Line x Tester analysis for Heterosis and Combining ability in Bottle Gourd
(*Langenaria siceraria (Mol.) standl)*

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By

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Introduction

In the changing global scenario, nutritional security in the country is an important issue of agriculture. In addition to health and nutritional security of human being, vegetables play an important role in economy of the country. India is the second largest producer of vegetables next to China in the world. The cucurbits occupy an important place in Indian agriculture. These crops are grown largely by the poor and marginal farmers throughout the country. The cucurbitaceae family in India encompasses about 34 genera and 108 species, of which 38 species are endemic. Bottle gourd [*Lagenaria siceraria* (Mol.) standl.] is one of humankind's first domesticated plants. It is one of the important cucurbit grown throughout the country for its tender fruits. It is known as poor man's vegetable in India. Bottle gourd is a climbing plant which bears hard-shelled and bottle shaped fruits. This delicious vegetable is also known by names of bottle squash, calabash gourd, doodhi and lowki (*Anonymous*, 2018).

It is generally accepted that *Lagenaria siceraria* (previously known as *Lagenaria vulgaris* ser.) is indigenous to Africa and that it reached temperate and tropical areas in Asia and the America about 10,000 years ago, with human help or probably as a wild species whose fruits had floated across the seas. Fruits are known to float in the sea for many months without the seeds losing their viability. Independent domestications from wild populations are believed to have occurred in both the old and New Worlds. African and American land races (sub spp. siceraria) are morphologically distinct from Asian land races (sub spp. asiatica). It is uncertain if the seemingly spontaneous populations in Africa are truly wild. However, it is possible that Wilkins-Ellert discovered an unusual free living plant of *Lagenaria siceraria* in a remote region of South Eastern Zimbabwe fairly recently. The genus name Lagenaria comes from lagena, the Latin name for a Florence flask; referring to the fruit of L. siceraria. The 2 species name siceraria probably also refers to the fruit which is useful when it is mature and dry (siccus).

Bottle gourd (*Langenaria siceraria* (Mol.) standl) is of division Magnoliophyta, class-Magnoliopside and while order is cucurbitales. It is a vigorous annual vine. Stems prostrate or climbing, angular, ribbed, thick, brittle, softly hairy up to 5 m long, cut stems exude no sap. Leaves simple, up to 400 mm long and 400 mm broad, shortly and softly hairy broadly egg, kidney-or heart-shaped in outline, undivided angular or faintly 3-7 lobed, lobes rounded, margins shallowly toothed, crushed leaves nonaromatic. Leaf stalks up to 300 mm long, thick, often hollow, densely hairy, with two small, lateral glands inserted at the leaf base. Tendril split in two flowers stalked (female flower stalks shorter than male), solitary, monoecious (male and female flowers on the same plant) : petals, crisped, cream or white with darker veins, pale yellow at the base, obovate up to 45 mm long, opening in the evenings, soon wilting. Fruit large variable, subglobose to cylindrical, flask-shaped or globose with a constriction above the middle; fleshy, densely hairy to ultimately glabrous, indehiscent, green, maturing yellowish or pa le brown, pulp drying out completely on ripening, leaving a thick, hard, hollow shell with almost nothing inside except the seeds. Seeds many, embedded in a spongy pulp, 7-20 mm long, compressed, with two flat facial ridges in some variants rather irregular and rugose (*Anonymous*, 2018). A rich source of minerals and vitamins, bottle gourd, contains many healing and medicinal properties. The cooked vegetable is not only easy to digest but also contains cooling, 3 calming (or sedative), diuretic properties. It contains low calories also has iron, vitamin C and B complex. Regular consumption of this vegetable provides relief to people suffering with digestive problems, diabetics and convalescents. The nutritional contents of bottle gourd are calories-22 K cal, sodium-347 mg, total fat-0.09 %, carbohydrates 5.49 g, cholesterol-0 mg, protein-0.9 g. Due to it's delicate and nutty flavor, bottle gourds are widely used for preparing many delectable recipes. It serves greatly to hot curries as well as cooling yogurt dishes like Raita. As a vegetable, it is widely used in southern Chinese cuisine as either a stir-fry or a soup. It can be used like squash but it has a firmer, crisper texture. The dried and empty bottle gourds are used as a utensil in households across West Africa. In some tribal areas of the world, dried bottle gourd are used for storing locally made liquors. In African countries, musicians use this vegetable in making musical instruments (*Anonymous*, 2018).

Bottle gourd has great export potential, but it is commercially grown in a few states of India. The exact figures of area and production are not available. However, it has some share in gourd cucurbitaceous vegetables. The gourd vegetables are grown on 4.05 lakh hectares In India, mostly local types of bottle gourd are being cultivated all over the country. In Punjab also a large number of local types are being cultivated. Now during the recent years few improved types have been developed by coordinated centre and state agricultural universities from wide spectrum of 4 genetic variability in bottle gourd from their local types and recommended for commercial cultivation. Though is one of the common cucurbits in the country, it has been neglected by the plant breeder so for exploitation of hybrid vigour in recent years has led to remarkable yield advances in many crops, however, the possibility of exploitation of hybrid vigour in bottle gourd as a result of inter varietal crossing, was shown by Rajendran (1961) owing to the existence of wide variability, monocious nature, conspicuous and convenient flower bottle gourd can serve as a gourd source for the manifestation of heterosis and it's commercial exploitation. Besides this, cucurbits are a distinct group among the cross pollinated crops that they do not suffer much from inbreeding depression thus heterosis breeding can prove as a useful tool in bottle gourd improvement for early maturity, higher yield, better quality and fruit uniformity are major advantages of bottle gourd hybrids. There is considerable scope to exploit heterosis in bottle gourd. Combining ability analysis is important to the plant breeder as it helps in understanding the nature of gene action governing the expression of the character in question and thus help in deciding upon the future breeding strategy. Development of the concept of combining ability has helped in choosing the best combiners which can exhibit maximum hybrid vigour in the F1. General combining ability is the average performance of lines in hybrid combinations while the specific combining ability refers to the deviation of certain crosses from expectations on the basis of 5 the average performance of the line evolved (Sprague and Tatum, 1942). General combining ability includes additive variance and variance arising due to additive x additive interaction, while specific combining ability includes non-additive genetic variances arising from dominance and epistasis.

In bottle gourd, various biometrical techniques namely line x tester, diallel and half diallel analysis are commonly used for the analysis of heterosis, combining ability and gene action. For any successful breeding programme, genetic information on variability, combining ability, gene action, extent of heterosis and association between different characters is of paramount importance. This information helps in identifying the best genotype, combination and also breeding methods to be followed either for exploiting hybrid vigour or different selection procedures through pedigree breeding and also to construct plant architecture through different selection indices.

In a recent years, bottle gourd breeding has been concentrated towards increased yield, earliness, quality, disease and pest resistance. A line x tester analysis as proposed by Kempthorne (1957) is the most popular, more desirable and has been found to be more suitable in many respects. It helps in testing a large number of genotypes to assess the heterosis, gene action and combining ability. The choice of right type of parents to be incorporated in programme is a crucial step for breeder because the use of parents of known superior genetic worth ensures much better success.

Accordingly, breeder should have genetic information with respect to genetic basis of fruit yield and its components and combining ability of the elite parents. Selection of parents is the most important aspect of any hybridization programme and the plant breeders should be sure that the selected genotypes could be explorable and must be in balance with the environments in which they are to be grown. All the selected parents may not result in production of desirable hybrids because of the ability to combine well with some, while poor with others. These aspects force the plant breeders to realize the importance of studying the general and specific combining ability of the parents and hybrids, respectively.

Practical Utility of Research Problem

In a recent year, bottle gourd (*Langenaria siceraria* (Mol.) standl) breeding has concentrated on increased yield, earliness, quality, disease and pest resistance. A line x tester analysis as proposed by Kempthorne (1957) is most popular, more desirable and has been found to be more suitable in many respects. Line x tester analysis helps in testing a large number of genotypes to assess the heterosis, gene action and combining ability. The choice of right type of parents to be incorporated in programme is crucial step for breeder because the use of parents of known superior genetic worth ensures much better success. A line x tester analysis has been a popular mating method to assess the combining ability of the parents.

Breeder should have genetic information with respect to genetic basis of fruit yield and its components and combining ability of the elite parents. Selection of parents is the most important aspect of any hybridization programme and the plant breeders should be sure that the selected genotypes could be explorable and must be in balance with the environments in which they are to be grown. All the selected parents may not result in production of desirable hybrids because of the ability to combine well with some, while poor with others. These aspects force the plant breeders to realize the importance of studying the general and specific combining ability of the parents and hybrids, respectively.

Keeping all the facts in view, the present investigation using line x tester mating design involving 20 genetically diverse genotypes (15 lines + 5 testers) of bottle gourd is proposed following objectives.

Objectives:

1. To study the nature and magnitude of heterosis for fruit yield and its component traits
2. To estimate the general and specific combining ability of parents and crosses, respectively for various traits
3. To study the nature and magnitude of gene actions governing fruit yield and its component traits

Review of literature:

Bottle gourd (*Langenaria siceraria* (Mol.) standl) is an important vegetable crop from cucurbitaceae family. Cucurbitaceous vegetables, besides the distinct groups, do not suffer much from inbreeding depression. This enabled considerable genetic improvement in this group particularly cucumber, muskmelon, watermelon and to some extent bottle gourd and bottle gourd. However, it appears that the crops such as sponge gourd, ridge gourd, snake gourd and ash gourd have not been paid enough attention, which they deserve. In spite of the diverse land races available in different parts of our country, the systematic efforts made to improve these crops appeared to be sporadic. The literature related to the various aspects on bottle gourd is also scanty and therefore, in order to strengthen the review of work done on bottle gourd and other related cucurbitaceous vegetables crops like bottle gourd, ridge gourd, are collected and reviewed under the following sub-headings.

The superiority of F_1 hybrids over their parents is termed as heterosis. The phenomenon of heterosis in plant hybrids was first recognized by Koelreuter (1763). Shull (1914) gave the term "Heterosis" to the developmental stimulus resulting from the union of different gamates. Many workers including Shull (1908 and 1914), East (1908), Bruce (1910) and Crow (1948) put forth hypothesis justifying the manifested effects of heterosis. The manifested effect of heterosis is called hybrid vigour. Fonseca and Patterson (1968) coined a new term "heterobeltiosis" to describe improvement of heterozygous in relation to better parent. Soon after Mather and Jinks (1971) defined heterosis as the amount by which the mean of F1 exceeds its better parent. Hays and Jones (1916) were the first investigators to report heterosis in cucurbits. In subsequent years, the exploitation of heterosis in cultivated plants became a potential tool in crop improvement. However, except cucumber and melons, the research workers did not worked on the other cucurbits till late forties.

Rashid *et al.* (2009) studied that highly significant differences for all the characters among the materials studied. Heterosis was higher for yield per plant, number of fruits per plant and individual fruit weight, medium in fruit length and fruit diameter, and lower in days to 1st harvest. Hybrids (F1) 10 x 17 and 19 x 26 manifested highest heterosis over midparent (73.1%) and better parent (61.8%), respectively, for yield per plant.

Kumar *et al.* (2014) studied that diallel cross analysis for development of Hybrid in Bottle Gourd (Lagenarian siceraria (Mol.) Standl. The gene effects with respect to its nature and magnitude for yield and yield contributing traits (12 characters) were studied by involving 45 hybrids obtained by crossing 10x10 half diallel pattern. The estimates components of variance and their related statistic for different characters especially fruits per plant (6.45*±0.97) and fruit yield per plant (2.12*±0.43) have been found significant ($p<0.05$) for dominance components H1. The values of additive components D were also significant ($p<0.05$) for most of the characters except for no. of fruits per plant and fruit yield per plant (kg). These results indicate importance of both additive and dominance gene action in expression of these characters. The average degree of dominance (H1/D) 1/2 involved in the action of genes was found as over dominance for all the traits.

Singh *et al.* (2000) evaluated seven parental lines and their 21 F1 hybrids of bitter gourd obtained from half diallel to study the extent of heterosis for yield and yield contributing characters. The parents BG-5, BG-23 and BG-11 were observed to be three top performing parents for yield per vine. The negative heterosis which is desirable for days to appearance of first male and female flower, number of nodes bearing first male and female flower and days to first fruit harvest were common in most of the crosses. Appreciable heterosis was recorded over better and standard parent BG-25 (Pusa Do Mausami) for all the traits studied. In order of merit, F1 hybrids namely BG-11 x BG-25, BG-11 x BG-29 and BG-5 x BG-25 were recorded to be three best performing F1 hybrids for fruit yield and BG-5 x BG-52, BG-5 x BG-29 and BG-11 x BG-29 for number of fruits per vine.

Singh *et al.* (2001) studied heterosis in bitter gourd and revealed expression of heterosis over better parent and standard check (Punjab–14). The hybrid BL-235–1 x Punjab-14 showed maximum heterosis over better parent for early female flower, whereas ARU-41 x PDM exhibited the highest heterosis over Punjab–14 (standard check) for days taken to first picking (earliness). Higher heterotic values over better parent as well as standard check were observed in cross combinations HK-12 x PDM for fruit length, ACC-23-1 x PDM and Palwal Selection x PDM for average fruit weight, BG-4-2-1 x PDM and Palwal Selection x PDM for number of fruits per vine and BL-240-1 x Punjab–14 and BG-4-2-1 x PDM for vine length. For fruit girth, HK-12 x PDM showed highest heterosis over Punjab–14. Palwal Selection x PDM showed high heterotic value over better parent and Punjab–14 for average fruit weight, number of fruits per vine and total as well as marketable yield per plant.

Tewari *et al.* (2001) studied heterosis using 15 crosses in bitter gourd, the 8 crosses showed high significant heterobeltiosis for fruit yield per plant. The outstanding hybrids in order of superiority were Kalyanpur sona x Kalyanpur baramasi, PBIG-2 x Priya white, Kalyanpur baramasi x Priya white, PBIG-2 x Kalyanpur sona and PBIG-4 x Kalyanpur sona.

Liu-Zheng Guo *et al.* (2003) studied heterosis for the node of the 1st female flower and number of female flowers at earlier stages. The node of the 1st female flower of 6 crosses showed negative heterosis over the mid-parent, and 13 crosses recorded negative heterosis over the superior parent. Four crosses were inferior to the small parent. The number of female flowers of 5 crosses showed positive heterosis over the mid-parent, whereas 4 crosses exhibited positive heterosis over the superior parent.

Behera (2004) reported gynoecy is in bitter gourd which could be a useful tool to exploit heterosis on commercial scale with cheaper rates. However, at present, hybrid seed is produced by hand pollination without emasculation.

Shweta *et al.* (2005) reported superior high yielding hybrids namely PBIG 3 x Kalyanpur Sona, PBIG 56 x PBIG 1, PBIG 56 x PBIG 44, NDBT 12 and PBIG 212 x Kalyanpur Sona with the yield of 154, 153, 169 and 132 q/ha, respectively. The range of standard heterosis for total yield for these five crosses varied from 10 to 40.83 per cent

Panda and Singh (2005) studied the diallel analysis in bitter gourd. The crosses PBIG 2 x PBIG 1, PBIG 2 x Priya White and PBIG 1 x Kalyanpur Sona were found to be best heterotic combinations. No direct relation could be established between genetics and heterosis. However, it was concluded that moderate to high level of diversity is essential to reap the fruits of heterosis.

Jadhav *et al.* (2009) studied heterosis in bitter gourd with eight parental lines and their 28 F1 hybrids of bitter gourd obtained from half diallel design. The parents Hirakani, DVBTG-7 and Phule Green Gold were observed to be three top performing parents for the fruit yield per plant. The negative heterosis which is desirable for days to appearance of first female flower, node number of first flower and days to first harvest were common in most of the crosses. Significant heterosis was recorded over better and best parents. In order of merit F1 hybrids Phule Green Gold x DVBTG-5, MC-84 x Co. White Long and Phule Green Gold x MC-84 were recorded to be three best performing F1 hybrids for fruit yield per plant.

Thangamani *et al.* (2011) studied heterosis for yield and quality characters by using full diallel analysis carried out in bitter gourd with 10 diversified parents. Hybrids Preethi x MC-30, KR X USL, MC-105 X MC-10 and Priyanka x CO-1 registered favorable values for standard heterosis for yield and quality parameters. Hence, these hybrids are recommended for commercial exploitation of heterosis. Hybrid 'Preethi x MC-30' registered favorable values for the most important characters like earliness, number of fruits, fruit yield and quality.

Laxuman *et al.* (2012) studied the heterosis by using diallel mating design involving eight parents and twenty eight hybrids. The hybrid, Gadag Local X Com Green Long exhibited the maximum positive heterosis of 23.16 per cent over commercial check followed by two hybrids ranging in the heterosis between 15.99 per cent (Gadag Local X IC-68310) and 17.51 per cent (Gadag Local X Pusa Vishesh) in contrast sixteen hybrids exhibited significantly positive average heterosis i.e. Gadag Local X Coimbatore Green Long also showed the highest per cent as well as standard heterosis for number of fruits per vine also, indicating the close association between number of fruits per vine and productivity.

12.2 Combining Ability and Gene Action:

The importance of combining ability has been well emphasized because phenotypically equally promising parents do not always give the desired cross combinations and produce superior off springs in segregating generations, whereas some combinations may give promising segregants. The ability of a parent to combine well and produce superior segregants in succeeding generations is an important criterion in selection of parents for a successful hybridization programme.

Sprague and Tatum (1942) described general combining ability (gca) as the average performance of lines in a series of crosses and ascribed it primarily to additive genetic variance or gene action and specific combining ability (sca) as those instances in which certain hybrid combinations do relatively better than would be excepted on the basis of average performance of parental lines which are regarded as the estimates of non-additive gene action. Further it was developed by Griffing (1956).

Khatra *et al.* (2000) reported that among males ARU-41 exhibited high GCA for earliness, fruit girth, average fruit weight, number of seed per fruit and number of fruit over vine and yield per plant. Among males, Punjab-41 and Pusa Do Mosmi (PDM) showed high GCA effect for most the characters regarding SCA effects. BL-240-1 x PDM and Palwal selection x PDM showed high SCA effect for number of fruit per vine as well as marketable yield per plant.

Sharma and Bhutani (2000) studied in combining ability, component and graphical analyses five genetically divergent parents by using half diallel in bitter gourd for the inheritance of fruit characters. The values of fruit diameters (1.13), average fruit weight (1.88) and number of seeds per fruits (2.83) were under the control of non additive type of gene action for their genetic control.

The combining ability of 15 hybrids was studied by Tewari *et al.* (2001). They reported that Kalyanpur sona, Priya white and PBIG-3 had high GCA for fruit yield per plant and the crosses Kalyanpur sona x Kalyanpur baramasi, PBIG-2 x Priya white, PBIG-2 x Kalyanpur sona, PBIG-1 x PBIG-2 and PBIG-2 x PBIG-4 had high SCA effect.

The parent MDU-1 was found to be good general combiner for node to first female flower, days to first female flowering and ascorbic acid. In general, a close association was observed between per se performance and gca effects of the parents. The per se performance of the hybrid, however, failed to show consistent relationship with the respective sca effects (Rajeswari and Natarajan, 2002).

The combining ability of 15 hybrids was studied by Bhave *et al.* (2004) and they found that Konkan Tara and Priya were the best general combiners for fruit yield and number of fruits per plant. The cross RHR-1 x Priya was the best specific combination for fruit yield and other yield contributing characters.

Singh *et al.* (2004) carried out 8x8 diallel analysis and reported that four parents possess significant GCA effects for earliness, two for vine length, three for number of fruits per vine, two for fruit length and four for fruit yield per vine. Kalyanpur Sona showed the highest GCA for earliness in both the seasons. PBIG 90 and PBIG 3 had highly significant GCA effects during the wet season, whereas it was highest with PBIG 4 during the summer season. PBIG 56 showed a highly significant GCA effect in both the seasons for number of fruits per vine. PBIG 4 and Kalyanpur Baramasi showed highly significant GCA effects for fruit length in both the seasons. PBIG 1, PBIG 90, PBIG 4 and PBIG 56 has positive GCA effects. PBIG 86 x Kalyanpur Baramasi and PBIG 2 x Kalyanpur Baramasi showed high SCA effect for earliness. PBIG 56 x Kalyanpur Baramasi and Kalyanpur Sona x PBIG 90 (wet season) and Kalyanpur Sona x PBIG 86 and PBIG 2 x Kalyanpur Baramasi (summer season) showed high SCA effect for vine length.

The analysis of variance for combining ability revealed more of gca effects than sca effects for most of the traits. None of the parents under present experiment showed good gca for all characters. Superior lines such as PBIG 4, PBIG 2 and PBIG 1 were selected on basis of gca. None of the crosses proved to be good specific combiner for all traits (Panda and Singh, 2005).

Sundharaiya and Venkatesan (2007) Studied the combining ability in eight bitter gourd lines and indicated that the line MC 13was good general combiner for yield per vine. The lines Ayakudi Local and Mithipagal recorded negative general combining ability and lower per se for days to first female flowering and days to fruit maturity. The hybrids MC 13 x Arka Harit, Panruti Local x VK 1 Priya and MC 13 x Co 1 registered higher per se and specific combining ability for fruit length, individual fruit weight and yield per vine. The lines MC 13, Panruti Local, Ayakudi Localand Mithipagal expressed higher per se and general combining ability for most of the characters can successfully be utilized for development superior hybrids in bitter gourd.

Yadav *et al.* (2008) studied the combining ability with six lines and four testers in bottle gourd for seventeen traits. Gy-I was found good combiner for number of fruits per vine, number of fruits per plot, intermodal length, days to first appearance of male flower and vine length. For yield per vine, yield per plot, yield/ha, fruit width and days to first appearance of female flower, MC-84 was best general combiner. While S-17for fruit length, fruit weight and JMC-21for number of nodes, first effective node and number of primary branches per vine were good general combiners. The crosses MC-84 x JMC-22 for yield per plot, yield (q/ha) and MC-84 x VRBT-69 for yield per plot, yield per vine, fruit width, days to first appearance of female flower, number of primary branches per vine exhibited significant sca.

Day *et al.* (2010) reported exploiting gynoecy for combining ability in bottle gourd. Thirty six F1 hybrids and nine inbred lines including one gynoecious line were used to assess combining ability. Among parent, gynoecious parent, DBGy-01 showed maximum GCA effect in desirable direction for vine length node to first female flower, days to first picking, number of fruits and yield per plant. The parent Priya exhibited the highest GCA effect for fruit length, weight and diameter. The gynoecious inbred DBGy-201 showed maximum GCA effect in desirable direction for node to first female flower, days to first picking, number of fruit and yield per plant.

Kumara *et al.* (2011) studied combining ability using six lines and four testers in a line x tester mating design. Out of ten parents Panurthy, Coimbatore Long, Chidambaram Small and VRBT-100 were observed to be the best general combiners as they have made significant contribution in yield contributing characters. The crosses Coimbatore Long x Panurthy exhibited high SCA effect for fruit yield per vine, node at first female flower appears and day to first harvest while VRBT-100 x Panurthy was best for sex ratio and number of seeds per fruit in desired direction.

Thangamani *et al.* (2011) studied combining ability for yield and quality characters. Evaluation of parents based on per se and gca effects revealed that the parents Preethi, CO-1, MC-30, Uchha Bolder, Green Long, MC-105 were identified as the best genotypes for improvement of yield combined with quality characters. The hybrids viz., Preethi x MC-30, KR x USL, MC-105 x MC-10 and Priyanka x CO-1 had registered favourable values of mean, significant sca for yield and quality parameters. A comparison of the parental gca and sca of hybrids revealed that hybridization between good x good and medium x poor or medium x medium combiners had given rise to hybrids with significant sca effects.

Laxuman *et al.* (2012) studied combining ability for productivity traits in bottle gourd. They observed predominant role of non-additive gene action for all the characters namely vine length at 90 days, days to opening of first male flower, days to opening of first female flower, number of fruits per vine, fruit length, fruit diameter and fruit yield per vine. The lines, Gadag local, Pusa Vishesh, Coimbatore Green Long and IC-68310 were identified as the good general combiners for fruit yield per vine. The hybrids Gadag local x Pusa Vishesh and Gadag local x Coimbatore Green Long were identified as good specific cross combinations for total fruit yield per vine and characters like days to opening of first male flower, days to opening of first female flower and number of fruits per vine.

Material and Methods

1	Name of the experiment	:	LINE X TESTER ANALYSIS FOR HETEROSIS AND COMBINING ABILITY IN BOTTLE GOURD (*Langenaria siceraria* (Mol.) standl)
2	Location	:	Three i. LPU Research station
3	Season	:	*summer* 2018
4	Date of sowing	:	Timely
5	Number of Genotype	:	20 + 1 = 16
6	Experimental design	:	RBD (Plot size 30x 30 m^2)
7	Number of replication	:	3
8	Spacing	:	120 x 90 cm
9	Agronomic practice	:	As per recommendation
10	Plant protection	:	Need based

Observation

1) **Days to open first female flower**

The days required for the appearance of first female flower from date of sowing on each of five observational plants will be recorded separately and average numbers of days required for appearance of female flower will be worked out.

2) **Days to opening of first male flower**

The number of days taken by the first male flower of all plants to open, from the day of sowing will be recorded.

3) **Number of nodes bearing first female flower**

The node number from cotyledonous leaves, at which the first female flower appeared will be recorded.

4) **Days to first picking**

The number of days required for first picking of green, tender, marketable fruits in respect to each observational plant from the date of sowing will be recorded and the average number of days to first picking will be worked out.

5) **Internodal length (cm)**

After final harvest five internodal length (cm) will be recorded per vine at random and average values will be calculated.

6) **Vine length (cm)**

The length of vine in (cm) will be measured with the help of measuring tape from the base of the vine to the growing tip of main shoot at last picking.

7) **Number of primary branches per vine**

The number of primary branches on main stem of each observational plant will be recorded and mean number of branches per vine will be calculated.

8) **Number of fruits per vine**

The number of fruits of all pickings, harvested from five observational plants will be summed up to workout average number of fruits per vine.

9) **Average weight of fruit (g)**

The mean weight of fruit will be calculated by dividing total weight of all harvested fruits per vine by number of fruits per vine in grams.

10) **Fruit length (cm)**

Five fruits from each observational plant will be selected randomly during peak period of harvesting for recording the length of fruit. The length in centimeter will be recorded from peduncle end to blossom end of the fruit and the average length of fruit will be worked out.

11) Fruit girth (cm)

The fruits used for recording the length will also be used for measuring the girth of fruit. The measurement at mid-portion of fruit will be taken with the help of vernier calipers.

12) Fruit yield per vine (kg)

The weight of harvested fruits of all pickings from each observational plant will be summed up after the last picking and the average fruit yield per vine, in kilograms will be calculated.

15. Statistical analysis

The mean values of parents and F_1 hybrids for all the characters will be subjected to statistical analysis on following aspects:

15.1 Analysis of variance for experimental design

The replication wise mean value of randomly selected five plants will be used for statistical analysis of different characters as per analysis of variance for randomization block design (Panse and Sukhatme, 1985).

15.2 Heterobeltiosis:

It will be calculated as the deviation of F_1 from the better parent (Fonseca and Patterson, 1968) and will be expressed in percentage by the following formula:

$$H_1 (\%) = \frac{F_1 - BP}{\overline{BP}} \times 100$$

Where,

$\overline{F_1}$ = Mean performance of F_1

$\overline{BP}$ = Mean value of better parent of the two parents used in the respectively cross combination

15.3 Standard heterosis

It refers to the superiority of F_1 over the standard commercial variety. It is also called as economic heterosis. It will be estimated as follows

$$H_2 = \frac{F_1 - SC}{SC} \times 100$$

Where,

$\overline{F_1}$ = Mean performance of F_1.

$\overline{SC}$ = Mean performance of the standard check (Priya).

15.4 Combining ability analysis

The combining ability analysis will be carried out for a line x tester mating design as per the procedure given by Kempthorne (1957).

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