | 20.258** | 19.543** | 0.251 | 0.260 | 0.579 | 1.619 |
| Fruit length (cm) | 45 | 20.508** | 23.478** | 5.512** | 31.491** | 0.037 | 24.314 | 3.721 | 0.746 |
| Fruit diameter (cm) | 45 | 0.478** | 0.375** | 0.361** | 0.323** | 0.015 | 0.0015 | 1.324 | 1.161 |
| No. of fruits/plant | 45 | 37.104** | 60.050** | 32.841** | 27.572** | 0.117 | 0.158 | 1.129 | 2.178 |
| Average fruit weight (g) | 45 | 55.00** | 284.487** | 122.815** | 63.190** | 0.976 | 0.885 | 4.478 | 4.502 |
| Yield/plant (g) | 45 | 5801.97** | 4088.54** | 3098.78** | 1345.93** | 841.972 | 751.449 | 1.872 | 3.039 |

Table 4. Estimates of general combining (gca) ability effects for various traits in bitter gourd

| Genotype | First male flower anthesis | First female flower anthesis | Days to first harvesting | Plant height (m) | No. of branches/plant | Fruit length (cm) | Fruit diameter (cm) | No. of fruits/plant | Average fruit weight (g) | Yield/ plant (kg) |
|------------|----------------------------|------------------------------|--------------------------|------------------|-----------------------|-------------------|---------------------|---------------------|--------------------------|-------------------|
| DVBTG-1 | 3.26 | 3.46** | 3.54** | -0.23** | -0.76** | -0.34** | 0.15 | 0.85 | -1.13 | 15.54** |
| VRBT-94 | -0.61** | -0.87** | -1.07** | -0.40** | 1.57** | -0.04** | 0.02 | 1.76** | -0.22** | 120.82** |
| VRBT-39 | 0.71** | 0.27** | 0.23 | 0.03 | -0.20** | -1.05** | 0.29 | 1.8** | -1.28** | 81.04** |
| VRBT-41 | -0.74** | -0.96** | -0.77** | 0.53** | 0.64** | -0.91** | 0.15** | 0.06 | 1.65** | 60.11** |
| VRBT-49 | -0.33** | -0.15** | 0.15 | -0.15** | 0.66** | -0.61** | -0.26 | -1.06** | -4.62** | -136.68** |
| VRBT-50 | 0.28** | -0.09** | -0.38** | 0.04** | 0.22** | 2.04** | 0.08** | 1.79** | 10.98** | 347.11** |
| VRBT-103 | 0.20** | 0.27** | 0.23 | -0.10** | -1.94** | -1.28** | -0.20** | 0.29 | -6.57** | -115.23** |
| VRBT-63 | -2.80** | -2.57** | -2.35** | -0.38** | -0.79** | -1.39** | 0.04 | -2.35** | -6.46** | -296.65** |
| VRBT-32 | 2.87** | 2.93** | 2.84** | 0.03 | -0.08 | -0.46** | -0.33** | -3.28** | -4.86** | -326.81** |
| VRBT-6 | -2.30** | -2.29** | -2.43** | 0.63** | 0.67** | 2.23** | 0.07** | 0.13** | 12.51** | 250.75** |
| SE (gi) | 0.0556 | 0.0593 | 0.0711 | 0.0130 | 0.045 | 0.0175 | 0.0112 | 0.0312 | 0.0901 | 2.6490 |
| SE (gi-gj) | 0.0375 | 0.0399 | 0.0479 | 0.0009 | 0.0308 | 0.0118 | 0.0008 | 0.0210 | 0.0607 | 1.7860 |

, = Significant at 5% and 1% level of probability, respectively

Table 5. Specific combining ability effects for various traits in the F₁ generation of bitter gourd

| Crosses | First male flower anthesis | First female flower anthesis | Days to first harvesting | Plant height (m) | No. of branches/plant | Fruit length (cm) | Fruit diameter (cm) | No. of fruits/plant | Average fruit weight (g) | Yield/ plant (kg) |
|--------------------|----------------------------|------------------------------|--------------------------|------------------|-----------------------|-------------------|---------------------|---------------------|--------------------------|-------------------|
| DVBTG-1 x VRBT-94 | -0.89** | -1.39** | -2.61** | -1.15** | 1.55** | 0.35** | 0.35** | -1.48** | -1.48** | -197.50** |
| DVBTG-1 x VRBT-39 | 2.00** | 1.81** | 1.09** | -0.04** | -2.22** | 0.47** | 0.27** | -1.19** | -3.31** | -260.89** |
| DVBTG-1 x VRBT-41 | -4.41** | -4.31** | -4.91** | 0.62** | 1.31** | 1.57** | -0.68** | 3.42** | -1.28** | 198.11** |
| DVBTG-1 x VRBT-49 | -8.16** | -6.78** | -7.16** | 0.47** | 4.39** | 0.02** | -0.10** | 0.01** | -1.32** | -106.34** |
| DVBTG-1 x VRBT-50 | 6.56** | 5.83** | 6.7** | 1.08** | 5.5** | 1.7** | 0.19** | 1.89** | 15.89** | 465.77** |
| DVBTG-1 x VRBT-103 | -0.03** | 0.81** | 2.09** | 0.83** | 3.82** | 0.39** | 0.33** | 3.06** | -1.76** | 137.52** |
| DVBTG-1 x VRBT-63 | -2.69** | -4.03** | -3.99** | -0.29** | -2.56** | -0.13** | 0.66** | -0.43** | -4.80** | -137.13** |
| DVBTG-1 x VRBT-32 | -5.36** | -4.86** | -4.52** | -0.74** | -3.37** | 2.04** | -0.60** | 2.5** | 5.36** | 338.49** |
| DVBTG-1 x VRBT-6 | -4.86** | -4.97** | -4.91** | 0.40** | -1.82** | 2.21** | 0.06** | 6.08** | 18.16** | 960.40** |
| VRBT-94 x VRBT-39 | -2.14** | -2.86** | -2.63** | 0.56** | 1.89** | 1.29** | 0.91** | 3080** | 7.71** | 501.63** |
| VRBT-94 x VRBT-41 | 2.45** | 2.69** | 2.37** | 0.79** | 6.65** | 1.33** | 0.52** | -1.93** | 7.44** | -16.63** |
| VRBT-94 x VRBT-49 | -3.64** | -4.11** | -4.22** | 0.27** | -1.63** | 0.02** | 0.22** | 8.16** | 4.17** | 597.41** |
| VRBT-94 x VRBT-50 | 2.75** | 2.5** | 1.98** | -0.35** | -3.69** | 0.96** | -0.12** | -5.39** | 6.68** | -296.98** |
| VRBT-94 x VRBT-103 | -2.83** | -3.53** | -3.97** | -0.64** | -3.30** | -0.28** | -0.40** | 10.31** | 1.99** | 685.74** |
| VRBT-94 x VRBT-63 | -2.16** | -2.36** | -2.38** | 0.54** | 5.19** | 2.5** | 0.26** | 5.05** | 7.95** | 517.69** |
| VRBT-94 x VRBT-32 | 3.84** | 3.14** | 3.09** | 1.00** | 6.87** | -0.63** | -0.74** | 4.35** | 0.31** | 280.71** |
| VRBT-94 x VRBT-6 | 7.34** | 6.69** | 7.03** | -1.54** | -5.51** | 1.77** | 0.53** | -0.13** | 14.28** | 269.36** |
| VRBT-39 x VRBT-41 | -1.00** | -1.78** | -1.94** | 0.03** | 3.15** | 0.85** | -0.16** | -0.43** | 0.14** | -73.20** |
| VRBT-39 x VRBT-49 | 0.59** | 0.08** | 0.14** | -0.19** | -1.87** | 1.24** | -0.35** | 7.92** | 3.7** | 551.29** |
| VRBT-39 x VRBT-50 | 2.31** | 2.03** | 1.67** | -1.04** | -3.69** | 1.88** | 0.61** | -0.23** | 8.48** | 177.73** |
| VRBT-39 x VRBT-103 | -5.61** | -6.00** | -5.94** | 0.14** | 1.16** | 0.37** | -0.31** | -2.66** | -0.07** | -201.83** |
| VRBT-39 x VRBT-63 | -0.94** | -1.83** | -2.69** | 1.09** | 2.09** | -0.38** | 0.55** | 6.51** | -2.55** | 352.83** |
| VRBT-39 x VRBT-32 | 0.72** | -0.33** | 0.45** | 1.58** | 5.87** | 0.62** | -0.84** | 3.68** | 0.45** | 258.65** |
| VRBT-39 x VRBT-6 | 1.22** | 0.89** | 1.06** | 0.64** | 3.69** | 0.96** | -0.48** | 3.76** | -0.55** | 302.86** |
| VRBT-41 x VRBT-49 | -0.50** | -1.03** | -0.52** | 0.71** | -3.97** | 0.87** | 0.53** | 4.36** | 4.27** | 340.06** |
| VRBT-41 x VRBT-50 | -4.11** | -4.42** | -3.66** | -0.81** | -1.53** | 0.05** | -0.54** | 4.14** | -4.36** | 262.23** |
| VRBT-41 x VRBT-103 | 4.64** | 3.89** | 4.06** | 0.06** | 2.42** | 0.68** | 0.48** | 0.98** | -0.58** | 22.51** |
| VRBT-41 x VRBT-63 | -1.36** | 2.06** | 2.64** | -0.09** | -3.15** | -0.54** | -0.31** | 0.02** | -5.65** | -143.40** |
| VRBT-41 x VRBT-32 | -0.03** | -0.78** | -1.88** | 1.13** | 6.27** | 1.76** | 1.07** | 2.82** | 11.78** | 384.12** |
| VRBT-41 x VRBT-6 | -3.53** | -3.89** | -3.61** | 0.03** | -2.89** | 1.00** | 0.37** | 4.67** | 12.64** | 669.84** |
| VRBT-49 x VRBT-50 | 0.47** | 0.11** | -0.24** | 0.63** | 8.08** | 2.71** | 0.56** | 4.39** | 23.54** | 861.42** |
| VRBT-49 x VRBT-103 | 4.22** | 3.08** | 3.81** | -0.79** | 1.7** | 2.06** | -0.33** | -1.80** | 4.06** | -93.84** |
| VRBT-49 x VRBT-63 | -3.44** | -3.42** | -2.94** | -0.51** | 0.36** | 0.04** | 0.03** | -3.93** | 1.95** | -266.42** |
| VRBT-49 x VRBT-32 | 5.89** | 6.75** | 6.53** | -0.05** | -1.89** | -0.32** | 0.77** | -4.63** | 0.31** | -343.56** |

| Crosses | First male flower anthesis | First female flower anthesis | Days to first harvesting | Plant height (m) | No. of branches/plant | Fruit length (cm) | Fruit diameter (cm) | No. of fruits/plant | Average fruit weight (g) | Yield/ plant (kg) |
|--------------------|----------------------------|------------------------------|--------------------------|------------------|-----------------------|-------------------|---------------------|---------------------|--------------------------|-------------------|
| VRBT-49 x VRBT-6 | -4.94** | -5.69** | -7.19** | 0.28** | 7.23** | 0.18** | -0.49** | 3.02** | -5.82** | 25.05** |
| VRBT-50 x VRBT-103 | -4.72** | -4.64** | -4.66** | 0.69** | 2.31** | 1.38** | -0.26** | 4.98** | -0.83** | 333.04** |
| VRBT-50 x VRBT-63 | -4.05** | -4.14** | -4.41** | 0.17** | 5.73** | 2.41** | 0.29** | 3.09** | 7.99** | 358.42** |
| VRBT-50 x VRBT-32 | 0.28** | 0.36** | -0.61** | -1.07** | -2.65** | -0.64** | -0.73** | 0.69** | -9.95** | -197.05** |
| VRBT-50 x VRBT-6 | -1.22** | -1.08** | -1.33** | -1.06** | -2.36** | -0.17** | 0.03** | 2.18** | 0.85** | 260.36** |
| VRBT-103 x VRBT-63 | 4.7** | 3.83** | 3.98** | 0.51** | -0.85** | 0.68** | 0.34** | -0.88** | 4.97** | 9.90** |
| VRBT-103 x VRBT-32 | -7.97** | -8.00** | -7.88** | 0.87** | 2.04** | 1.68** | 0.35** | 2.72** | 5.43** | 254.03** |
| VRBT-103 x VRBT-6 | 0.86** | 1.22** | 1.73** | 0.33** | -0.38** | 2.16** | 1.15** | 2.44** | 8.57** | 347.84** |
| VRBT-63 x VRBT-32 | 0.70** | 0.83** | 0.37** | 0.25** | -0.30** | 1.13** | 0.41** | 2.40** | 4.96** | 232.25** |
| VRBT-63 x VRBT-6 | 1.20** | 0.39** | 0.31** | 0.58** | 2.95** | 1.37** | 0.71** | 1.71** | 4.59** | 121.42** |
| VRBT-32 x VRBT-6 | -6.8** | -5.78** | -5.88** | 0.54** | 5.37** | 1.30** | 0.18** | -2.19** | 4.18** | 201.12** |
| SE (sij) | 0.0845 | 0.0901 | 0.1082 | 0.0198 | 0.0695 | 0.0266 | 0.0171 | 0.0474 | 0.1372 | 4.0290 |
| SE (sij-sik) | 0.1243 | 0.1325 | 0.1590 | 0.0291 | 0.1022 | 0.0391 | 0.0251 | 0.697 | 0.2016 | 5.9230 |

*, ** = Significant at 5% and 1% level of probability, respectively

3.1 Analysis of Variance

Analysis of variances for diallel progenies for 10 characters in bitter gourd revealed vast diversity which contributes significantly in development of various cross combinations in bitter gourd. The value indicates the parent's utility for earliness, total yield and other yield related traits. Analysis of variances for combining ability with respect to different characters is presented in Table 1. The analysis of variance revealed significant among the parents for the characters under study. The difference between parents found significant for all the characters, indicating that the parents differed significantly for these characters.

3.2 Genetical Contribution

The total variability among F_1 hybrids was further portioned into different components and their significance was tested. It is evident from the Table 2 that the mean sum of squares due to crosses was significant for all ten characters studied [9]. The characters under study indicated the importance of both additive and non-additive genetic components which is corroborated with the findings of Ram et al. [10]. The additive component was significantly higher in F_1 and F_2 generation suggesting additive and dominant component in expression 1st male flower anthesis, 1st female anthesis and days to 1st harvesting. The ratio of dominant and recessive gene was more than in F_1 and F_2 indicating excess of dominant gene for plant height but symmetrical distribution of gene with positive and negative among the parents were prominent for No. of branches of per plant. The proportion of dominant gene and recessive alleles among the parents was higher in both F_1 and F_2 generation for fruit length. In general The relative role of gene action was in general more complex for yield and other associated traits. The nature and magnitude of gene effects vary with different cross/character-wise. Further, duplicate type of epistasis was also found in majority of traits in one or the other cross combinations. In such crosses, the selection intensity should be mild in the earlier and intense in the later generations because it marks the progress through selection.

General combining ability effects: Positive and significant gca effects were observed by parents DVBTG-1, VRBT-32, VRBT-50 showed negative gca for first female flower anthesis and negative significant gca effects for days to first harvesting.

(Table 4). The estimates of gca effects (Table 4 showed that parents DVBTG-1(3.26) and VRBT-32 (2.87) were good general combiner for male flower anthesis Parents VRBT-63 (-2.57) VRBT-63 (-2.57) VRBT-41 (0.53) and VRBT-6 (0.63) were found significant for plant height. Significant and negative gca effects were shown by VRBT-94 (-0.40), VRBT-63 (-0.38) and VRBT-6 (0.63) showed positive gca effects for plant height. Parent VRBT-41 (0.64); VRBT-6 (0.67) also showed positive effects for number of branches/plant whereas DVBTG-1 (-0.76) expressed negative value towards this trait. Parent VRBT-41, VRBT-50, VRBT-6 and VRBT-32 were noted good general combiners. Positive and significant gca effects were exhibited by VRBT-50 (347.1), VRBT-6 (250.75) and VRBT-94 (120.82) for yield/plant and found good general combiners for this trait. It was observed that performance of parents bear direct relation for their respective gca effects in the parents which showed highest gca effects for different character were also observed good performers with respect to that particular character. Above findings are very much similar to the results put forth by Ram et al. [9].

Specific combining ability effects: Since in the present study, the magnitude of non-additive variances were higher, the *per se* performance may not be real indicative for their gca effects (Table 5). Hence the sca effects were also calculated. The estimates of sca effects (Table 5) revealed that crosses VRBT-94 x VRBT-6, DVBTG-1 x VRBT-50, VRBT-49 x VRBT-32, VRBT-49 x VRBT-103 and VRBT-41 x VRBT-103 combine well to produce significant positive sca effects being desirable for days to male, female anthesis and days to harvesting. High positive sca effects were observed in cross combinations VRBT-39 x VRBT-32, VRBT-41 x VRBT-32, VRBT-39 x VRBT-63, DVBTG-1 x VRBT-50, VRBT-94 x VRBT-32 but significant and high negative sca effects found in cross combinations VRBT-94 x VRBT-6, VRBT-39 x VRBT-50, VRBT-50 x VRBT-32, VRBT-50 x VRBT-6 and VRBT-41 x VRBT-50 indicating poor specific combination for plant height. Similarly the crosses VRBT-49 x VRBT-50, VRBT-49 x VRBT-6, VRBT-94 x VRBT-32, VRBT-94 x VRBT-41, VRBT-41 x VRBT-32, VRBT-39 x VRBT-32 and VRBT-50 x VRBT-63 expressed significant sca effects for number of branches/plant. For fruit length highly positive and significant sca effects were noted in the cross combinations VRBT-49 x VRBT-50, VRBT-

50 x VRBT-63, DVBTG-1 x VRBT-6, VRBT-49 x VRBT-103, VRBT-103 x VRBT-6, VRBT-94 x VRBT-6 and VRBT-41 x VRBT-32. Highly positive and significant sca effects were noted in the cross combinations DVBTG-1 x VRBT-6, VRBT-94 x VRBT-103, VRBT-41 x VRBT-6, VRBT-94 x VRBT-49, VRBT-39 x VRBT-49 and VRBT-94 x VRBT-39 but combinations VRBT-49 x VRBT-32, VRBT-94 x VRBT-50, DVBTG-1 x VRBT-39, VRBT-39 x VRBT-103, VRBT-49 x VRBT-63 and DVBTG-1 x VRBT-94 gave significant and highly negative sca effects indication poor specific combination for this trait Ram et al. [9] and Mishra et al. [11].

Most of the crosses included high x high and high x medium type of general combiners. The desirable cross combination with medium x medium and poor x poor type of general combiners also observed which may be due to complimentary effects. The crosses involving parents with good gca effects can be exploited effectively by conventional breeding procedure like pedigree method. However, the crosses involving good combiner and other medium poor combiner could produce desirable transgressive segregants if additive genetic system was operative good combining parents and epistatic effect also act in the same direction. Similar results were also reported by Singh et al. [12], Shukla et al. [13], Laxuman et al. [14] and Mishra et al. [11].

4. CONCLUSION

It is concluded that it would be desirable to follow cyclic method of breeding for combining superior recombinants which will simultaneously exploit additive and non-additive gene effects for evolving the desirable genotypes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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