Combining ability and gene action in cucumber (Cucumis sativus L.)

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Abstract
The experimental material for the present study comprised of F1 population of twenty four crosses, developed by crossing four female parents viz., Sheetal, Shubhangi, Himangi, and Puna khira of cucumber with six male parents viz., AAUC-2, DC-2, AAUC-1, VRC-19, DARL-103 and Fansu local. The experiment was laid out with 24 F1s, 4 females 6 males and one check Konkan kakadi in Dapoli, Ratnagiri, Maharashtra, India. The experiment was conducted under Dapoli, Ratnagiri, Maharashtra, India

Keywords:
- Cucumber, F1 hybrids, GCA, SCA and yield characters
- Combining ability and gene action in cucumber
- Combining ability

Introduction
Cucumber (Cucumis sativus L.) belongs to the family cucurbitaceae and its centre of origin is India (Renner et al., 2007). It is an important and one of the most popular fruit vegetable in Asia. Cucumber is also an ideal vegetable for its edible tender fruits, preferred as salad ingredient, pickles, desert fruit and as a cooked vegetable. Since there exist a considerable variability of this crop, it is possible to develop high yielding varieties through breeding approaches like selection or hybridization. Combining ability is one of the important and powerful tools to identifying the best combiner that may be used in crosses to exploit heterosis. It helps to know the genetic architecture of various characters that enable the breeder to design effective breeding plan for future improvement of the existing materials. The combining ability analysis gives useful information regarding the selection of parents in terms of the performance of their hybrids. Information on the relative importance of general combining ability (GCA) and specific combining ability (SCA) is of value in breeding programs for species which are amenable to the development of F1 hybrid cultivars such basic information on combining ability in cucumber would aid the breeder in developing improved hybrid cultivars (Tasdighi and Baker, 1981). The line x tester technique was developed by Kempthorne in 1957. It is a good approach for screening the germplasm on the basis of GCA and SCA variances and effects. Line x tester analysis involving parents give the additional information about the presence or absence of epistasis, average degree of dominance, as well as distribution of dominant and recessive genes in the parents. Application of line x tester technique in a cross-pollinated crop like cucumber for this purpose may be appropriate. The estimates of gene effects and genetic variance help in understanding the
For the fruit length estimates of variances due females and males for combining ability were found to be non-significant whereas estimates of gca variances due females x males were significant. For average fruit weight the mean squares due to females x males were significant. Number of marketable fruits vine\(^1\) showed that general combining ability variance due to females and females x males were significant. In case of marketable yield vine\(^1\)the mean squares due to females and females x males were found to be significant to were highly significant while, variances for males were non-significant. The variance due to females x males was non-significant. The mean square for number of primary branches plant\(^1\) due to females and females x males. Total soluble solid exhibits non - significant results in all interaction.

**Studies on combining ability effects**

The estimates of general combining ability (gca) effects (Table 2) of parents and specific combining ability (sca) effects of hybrid for thirteen characters are presented in (Table 3).
Table 2: cont.

| Sr. No. | Female parents | Marketable yield vine\(^{-1}\) (kg) | Harvest duration | Number of primary branches plant\(^{-1}\) | Vine length (m) | Total soluble solids (%Brix) |
|---------|----------------|-------------------------------------|------------------|-------------------------------------------|----------------|-----------------------------|
| 1       | Sheetal        | 0.572**                            | 2.667            | 0.502**                                   | -0.324**       | 0.263**                     |
| 2       | Shubhangi      | -0.360**                           | 0.250            | -0.406**                                  | -0.041**       | -0.029**                    |
| 3       | Himangi        | -0.447**                           | -2.000**         | -0.640**                                  | 0.111          | 0.138**                     |
| 4       | Punakhiha      | 0.235**                            | -0.917**         | 0.544**                                   | 0.254          | -0.371**                    |

No. of female parents showed (-ve) significant gca effects

| Sr. No. | Female parents | Marketable yield vine\(^{-1}\) (kg) | Harvest duration | Number of primary branches plant\(^{-1}\) | Vine length (m) | Total soluble solids (%Brix) |
|---------|----------------|-------------------------------------|------------------|-------------------------------------------|----------------|-----------------------------|
| 5       | AAUC-2         | -0.017**                           | 2.792            | 0.152**                                   | -0.131**       | 0.317**                     |
| 6       | DC-2           | -0.258**                           | 2.417            | 0.077**                                   | 0.187          | -0.121**                    |
| 7       | AAUC-1         | -0.583**                           | -2.833**         | 0.090**                                   | 0.114          | -0.196**                    |
| 8       | VRC-19         | 0.376**                            | -2.708**         | 0.027**                                   | 0.042          | -0.133**                    |
| 9       | DARL-103       | -0.114**                           | -0.708**         | -0.173**                                  | -0.236**       | 0.079**                     |
| 10      | Fansu local    | 0.596**                            | 1.042            | -0.173**                                  | 0.024          | 0.054**                     |

No. of female parents showed (-ve) significant gca effects

**Table 3: Estimation of specific combining ability for different characters in cucumber**

| Sr. No. | Hybrids         | Days to first male flower appearance | Days to first female flower appearance | Nodal position of first female flower | Days to first picking | Fruit length (cm) | Fruit diameter (cm) | Average fruit weight (g) | Number of marketable fruits vine\(^{-1}\) |
|---------|-----------------|--------------------------------------|----------------------------------------|--------------------------------------|-----------------------|-------------------|---------------------|------------------------------|--------------------------------------------|
| 1       | Sheetal x AAUC-2 | 0.479                                | 1.042                                  | 0.958                                | -1.396                | 0.730             | -0.084              | -1.977                       | -1.125**                                   |
| 2       | Sheetal x DC-2   | 2.354*                               | 0.417                                  | 0.958                                | 1.229                 | 0.088             | 0.208               | 0.310                       | -1.238**                                   |
| 3       | Sheetal x AAUC-1 | 2.854*                               | 1.042                                  | 1.958**                              | 0.604                 | -0.879            | 0.231               | -25.602*                    | -0.750                                     |
| 4       | Sheetal x VRC-19 | 0.104                                | 0.917                                  | -0.417                               | 2.104                 | -1.153*           | 0.051               | 10.060                      | 1.500**                                   |
| 5       | Sheetal x DARL-103| -1.271                               | 0.542                                  | -1.667**                             | 0.854                 | 1.618**           | -0.319              | 15.623                      | 0.450                                     |
| 6       | Sheetal x Fansu local | -4.521**                             | -3.958**                               | -1.792**                             | -3.396**              | -0.404            | -0.087              | 1.585                       | 1.163*                                    |
| 7       | Shubhangi x AAUC-2 | 2.313*                               | 3.792**                                | 0.125                                | 5.271**               | -0.306            | 0.172               | -14.519                     | -0.033                                     |
| 8       | Shubhangi x DC-2  | -2.813*                              | -2.333**                               | 0.125                                | -1.104                | 0.402             | 0.435               | -9.731                      | 1.154*                                    |
| 9       | Shubhangi x AAUC-1 | -1.313                               | -1.708                                 | -1.375*                              | -0.729                | -0.535            | 0.027               | 18.306                      | 2.092**                                   |
| 10      | Shubhangi x VRC-19| 1.438                                | 0.667                                  | -0.750                               | -2.229                | 1.396*            | -0.302              | -0.031                      | -1.358**                                  |
| 11      | Shubhangi x DARL-103| 2.563*                               | -0.208                                 | 1.000                                | 0.021                 | -0.958            | -0.283              | -1.919                      | 0.092                                     |
| 12      | Shubhangi x Fansu local | -2.188*                               | 0.875                                  | -1.229                               | 0.000                 | -0.050            | 7.894               | -1.946**                    |                                            |
| 13      | Himangi x AAUC-2 | -0.104                               | -2.375*                                | -0.875                               | -2.563*               | -1.013            | -0.346              | 8.323                       | 0.025                                     |
| 14      | Himangi x DC-2   | -5.229**                             | -1.000                                 | 0.625                                | -0.938                | -0.414            | -0.303              | 11.510                      | 0.913*                                    |
The hybrids having highest significant negative SCA effects in order were Himangi x DC-2 (-5.229), Sheetal x Fansu local (-4.521) and Puna khira x DARL-103 (-3.938). The cross combinations exhibited significant negative SCA effects were designated as good specific combiners. Hence, they were considered as good cross combinations for exploiting earliness in male flowering.

Days to first female flower appearance
In days to first female flower appearance the estimates of GCA effects revealed that the two female parent viz. Himangi (-1.875) and Shubhangi (-0.042) and three male parents viz.
AAUC-1 (1.708), DARL-103 (1.208) and DC-2 (1.083) had significant negative gca effects. Pati et al. (2015) [13], Kumar and Kumar (2017) [5] and Naik et al. (2018) [10] had revealed significant gca effects for this trait. The estimates of sca effects revealed that significant negative sca effects in order were Sheetal x Fansu local and Puna khira x DARL-103 exhibited (-3.958) same sca effects. The cross combinations in F1exhibited significant negative sca effects were designated as good specific combiners. These cross combinations were exploiting earliness and used in crop improvement. Kaur and Dhall (2017) [3] and Nimitha et al. (2017) [11] reported highly significant sca effects for above trait.

Nodal position of first female flower

In nodal position of first female flower the estimates of gca effects revealed that the second female parent Puna khira (-0.417), Shubhangi (-0.250) and three male parents viz, DARL-103 (-1.083), VRC-19 (-0.333) and DC-2 (-0.208) had exhibited significant negative gca effects. Thus, negative estimates of gca effects indicated the parents are good general combiners for node bearing of first female flower. Kumar and Kumar (2017) [5] recorded highly significant gca effects for nodal position of female.

The estimates of sca effects revealed that four hybrids recorded significant negative sca effects. The hybrids having highest significant negative sca effects in order were Sheetal x Fansu local (-1.792), and Puna khira x DC-2 (-1.708). The cross combinations were designated as good specific combiners which bearing first female flower earlier. Pati et al. (2015) [13], Tiwari and Singh (2016) [21] and Kaur and Dhall (2017) [5]. The cross combinations were designated as good specific combiners which bearing first female flower earlier.

Days to first picking

An examination of gca estimates revealed that the three female parents viz., Himangi (-1.813), Sheetal (-0.979), Shubhangi (-0.146) and among male parents DC-2 (-1.396), AAUC-2 (-0.271) and DARL-103 (-0.021) recorded highest significant negative gca effects. In overall result in the female parent Himangi is good general combiner in all season and on pooled basis in early picking. Singh and Ram (2016) [19] and Bhutia et al. (2017) [2] also reported similar finding in cucumber.

The estimates of sca effects revealed that two hybrids Sheetal x Fansu local (-3.396) and Himangi x AAUC-2 (-2.563) were found good specified combination designated as good specific combiners in early picking character These results are in agreement with Reddy et al. (2014) [15].

Fruit length (cm)

The estimates of gca effects revealed that only one female parent Shubhangi (0.263) exhibited highly significant positive gca effects while in only one male parent DARL-103 (0.336) showed significant positive gca effects. This indicated that these parents were good general combiners for this character. Naik et al. (2018) [10] and Pati et al. (2015) [13] explain the positive gca effects for this trait.

A study of estimates for the sca effect revealed that three hybrids viz., sheetal x DARL-103 (1.618), Shubhangi x VRC - 19 (1.396) and Himangi x AAUC-1 (1.138) highly significant positive sca effects this indicates that they are good specific combiners for this trait. Similar results were reported by earlier workers Mule et al. (2012), Xian and Ying (2012), Kaur and Dhall (2017) and Malav and Verma (2017) [9, 23, 3, 7].

Fruit diameter (cm)

For fruit diameter the estimates of gca effects revealed that only one female parent Punakhira (0.548) exhibited highly significant positive gca effects. These parents were good general combiners for said trait. As regard to sca effects only one hybrid Himangi x DARL-103 exhibited highly (0.989) significant positive sca effects. Malav and Verma (2018) [7] had reported highly significant gca and sca effects for this trait.

Average fruit weight (g)
The average fruit weight estimates of gca and sca effects was non significant indicating that they are poor specific combiners for this trait.

Number of marketable fruits per vine

An examination of gca estimates revealed that among these two female parents Sheetal (2.700) and Punakhira (1.191) as well as three male parents Fansu local (1.604), VRC-19 (0.817) and AAUC-2 (0.692) exhibited highest gca effects These parents were exhibits good general combining ability. These results were in similar line with Pati et al. (2015) [13] and Reddy et al. (2014) [15].

A perusal of estimates of sca effects of hybrids revealed that ten hybrids showed significant positive sca effects, among these Puna khira x Fansu local (2.221) and Shubhnagi x AAUC-1 (2.093) recorded highest significant positive sca effects. Bhutia et al. (2017) [2] and Naik et al. (2018) [10] obtained similar findings for this trait.

Marketable yield per vine (kg)
The perusal of estimates of gca effects revealed that two female parents viz., Sheetal (0.572), Puna khira (0.235) and two male parents Fansu local (0.596) and VRC-19 (0.376) exhibited significant positive gca effect These showed that these parents were good general combiner for the said trait. Ahammed et al. (2018) [1] exhibits similar finding for this fruit.

With regards to sca effect three hybrids towards significant positive direction for this trait. The best three hybrids with respect to marketable yield vine ‘based on significant positive sca were viz., Sheetal x Fansu local (0.942), Shubhangi x DC-2 (0.532), Puna khira x VRC-19 (0.484). Kumar and Kumar (2017) [5] and Moradipour et al. (2017) [8] found similar results for positive marketable yield in cucumber.

Harvest duration

An examination of gca estimates all male and female parents had non significant gca effects. A perusal of estimates of sca effects of hybrids revealed that only one Himangi x VRC-19 (4.625), hybrid recorded significant positive sca effects registered significant highest positive effects which are good specific combiner for longest harvest duration.

Number of primary branches per plant

An examination of gca estimates revealed that female parent Sheetal (0.502) and Punakhira (0.544) recorded significant positive gca effects. A perusal of estimates of sca effects of hybrids revealed that two hybrids Shubhnagi x AAUC-2 (0.281) and Punakhira x Fansu local (0.283) recorded significant positive sca effects. Similar findings were obtained by Prasad and Singh (1992) [12].
Vine length (m)
The persual of estimates of gca and sca effects indicated that all these parents and hybrids exhibited on significant gca and sca effects respective.

Total soluble solids (°Brix)
Based on estimates of general combining ability effects among female two parents Sheetal (0.263) and Himangi (0.138) were observed to be the good general combiners while three male parents viz., AAUC-2(0.317), DARL-103(0.079) and Fansu local (0.054). The parent had highest gca effects exhibit good general combining ability. Similar findings obtained by Li. et. al. (2005) and Reena Kumari et al. (2017) [16].

In regards to sca effects seven hybrids showed positive significant sca effects. Among these the hybrids Sheetal x AAUC-1 (0.562) displayed highly significant positive sca effects followed by Shubhangi x YRC-19 (0.492) and Himangi x DC-2(0.463). This indicated that these were good general combiner for total soluble solids. Nimitha et al. (2017) [11] and Malav and Verma (2018) [7] revealed the similar results for estimation of highest sca effects for this trait.

| Sr. No. | Characters | GCA² of GCA | GCA² of Males | GCA²(Average) | SCA² of female x male | σ²A | σ²D | σ²A/σ²D | h² in% | Genetic Advance |
|---------|------------|-------------|---------------|---------------|----------------------|-----|-----|---------|-------|-----------------|
| 1       | Days to first male flower appearance | 6.63 | 0.93 | 4.354 | 12.56 | 8.70 | 12.56 | 0.69 | 38.92 | 3.79 |
| 2       | Days to first female flower appearance | 0.94 | 0.68 | 0.844 | 6.36 | 1.68 | 6.36 | 0.26 | 18.85 | 1.16 |
| 3       | Nodal position of first female flower | -0.10 | 0.13 | -0.0078 | 1.22 | -0.015 | 1.22 | -0.012 | -1.01 | -0.02 |
| 4       | Days to first picking | 3.30 | 0.83 | 2.3122 | 4.58 | 4.62 | 4.58 | 1.009 | 43.57 | 2.92 |
| 5       | Fruit length (cm) | -0.10 | -0.11 | -0.1103 | 0.64 | -0.22 | 0.64 | -0.34 | -31.89 | -0.54 |
| 6       | Fruit diameter (cm) | 0.17 | -0.00 | 0.089 | 0.08 | 0.19 | 0.08 | 2.26 | 55.20 | 0.68 |
| 7       | Average fruit weight (g) | -14.87 | 51.77 | 11.78 | 176.92 | 23.56 | 176.92 | 0.13 | 7.79 | 2.79 |
| 8       | Number of marketable fruits vine⁻¹ | 5.02 | 0.88 | 3.371 | 2.83 | 6.74 | 2.83 | 2.37 | 69.02 | 4.44 |
| 9       | Marketable yield vine⁻¹ (kg) | 0.186 | 0.107 | 0.154 | 0.255 | 0.309 | 0.255 | 1.212 | 50.34 | 0.81 |
| 10      | Harvest duration | 2.35 | 3.63 | 2.863 | 5.21 | 5.72 | 5.21 | 1.09 | 36.58 | 2.98 |
| 11      | Number of primary branches plant⁻¹ | 0.369 | 0.0128 | 0.228 | 0.01 | 0.453 | 0.01 | 45.28 | 94.40 | 1.34 |
| 12      | Vine length (m) | 0.033 | -0.017 | 0.0131 | -0.64 | 0.026 | -0.64 | 0.0406 | 13.59 | 0.12 |
| 13      | Total soluble solids (°Brix) | 0.035 | -0.02 | 0.0113 | 0.226 | 0.0226 | 0.2276 | 0.0993 | 8.54 | 0.09 |

Heritability
The effectiveness of selection for a trait depends on relative importance of genetic and non-genetic factors in the expression of phenotypic difference among genotypes in population, a concept referred to as heritability. The heritability has major impact on the methods chosen for population improvement, in breeding and other aspect of single plant selection may be effective for the character with low (5 to10%), medium (10 to 30%), high (30 to 60%) and very high (above 60%) heritability (Robinson, 1966) [13]. The heritability estimates were made from different variance components (Table 4) obtained for kharif 2017 very high heritability obtained for number of primary branches plant⁻¹(94.40%), number of marketable fruits vine⁻¹ (69.02%). High heritability observed for marketable yield vine⁻¹ (50.34%) similar results obtained by Gu-Xing et al. (2004) for this character. The fruit diameter (55.20%), days to first picking (43.57%) and days to first male flower appearance (38.92%), similar findings obtained by Uddin et al. (2009) [22] for all these characters. The harvest duration (36.58%) recorded high heritability which had utility in prolongs the duration of harvesting in cross combination.

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