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Studies on combining ability and gene action in kharif season bottle gourd [*Lagenaria siceraria* (Molina) standl.]

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Abstract
Observations were recorded on parents and F1 for 12 traits viz. days to first male and female flower anthesis, node number to first male and female flower appearance, days to first fruit harvest, vine length (m), number of primary branches per plant, fruit length (cm), fruit circumference (cm), fruit weight (kg), number of fruits and fruit yield per plant (kg).

Parent NDBG-744, Pusa Naveen and NDBG-707 for number of fruits and yield per plant, for number of fruits and yield along with earliness parent NDBG-707 and Pusa Naveen, for small fruit NDBG-749-2 and Pusa Naveen, were found good general combiners. Combining abilities coincides with per se performance.

Additive and non additive gene action with over mean degree of dominance indicated predominant role of non-additive gene action in the inheritance of most of the traits. Asymmetrical distribution of genes showing dominance with more proportion of dominant gene than recessive one were detected for all the trait's no major gene group were involved in the inheritance of all the traits studies.

Keywords: kharif season bottle gourd, Additive and non additive gene action

Introduction
Bottle gourd [Lagenaria siceraria (Mol.) Standl.] having chromosome number 2n=22 also called white flowered gourd or calabash gourd is an important cultivated annual crop grown throughout the country. It is grown for its tender fruits which is basically used as vegetable and also used to prepare sweets, pickles, rayata and other delicious preparations. The dried shells of mature fruits are hard and used as containers, utensil, musical instrument or ornamental items. Lagenaria siceraria is used in Ayurvedic Pharmacopoeia in India. Its fruits are traditionally used as a nutritive agent having cardio protective, cardio tonic, general tonic, diuretic, aphrodisiac, antidote to certain poisons and scorpion stings, alternative purgative and cooling agents. It cures pain, ulcers and fever and is used for pectoral-cough, asthma and other bronchial disorders. The seeds are edible part in China where people boil it in salt and eat as an appetizer. It has been used routinely as a source of rootstock for watermelon and other cucurbit crops in both Korea and Japan as a mean to reduce the incidence of soil-borne diseases and to promote the vigour of the root system of the crop under conditions of low temperature.

India being the second largest producer of vegetable in the world stands next only to China, shares about 15 per cent of the world output of vegetables possessed about 3 per cent of total cropped area in the country. The current production level is over 129.077 million tonnes with an area of 7.98 million hectares (NHB, 2008-09). In spite of such a large production, the per capita per day supply of vegetables could not rise above 175 g in country, which is lower than the recommended dietary allowance (RDA) of 280 g per capita per day for a balanced diet (Rai and Pandey, 2007) [22]. The vegetable requirement of our country is estimated to be 220 million tonnes by 2020 (Singh, 2004). This target can best be achieved through use of improved varieties and hybrid technology in combination with superior crop management skills. Substantial increase in productivity appears feasible even with diminishing land and water resources.

It is one of the most nutritive menu for human and tone up his energy and vigour, because it happens to be valuable source of carbohydrates, proteins, vitamins and minerals. The edible 100 g bottle gourd fruit contains 96.3 per cent moisture, 2.9 per cent carbohydrate, 0.2 per cent protein, 0.1 per cent fat and 0.5 per cent mineral matter. The mineral matter reported to be present in fair amount of calcium, phosphorus, iron, potassium, sodium and iodine. The fruits are also known to have good sources of essential amino acid as leucine, phenylalanine, threonine, cystine, valine, asparatic acid and proline, along with a good source of vitamin B, specially thiamine, riboflavin, niacin and ascorbic acid. The fruits are rich in pectin also, which shows good prospects for Jelly preparation.

Among the various mating designs, diallel cross techniques has been most frequently used to determine nature and magnitude of gene actions through the estimates of genetic components, general and specific combining ability variances and their effects in many self, often–cross and cross pollinated crops. In bottle gourd, several workers have used this design for estimating the components of variance and combining ability (Sivakami *et al*., 1987; Jankiram and Sirohi, 1989; Maurya *et. al*., 1993 and Kumar, 2000) [19].

High level of specific combining ability (sca) variance and non-additive type of gene action have also been reported in several major economic traits of bottle gourd including yield by Rajendran, 1961; Chaudhary and Singh, 1971 [5]; Sharma *et al.*, 1993 [26] and Pitchaimuthu and Sirohi, 1994 indicating thereby ample scope of exploitation of hybrid vigour in bottle gourd.

Methods and Materials

The experiment investigation aims at determining heterosis, combining ability and gene action in an experiment involving evaluation of 9 parental lines (Pusa Naveen, NDB-739, 707, 709-3, 718, 741, 744, 748 and 749-2) of bottle gourd and their 36 F1 conducted at MES, Vegetable Science, NDUAT, Kumarganj, Faizabad during Kharif, 2010. The experiment was laid out in RBD with three replications in single row of 3 x 3 m^2 plot size with row to row spacing of 3 m and plant to plant 50 cm. The selected parental lines i.e. Pusa Naveen (P_1), NDBG-739 (P_2), NDBG-707 (P_3), NDBG-509-3 (P_4), NDBG-718 (P_5), NDBG-741 (P_6), NDBG-744 (P_7) and NDBG-748 (-P_8) and NDBG-749-2 (P_9)were crossed in the all possible combinations in diallel technique, excluding reciprocals, during summer, 2009 to get 36 F1 hybrids for the study of combining ability and gene action for twelve characters. The experiment was carried out in a Randomized Complete Block Design with three replications to assess the performance of 36 F1 hybrids and their 9 parental lines. The crop was planted in rows spaced at 3.0 meters with plant to plant spacing of 0.5 meter. The experiment was sown on 10th August, 2010. All the recommended agronomic package of practices and plant protection measures were followed to raise a good crop.

The analysis of variance for design of experiment was done for partitioning the variance into treatments and replications according to procedures given by Panse and Sukhatme (1967).

The combining ability analysis for different characters was carried out following the method 2 model 1 of Griffing (1956 b), where parents and F1's were included but not the reciprocals. Thus the experimental material for this method comprises of n (n+1)/2 genotypes.

The genetic components of variation were calculated for the analysis of numerical approach followed the method given by Jinks and Hayman (1953), Hayman (1954a) [12] and Askel and Johnson (1963) [2].

Results and Discussion

Bottle gourd has become a crop of commercial importance owing to the increased awareness about its nutritional and medicinal value, and consequent demand round the year among consumers. The major objective of bottle gourd breeding is to develop homogeneous high yielding varieties with earliness, desirable/ attractive fruit shape and size. Heterosis breeding offers the most efficient tool in form of hybrid to achieve this objective. With the use of inbreds in cross pollinated vegetable crops like bottle gourd hybrid with earliness, uniform fruits, fruit size, wide adaptability, resistance and high yield potential can be developed to enhance productivity and production.

The success in breeding depends mainly on the choice of superior parents for hybridization and the information on nature and magnitude of gene action and combining ability of the parents. These genetic parameters help in deciding the most appropriate breeding methodology for further improvement. Among the various mating designs, diallel cross techniques has been most frequently use to determine the nature and magnitude of gene action through the estimates of genetic components, general and specific combining ability variances and their effects in many cross pollinated vegetable crops. In bottle gourd many workers (Samadia and Khandelwal, 2001; Singh and Kumar, 2002; Pandey *et al.*, 2003; Dubey and Maurya, 2004; Sharma *et al.*, 2004; Sirohi *et al.*, 2005; Dubey and Maurya, 2007; Sharma *et al.* 2010) [8, 25] have also used this technique for estimating heterosis, combining ability and gene action.

Keeping all these points in view, the present investigation was designed to investigate the extent of heterosis, combining ability and gene action, for twelve important quantitative traits, including fruit yield per plant, in a 9 x 9 diallel cross of bottle gourd. The important features of the findings of present investigation are discussed in the light of pertinent literature in the offing pages.

Per se performance of parental lines and F_1 hybrids

Analysis of variance due to source of variations for different characters revealed highly significant differences among the genotypes, parents, hybrids and parents *vs* hybrids which suggested great variability in these source of variations for almost all the 12 characters studied.

Perusal of *Per se* performance of the parental lines and F_1 hybrids (Table-1) for all the traits studied revealed a wide range of mean values which indicated that the parental lines involved in this study were genetically diverse and had good breeding value, which confirmed the predictions of analysis of variance. Among the parental lines, P_1 was the earliest with respect to days to first male flower anthesis (43.83 days), days to first female flower anthesis (45.04) and days to first fruit harvest (52.81); parent P_5 had highest fruit length (57.56); parent P_6 had highest number of primary branches per plant (25.01) and longest vine length (7.26 cm). P_9 had thickest fruit circumference (38.75 cm) minimum nodes to first male flower appearance (10.1), parent P_7 had maximum number of fruits per plant (6.65) and P_8 had maximum fruit yield per plant (7.79 kg) and fruit weight (1.24 kg).

Out of 28 F_1 hybrids fifteen hybrids *viz*., P_1 x P_3, P_1 x P_5, P_1 x P_7, P_1 x P_9, P_2 x P_5, P_2 x P_7, P_3 x P_4, P_3 x P_6, P_3 x P_7, P_3 x P_8, P_4 x P_9, P_5 x P_6, P_5 x P_7, P_7 x P_8 and P_7 x P_9 produced significantly highest yield than the standard variety Pusa Naveen along with good fruit shape (Table 4.2). However, the best five hybrids (P_7 x P_9, P_1 x P_7, P_3 x P_7, P_1 x P_3 and P_3 x P_8 among the F_1 in respect to fruit yield per plant were also found superior for number of fruits per plant. These top hybrids viz., P_7 x P_9, P_1 x P_7, P_3 x P_7, P_1 x P_3 and P_3 x P_8 were observed for small near cylindrical slight curve, medium long cylindrical slight curve, long thin curved, medium long near cylindrical and long thin slender bottled shaped fruits respectively and were found suitable for market demand. This

indicated the superiority of F_1 hybrids against the standard variety.
It may, therefore, safely be concluded that either of the parents P_1 or P_8 or both may be a better choice in any heterosis breeding programme intended to breed early hybrids. Present results are in conformity with the findings of Dubey and Maurya (2004) [8] and Singh (2008).
Standard heterosis over rest of the economic traits *viz*., vine length, number of primary branches per plant, fruit length, fruit weight, number of fruits per plant and fruit yield per plant were quite high, except for fruit circumference. High heterosis compared to early maturity traits for these characters have also been reported by Dubey and Maurya (2004) [8]; Pal *et al.* (2005) and Sirohi *et al.* (2005).

Combining ability variances and their effects

In any breeding method it is necessary to choose the parents objectively. *Per se* performance has been an important criteria for selection of parents for making crosses by the breeder. But good performing, parental lines do not always produced desirable F_1 or segregates. The information regarding combining ability of the parents, for yield and various yield attributes becomes relevant to the plant breeders for chalking out an efficient breeding methodology.
Among the several techniques available for quantitative genetic analysis, diallel cross analysis has usually been found to be efficient and easiest method to identify the best donors for hybridization. Combining ability studies (Griffing, 1956b) are not only useful in analyzing the genetic architecture of the characters under study but also help in evaluating the breeding potential of the parental lines on the basis of several parameters.
The information thus obtained, helps in designing suitable breeding procedures for the genetic improvement of the crop and the selection of suitable parents which when crossed will give rise more desirable F_1 and or segregates. Fixed effect model was used in the present study as advocated by Hayman (1963) [16] that fixed model is appropriate if the number of parents does not exceed ten.
Genetic analysis in the present investigation was done by two methods namely, variance component analysis Hayman (1954 a) [12] and combining ability analysis (Griffing, 1956 b). These analysis can be equated as g.c.a. variance consist of additive genetic variance and additive x additive interaction (Griffing, 1956 b). The s.c.a. variance accounts for non-additive type of gene action which is composed of dominant and epistatis (Griffing, 1956 b) and can be equated to dominance variance by Hayman's analysis (1954a) [12]. The choice of parents especially for heterosis breeding should be based on combining ability test and their mean performance (Yadav and Murti, 1966). In the following pages the results of combining ability for a diallel analysis consisting nine parental lines 36 F_1 hybrids are discussed.
Highly significant variances were observed both for general and specific combining ability for all 12 characters studied. Highly significant g.c.a. and s.c.a. variance revealed that both additive and non-additive gene action were important in expression of all the traits under study. Thus, both selection and heterosis breeding methods, respectively might be advantageous for effective utilization of additive and non-additive genetic variance for improvement of these traits. Similar findings had also been reported by Singh *et al.* (2005) and Dubey and Maurya (2006).

General combining ability effects

Perusal of g.c.a. effects of the parents as presented in Table-2 and ranking of desirable parents on the basis of estimate of gca effect for 12 character (Table 2) revealed that it was difficult to pick-up a single good combiner for all the characters. However, parental lines P_1 and P_3 having significant and negative g.c.a. effect for most of maturity traits and parents P_7, P_3 and P_1 showed significant positive gca effects for fruit yield per plant along with number of fruits per plant (Table-2).
Thus, these two lines (Pusa Naveen and NDBG-707) appeared to be good general combiner for early maturity while the lines NDBG-744, NDBG-707 and Pusa Naveen found good general combiner for fruit yield as well as number of fruits per plants. Parents P_4, P_6 and P_7 showed poor general combiner for maturity traits and fruit yield per plant but parent P_7 was best general combiers for yield tirats. This result may be due to low performance of parent P_4 and P_6 for yield per plant. In an attempt to identify most desirable parents based on gca effect as well as *per se* performance the three best parents were considered for each traits. This indicated a positive association between the two parameters (gca effect and *per se* performance). Similar correspondence between these two parameters was observed by Gill and Kumar (1988) [9] in water melon, Musmade and Kale (1986) [21] in cucumber, Singh *et al.* (1996), Sit and Sirohi 2005) [30] and Sreevani (2005) in bottle gourd. Commonness of parents both for gca effect and *per se* performance suggested that mean value of parents for a particular trait may have some predictive significance for its gca effect for that trait.

Specific combining ability effects

The s.c.a. effects represent non-additive gene action is non-fixable. Specific combining ability helps in the identification of superior cross combinations for development of promising varieties/hybrids. The crosses showing high s.c.a. effects involving parents with high g.c.a. effects may give rise to desirable segregants in future generations. Since, s.c.a. effect of the cross is an estimate while, the *per se* performance is the realized value, the later should also be given due consideration, while, making selection of best cross combinations. The sca effects of parents involved in the cross/crosses based on the above two criteria have been presented in Table-4.8. out of 36 F_1 hybrids, significant sca effects in favourable direction were exhibited by six hybrids for days to first male flower anthesis, six hybrids for days to first female flower anthesis, five hybrids for days to first fruit harvest, seven hybrids for fruit length, eleven hybrids for number of fruits per plant eleven hybrids for fruit yield per plant (Table 2). It was observed that in general, the majority of the crosses which shoed significant sca effect for increased yield also involved at least one parent having high and significant gca effect. Similar results have also been reported by Singh *et al.* (1996), Kushwaha and Ram (1997), Dubey and Maurya (2006).
The three best F1 hybrids showing the highest significant desirable sca effect for fruit yield per plant in order of merit were P_4 X P_9 (2.55), P_7 x P_9 (2.16) and P_3 x P_4 (1.93). The top three crosses found for highest sca effect for fruit yield per plant also showed significant sca effect for some other components as well (Table 2). The hybrid P_3 x P_9 possessed highest negative sca effect (-2.83) for fruit yield per plant. The cross P_6 x P_7 exhibited highest negative sca effect (-5.51)

followed by P_5 x P_9 (-2.83) and P_1 x P_4 (-2.76) for days to first fruit harvest. Highest sca effect for fruit length was observed for P_2 x P_8 (7.83) and fruit circumference for p_2 x P_9 (2.60) (Table-2).

The crosses, which had significant estimate of s.c.a. effect, involved in general high x high, high x low and low x low combiners. In the bottle gourd in general, such trends were also reported by Singh *et al.* (1996), Singh *et al.* (1999), Kumar (2000) and Kumar (2007).

Table 1: Mean values for yield and yield attributing traits of parents and their F_1s in bottle gourd.

Genotypes	Days to first male flower anthesis	Days to first female flower anthesis	Node no. to first male flower appearance	Node no. to first female flower appearance	Days to first Fruit harvest	Vine length (m)
1	2	3	4	5	6	7
Parents						
Pusa Naveen (P_1)	43.8333	45.0433	10.8333	13.8333	52.8100	6.0267
NDBG-739 (P_2)	47.3000	49.3333	11.6500	14.6333	55.4667	7.2333
NDBG-707 (P_3)	51.2667	46.2500	10.6033	12.8033	55.5000	4.9500
NDBG-509-3 (P_4)	49.9333	50.1333	14.5800	16.4000	58.8667	7.1667
NDBG-718(P_5)	47.5667	47.1833	13.2667	14.4333	54.5333	7.0667
NDBG-741 (P_6)	49.0667	48.7000	14.5733	16.1333	58.5333	7.2667
NDBG-744 (P_7)	48.0000	47.3267	14.7667	16.0333	57.0000	6.8000
NDBG-748(P_8)	47.6667	47.4000	13.8000	15.6867	55.3100	7.2333
NDBG-749-2(P_9)	45.9167	47.5500	10.1767	13.2800	55.6467	6.8500
F1 hybrids						
P_1XP_2	42.0700	43.8733	10.4100	11.2833	52.5000	4.5800
P_1XP_3	47.5267	47.7667	11.0933	13.1767	55.4667	7.4833
P_1XP_4	44.6600	43.6333	10.8733	14.0033	52.5000	6.3300
P_1XP_5	44.2667	50.2733	12.2233	14.2200	53.6267	7.3467
P_1XP_6	46.2667	47.6633	13.5600	14.3867	55.0367	6.8567
P_1XP_7	44.7567	44.3867	13.6633	14.6700	52.2267	6.7500
P_1XP_8	43.6000	42.9000	11.3133	13.4500	51.5000	5.0433
P_1XP_9	45.2333	44.4367	12.2500	11.6433	53.6767	8.3633
P_2XP_3	43.1000	46.9300	12.7267	13.0467	54.1133	7.4467
P_2XP_4	48.1033	50.1333	13.4900	15.2067	56.4767	7.3733
P_2XP_5	47.6800	48.1767	12.7333	13.6700	54.4167	6.7567
P_2XP_6	46.6667	46.5133	12.2600	14.2233	54.0000	7.0067
P_2XP_7	48.0000	48.4833	12.8267	14.4200	56.4467	6.8167
P_2XP_8	46.7567	46.5100	12.8333	13.6800	53.2967	6.7133
P_2XP_9	45.7967	47.1300	9.9700	13.7200	52.8300	6.2133
P_3XP_4	48.1667	47.9000	12.8033	15.5333	55.8333	6.4900
P_3XP_5	46.6067	44.5400	12.6600	13.7133	54.3733	7.6433
P_3XP_6	47.1667	44.7833	13.1533	14.5867	54.6333	8.6500
P_3XP_7	45.1333	43.8600	14.6500	14.9700	53.1000	7.4600
P_3XP_8	45.8000	45.4667	13.3433	15.4367	53.1333	6.8633
P_3XP_9	45.1167	44.9300	11.5933	13.1567	52.5000	6.3000
P_4XP_5	48.2700	49.1000	12.4933	15.3400	55.1000	7.1133
P_4XP_6	50.1333	50.6200	15.0467	16.8200	58.4000	7.6667
P_4XP_7	51.7933	54.1567	13.7367	16.4200	63.0233	5.5800
P_4XP_8	46.4500	47.1733	12.7533	14.3433	54.6733	4.6600
P_4XP_9	50.2900	51.4633	12.1500	15.1800	59.5767	7.3833
P_5XP_6	47.7800	47.1967	13.6567	15.2267	56.1300	7.7700
P_5XP_7	50.5333	49.7867	12.6600	14.3833	55.9733	8.6833
P_5XP_8	48.4467	47.6933	13.8133	15.7967	54.6667	6.7633
P_5XP_9	45.3767	43.9733	11.6067	11.7767	52.5000	6.3400
P_6XP_7	45.5667	46.1733	12.1233	13.7567	51.5000	5.6400
P_6XP_8	47.3833	47.5633	13.4167	16.3033	56.6233	7.8900
P_6XP_9	50.7333	52.5633	13.7200	14.5767	64.1667	8.7300
P_7XP_8	48.9000	48.8067	13.1533	14.6333	56.4333	9.0733
P_7XP_9	47.4667	48.6667	12.7833	13.6633	54.4400	8.0800
P_8XP_9	50.9567	50.7933	10.5067	8.4833	59.3333	4.5200
Grand Mean	47.1801	47.4431	12.6289	14.2697	55.2865	6.9105
C.V.(%)	3.9803	3.8060	7.2030	7.2673	3.8119	11.2411
S.E.(+_)	1.0842	1.0425	0.5252	0.5987	1.2167	0.4485
C.D. 5%	3.0471	2.9299	1.4760	1.6827	3.4195	1.2605
C.D. 1%	4.0369	3.8817	1.9555	2.2293	4.5304	1.6699

Genotypes	No. of Primary Branches per Plant	Fruit Length (cm)	Fruit Circumference (cm)	Fruit Weight (kg)	No. of Fruits per Plant	Fruit Yield per Plant (kg)
1	2	3	4	5	6	7
Parents						
Pusa Naveen (P_1)	19.1000	44.4333	24.0167	1.0967	5.1867	5.7000
NDBG-739 (P_2)	21.5333	50.3667	21.6000	1.0833	6.2700	6.7667
NDBG-707 (P_3)	12.3400	47.1333	21.0833	0.9167	5.6000	5.1267
NDBG-509-3 (P_4)	19.4667	44.0167	24.0167	1.0067	3.6867	3.6900
NDBG-718(P_5)	14.0000	57.5667	23.3000	1.2000	5.7333	6.8600
NDBG-741 (P_6)	25.0167	56.4500	23.0333	0.9100	5.7200	5.1667
NDBG-744 (P_7)	16.0000	49.7000	25.0000	1.1067	6.6500	7.2733
NDBG-748(P_8)	19.7000	45.2867	23.7000	1.2433	6.4233	7.7900
NDBG-749-2(P_9)	18.7500	28.9167	38.7500	1.1333	4.4800	5.0567
F1 hybrids	11.4000	42.4333	23.4333	0.9933	6.3567	6.2467
P_1XP_2	21.5567	47.3333	23.3400	1.0067	8.0033	8.0367
P_1XP_3	17.2500	47.6667	24.2833	1.0233	6.0067	6.1433
P_1XP_4	15.8933	43.5667	23.2800	1.0567	6.7000	7.0533
P_1XP_5	15.6567	44.5200	23.9000	0.9367	6.1867	5.7467
P_1XP_6	21.5567	41.5200	25.3667	1.0633	7.9200	8.4033
P_1XP_7	17.1200	44.1333	23.9833	1.1033	5.5267	6.0667
P_1XP_8	25.0867	31.4233	26.4067	1.2333	5.9733	7.3667
P_1XP_9	20.1267	51.4000	23.8500	1.1700	5.1267	6.0167
P_2XP_3	27.1600	48.0767	21.3667	0.8733	6.9400	6.0767
P_2XP_4	15.3967	53.0733	21.9900	1.1167	5.9333	6.6233
P_2XP_5	20.0333	43.1500	20.4167	0.9133	5.7300	5.2400
P_2XP_6	19.6533	48.8333	22.4500	1.1333	6.5367	7.3933
P_2XP_7	20.0733	56.2633	24.6100	1.1800	5.1967	6.1067
P_2XP_8	19.3100	38.5333	29.6167	1.1667	3.5367	4.1167
P_2XP_9	20.8000	46.9033	20.2000	1.1333	6.7200	7.5833
P_3XP_4	25.2233	57.0200	23.1833	1.2600	4.8967	6.1400
P_3XP_5	26.1467	60.0067	23.3833	1.1367	6.5533	7.4400
P_3XP_6	25.1167	57.9167	22.6833	1.0067	8.3200	8.3533
P_3XP_7	21.2000	56.8000	23.1400	1.1433	7.0167	8.0067
P_3XP_8	26.4767	39.8233	25.2333	1.1300	2.7867	3.1433
P_3XP_9	24.1367	59.2000	23.1667	1.1333	3.8033	4.3167
P_4XP_5	23.5967	52.5333	22.4667	0.8800	3.5533	3.1167
P_4XP_6	16.7800	52.5333	24.0833	0.8267	7.6133	6.3100
P_4XP_7	18.4033	45.2167	22.2167	1.0000	4.5067	4.5167
P_4XP_8	21.4333	37.4000	22.4800	1.2233	6.0900	7.4267
P_4XP_9	19.4467	56.5767	21.8033	0.9367	7.7000	7.2000
P_5XP_6	24.4067	53.2367	23.7833	1.1267	6.3100	7.1200
P_5XP_7	19.7500	54.1333	23.3433	1.0400	5.3467	5.5667
P_5XP_8	21.0933	40.2167	24.7167	1.1400	4.8100	5.4833
P_5XP_9	20.8100	49.6000	23.5833	1.1100	4.0467	4.4467
P_6XP_7	24.5667	52.6667	22.0833	1.0500	5.8100	6.1067
P_6XP_8	31.0200	39.6000	22.4833	1.1433	3.5800	4.0867
P_6XP_9	29.5667	42.0000	23.3000	1.1033	6.4167	7.0767
P_7XP_8	26.1833	39.1500	28.3667	1.1900	7.4333	8.8200
P_7XP_9	14.3100	35.2333	23.9667	1.1200	5.1767	5.8067
P_8XP_9	11.4000	42.4333	23.4333	0.9933	6.3567	6.2467
Grand Mean	20.7477	47.4125	23.8324	1.0778	5.7759	6.1807
C.V.(%)	7.2327	4.1591	4.1725	7.5959	9.8985	8.6416
S.E.(+_)	0.8664	1.1385	0.5741	0.0473	0.3301	0.3084
C.D. 5%	2.4349	3.1996	1.6135	0.1328	0.9277	0.8667
C.D. 1%	3.2259	4.2390	2.1377	0.1760	1.2290	1.1482

Table 2: Estimates of s.c.a. effects of F_1 hybrids for twelve characters in Bottle gourd.

Crosses	Days to first male flower anthesis	Days to first female flower anthesis	Node no. to first male flower appearance	Node no. to first female flower appearance	Days to first fruit harvest	Vine length (m)
1	2	3	4	5	6	7
P1XP2	-1.95	-1.99 *	-0.86	-1.86 **	-0.19	-1.78 **
P1XP3	2.75 **	3.52 **	-0.42	-0.03	2.86 *	1.04 *
P1XP4	-1.63	-3.86 **	-1.48 **	-0.70	-2.76 *	0.01
P1XP5	-0.78	4.53 **	0.24	0.67	0.86	0.51
P1XP6	0.70	1.44	0.88	0.00	0.30	-0.18
P1XP7	-0.66	-1.70	1.07 *	0.57	-1.57	0.00
P1XP8	-1.40	-2.53 *	-0.70	-0.15	-1.67	-1.19 **
P1XP9	0.30	-1.66	1.49 **	-0.61	-0.40	1.80 **
P2XP3	-3.20 **	0.74	0.90	-0.53	0.33	0.77
P2XP4	0.30	0.69	0.82	0.14	0.04	0.82
P2XP5	1.11	0.49	0.44	-0.25	0.48	-0.31
P2XP6	-0.42	-1.66	-0.74	-0.53	-1.91	-0.26
P2XP7	1.06	0.45	-0.08	-0.04	1.49	-0.17
P2XP8	0.23	-0.87	0.50	-0.28	-1.04	0.24
P2XP9	-0.65	-0.91	-1.10 *	1.10	-2.42 *	-0.59
P3XP4	-0.40	0.07	-0.11	0.40	-0.52	-0.14
P3XP5	-0.72	-1.53	0.12	-0.27	0.52	0.50
P3XP6	-0.68	-1.78	-0.09	-0.23	-1.20	1.31 **
P3XP7	-2.56 *	-2.56 *	1.50 **	0.44	-1.78	0.39
P3XP8	-1.49	-0.30	0.77	1.41 *	-1.13	0.31
P3XP9	-2.10 *	-1.50	0.27	0.47	-2.67 *	-0.58
P4XP5	-0.57	-0.22	-0.89	0.13	-1.41	0.09
P4XP6	0.77	0.81	0.96	0.51	-0.08	0.44
P4XP7	2.59 *	4.48 **	-0.26	0.40	5.49 **	-1.37 **
P4XP8	-2.34 *	-1.84	-0.66	-1.18 *	-2.24	-1.77 **
P4XP9	1.57	1.78	-0.01	1.00	1.75	0.62
P5XP6	-0.34	-0.86	-0.05	0.07	0.15	0.03
P5XP7	2.57 *	1.87	-0.96	-0.48	0.94	1.23 **
P5XP8	0.89	0.44	0.77	1.43 *	0.25	-0.18
P5XP9	-2.10 *	-3.95 **	-0.18	-1.25 *	-2.83 *	-0.93 *
P6XP7	-2.92 **	-2.23 *	-2.20 **	-1.94 **	-5.51 **	-2.02 **
P6XP8	-0.69	-0.18	-0.32	1.10	0.24	0.75
P6XP9	2.73 **	4.15 **	1.23 *	0.71	6.87 **	1.26 **
P7XP8	0.98	1.20	-0.50	-0.28	0.99	2.21 **
P7XP9	-0.38	0.39	0.38	0.09	-1.91	0.89 *
P8XP9	3.52 **	3.18 **	-1.31 **	-4.59 **	3.60 **	-2.16 **
S.E.(Sij)	2.01	1.94	0.98	1.11	2.26	0.83
S.E.(Sij-Sik)	2.97	2.85	1.44	1.64	3.33	1.23

*-Significant at 5 per cent probability level
**- Significant at 1 per cent probability level

Crosses	No. of primary Branches per plant	Fruit length (cm)	Fruit circumference (cm)	Fruit weight (kg)	No. of fruits per plant	Fruit yield per plant (kg)
1	2	3	4	5	6	7
P1XP2	-6.16**	-1.86	-0.06	-0.06	0.09	-0.32
P1XP3	2.62**	0.40	0.18	-0.06	1.49**	1.14**
P1XP4	-1.43	3.82**	1.03	0.02	0.22	0.35
P1XP5	-1.41	-5.24**	-0.30	-0.05	0.52	0.32
P1XP6	-5.10**	-2.42*	0.83	-0.05	0.22	-0.12
P1XP7	2.19**	-2.93**	0.72	0.00	0.74*	0.83**
P1XP8	-1.19	0.34	0.20	0.00	-0.74*	-0.81**
P1XP9	5.14**	-1.66	-1.62**	0.09*	0.57	1.26**
P2XP3	0.05	-0.17	1.70**	0.09*	-0.92**	-0.41
P2XP4	7.34**	-0.41	-0.88	-0.14**	1.62**	0.75*
P2XP5	-3.04**	-0.38	-0.58	0.01	0.22	0.36
P2XP6	-1.86*	-8.43**	-1.64**	-0.08	0.23	-0.16
P2XP7	-0.85	-0.26	-1.19*	0.06	-0.17	0.28
P2XP8	0.63	7.83**	1.84**	0.07	-0.60	-0.31
P2XP9	-1.77*	0.81	2.60**	0.02	-1.40**	-1.53**
P3XP4	-0.39	-4.22**	-1.71**	0.11*	1.15**	1.93**
P3XP5	5.41**	0.94	0.95	0.14**	-1.07**	-0.46
P3XP6	2.88**	5.80**	1.67**	0.13**	0.80*	1.71**
P3XP7	3.24**	6.19**	-0.62	-0.07	1.36**	0.92**
P3XP8	0.38	5.73**	0.71	0.02	0.97**	1.26**

P3XP9	4.02**	-0.54	-1.44**	-0.03	-2.39**	-2.83**
P4XP5	4.58**	6.20**	0.83	0.08	-1.43**	-1.18**
P4XP6	0.59	1.41	0.65	-0.06	-1.47**	-1.52**
P4XP7	-4.84**	3.89**	0.68	-0.19**	1.38**	-0.03
P4XP8	-2.16**	-2.77*	-0.31	-0.06	-0.81*	-1.13**
P4XP9	-0.76	0.12	-4.30**	0.13**	1.64**	2.55**
P5XP6	-2.18**	0.49	-0.34	-0.10*	2.28**	1.63**
P5XP7	4.16**	-0.37	0.06	0.01	-0.32	-0.16
P5XP8	0.57	1.18	0.49	-0.12**	-0.36	-1.02**
P5XP9	0.27	-2.02	-2.39**	-0.05	-0.04	-0.33
P6XP7	-2.89**	-2.13*	0.37	0.11*	-2.36**	-1.97**
P6XP8	1.93*	1.59	-0.26	0.01	0.31	0.39
P6XP9	6.75**	-0.77	-4.10**	0.07	-1.05**	-0.86**
P7XP8	8.32**	-6.59**	-0.62	-0.01	-0.29	-0.35
P7XP_9	3.30**	1.27	0.19	0.04	1.59**	2.16**
P8XP9	-7.51**	-2.00	-3.34**	-0.07	0.25	-0.15
S.E.(Sij)	1.61	2.11	1.07	0.09	0.61	0.57
S.E.(Sij-Sik)	2.37	3.12	1.57	0.13	0.90	0.84

*-Significant at 5 per cent probability level
**- Significant at 1 per cent probability level

Conclusion

The mean square due to genotypes, parents, hybrids and parents vs hybrids were almost highly significant for all the 12 characters, except for days to first fruit harvest, days to first female flower anthesis, node number of first male flower appearance, fruit length and vine length only due to parents vs hybrids indicating therefore, significant differences among these source of variations with respect to the traits under study.

Highly significant variances were observed for both general and specific combining ability for all the twelve characters studied. Highly significant gca and sca variances revealed that both additive and non additive gene actions were important in the expression of all the traits studied.

Considering higher number of fruits and fruit yield per plant, parents P_3 (NDBG-707), P_1 (Pusa Naveen) and P_7 (NDBG-744) were found as good general combiner. Parent P_7 (NDBG-744) the best general combiner for fruit yield per plant was also found as the best general combiner for number of fruits per plant. Fruit circumference, fruit length, number of primary branches, Parent P_9 (NDBG-749-2) and P_1 (Pusa Naveen) were found as the top two good general combiner for smaller fruit length.

General combining ability coincides with the *per se* performance of the parents.

The three best F_1 hybrids showing significant desirable sca effects for fruit yield per plant in order of merit were P_4 x P_9 (2.55), P_7 x P_9 (2.16) and P_7 x P_9 also found as top heterotic F_1 over standard parent for this trait.

The best specific combination was P_5 x P_9 for days to first female flower anthesis, P_8 x P_9 for node number to first female flower appearance, P_6 x P_7 for days to first fruit harvest and P4 x P9 for fruit yield per plant.

It was noted that the best F_1 hybrids which expressed higher *per se* performance for a particular trait also exhibited desirable significant sca effect for other traits but this trend was not always true *i.e.*, the best specific cross might or might not have the parent with high *per se* performance.

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