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Studies on gene action involved in inheritance of yield and yield attributing traits 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, inheritance of yield

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) [11]. 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.
The family cucurbitaceae, consists of 120 genera and more than 800 species (Swarup, 2006) [19], of which approximately 20 species are of commercial importance in India. The family is represented by about 34 genera and 108 species which includes 38 endemic species (Singh, 2006). They are used as fruits, vegetables, edible seeds, oilseeds, fodder and useful fibres. The genus Lagenaria has total six recognized species, out of which only Lagenaria siceraria is the domesticated annual and monoecious in nature while the other five are wild congeners, perennial and diocious (Bisognin, 2002) [3]. The archaeological seeds and rind indicate that bottle gourd has reached Asia and the New world by 9000-10000 years ago (Culter and Whitaker, 1961) [5, 6], Probably as a wild species who's fruits had floated across the seas (Hieser, 1973) [10]. It travelled to India, Where it has evolved into numerous local varieties and from India to china, Indonesia and as far as New Zeeland. At the present time this annual running or climbing monoecious vine crop is cultivated through out the tropical and sub tropical regions of the world for food and useful gourds 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.
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; [4] Sharma *et al*., 1993 [15] 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 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 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).

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. Bottle gourd being predominantly monoecious, highly cross pollinated crop but does not suffer much from inbreeding depression (Allard, 1960) [1], and has the advantage of producing a large number of seed per fruit, facilitating heterosis breeding by economizing the cost of hybrid seed production.
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. 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) [7, 13, 14] have also used this technique for estimating gene action.
Keeping all these points in view, the present investigation was designed to investigate the extent of 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.

Gene action
This analysis provides detailed accounts of additive and dominant components and the allied statistics. The genetic progress in a population depends largely upon the relative values of the components. The diallel cross analysis through analytical method is based on a number of assumptions regarding applicability of this method was advocated by Hayman (1954 a) *viz*., homozygous parents, diploid segregation, no reciprocal differences, no multiple allelism, no espistasis and absence of linkage, absence of epistatic and random mating.
The validity of specific assumption of diploid segregation, lack of reciprocal differences and multiple allelism was presumed. Bottle gourd being cross pollinated crop it is tedious to get complete homozygous parents for all the traits. However, if some traits exhibits the partial non fulfillment of assumption, the estimate of population parameters are still possible (Hayman, 1954a). However, the result in such cases are less reliable than would have been if all the assumptions are fulfilled.
Highly significant values for dominance components ($\hat{H}_1$ and $\hat{H}_2$) for most of the traits except node number to first female flower appearance, along with highly significant values of additive components ($\hat{D}$) for a half of the traits under study viz., node number to first male flower appearance, number of primary branches per plants, fruit

length, fruit circumference, fruit weight, days to first male flower anthesis indicated the importance of both additive and dominance gene action in expression of these characters which is in consonance with the findings of Sharma *et al.* (1983) [12]; Rayes *et al.* (1993); Kumar *et al.* (2000); Kathira *et al.* (2005) and Singh *et al.* (2005).

However, additive ($\hat{D}$) component was lower in magnitude than dominance components of genetic variance for all the characters except fruit circumference which reveled preponderance of dominance component of variance in the expression of fruit yield and its attributes (Table 2). Sirohi *et al.* (1986) recorded similar result in bottle gourd. The positive values of F were found for all the traits except for days to first female flower anthesis, node number of first female flower appearance, days to first harvest and fruit length. The positive values of F for the traits under study showed that there is an excess of dominance gene in the inheritance of these traits among the parents.

The average degree of dominance $(\hat{H}_1/\hat{D})^{1/2}$ involved in the action of genes was found as over dominance for all the traits except (node number to first male flower appearance and fruit circumference) which showed incomplete dominance (Table 2).

Proportion of genes ($\hat{H}_2/4\hat{H}_1$) in the parents were less than 0.25 for all the traits except days to first fruit harvest (Table 4.9) which showed asymmetrical distribution of loci showing dominance in the inheritance of these character. The ratio of $(4\hat{D}\ \hat{H}_1)^{1/2} + \hat{F}\ (4\ \hat{D}\ \hat{H}_1)^{1/2} - \hat{F}$ indicated the excess of dominant genes among the parental strains for most of the characters (Table 2). The ratio of $\hat{h}^2/\hat{H}_2$, provides information about groups of gene exhibiting little or no dominance. The less than one $\hat{h}^2/\hat{H}_2$ ratio suggested that minor gene mainly governed the characters under study, which may be due to concealing effects of dominant gene with positive and negative effect, which nullify the effects of each other. The positive correlated coefficient (r) between parental order of dominance (Wr + Vr) and parental measurement (Yr) for majority of traits indicated the direction of dominance towards negative side (Table2). The above findings are in agreement with that of Singh *et al.* (2005).

The result of present study suggested preponderance of dominance genes in the expression of all the component traits studied.

Table 1: Analysis of variance (mean squares) in a set of 9 x 9 diallel cross for 12 characters in bottle gourd

Source of variation	Degree of freedom	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)
Replicates	2	1.1337	3.0655	1.8446	3.1187	0.6108	0.8016
Treatments	44	15.6107**	18.9585**	5.0664**	7.0979**	22.1081**	3.5460**
Parents	8	14.1762**	7.2195*	10.5735**	5.2645**	10.9072*	1.7929**
Hybrids	35	15.9661**	22.1389**	3.9482**	7.4444**	24.8587**	4.0175**
Parent Vs. Hybrids	1	14.6487*	1.5553	0.1450	9.6374**	15.4432	1.0684
Error	88	3.5265	3.2605	0.8275	1.0754	4.4413	0.6034

Source of variation	Degree of freedom	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)
Replicates	2	2.2824	8.0030	9.5228**	0.0321*	0.4304	0.6951
Treatments	44	58.0556**	170.3601**	24.5328**	0.0341**	5.1973**	6.0114**
Parents	8	44.5768**	211.8546**	84.8688**	0.0397**	2.7377**	5.2087**
Hybrids	35	57.6334**	165.6469**	10.2502**	0.0338**	5.8487**	6.3092**
Parent Vs. Hybrids	1	180.6598**	3.3670	41.7334**	0.0000	2.0770*	2.0106**
Error	88	2.2519	3.8884	0.9888	0.0067	0.3269	0.2853

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

Table 2: Estimates of genetic components of variation and their related statistics for 12 characters in 9x9 diallel cross of bottle gourd

Components of variation and related statistics	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
1	2	3	4	5
$\hat{D}$ (Additive effect)	3.568**±1.068	1.321±1.586	3.241**±0.324	1.381±1.185
$\hat{H}_1$ (Dominance effect)	13.242**±2.356	17.615**±3.500	3.081**±0.716	5.020±2.615
$\hat{H}_2$ (Dominance indicating asymmetry of +/- effect of genes)	10.204**±2.026	16.836**±3.009	2.580**±0.616	4.382±2.248
$\hat{F}$ (Mean Fr over arrays)	1.573**±2.490	-3.055±3.699	2.035*±0.757	-0.648 ±2.764
$\hat{h}^2$	1.686± 1.357	-0.201± 2.016	-0.091± 0.412	1.263±1.506
$\hat{E}$ (Environmental component)	1.158**±0.338	1.085±0.501	0.283*±0.103	0.374±0.375

$(\hat{H}_1/\hat{D})^{1/2}$ (Mean degree of dominance)	1.927	3.652	0.975	1.906
$\hat{H}_2/4\hat{H}_1$ (Proportion of genes with+/- effects in parent)	0.193	0.239	0.209	0.218
$(4\hat{D}\hat{H}_1)^{1/2}+\hat{F}/(4\hat{D}\hat{H}_1)^{1/2}-\hat{F}$ (Proportion of dominant and recessive genes in parents)	1.258	0.519	1.950	0.781
$\hat{h}^2/\hat{H}_2$ (No. of gene groups)	0.165	-0.012	-0.035	0.288
R (correlation coefficient)	0.121	0.649	0.769	0.261
t^2	1.820	4.634	4.689	38.703**
byx	0.075	0.361	1.270	0.055
(1-b/SEb)	0.675	-1.256	-2.183	0.286
a (Intercept)	1.187	-0.660	-0.418	0.786

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

Table 2. 1: Estimates of genetic components of variation and their related statistics for 12 characters in 9x9 diallel cross of bottle gourd

Components of variation and related statistics	Days to first fruit harvest	Vine length (m)	No. of primary Branches per plant	Fruit length (cm)
1	2	3	4	5
$\hat{D}$ (Additive effect)	2.184 ±3.492	0.395 ±0.456	14.108*±4.064	69.292**±6.183
$\hat{H}_1$ (Dominance effect)	19.026**± 7.707	4.985** ±1.006	87.222** ±8.970	70.792**±13.646
$\hat{H}_2$ (Dominance indicating asymmetry of +/- effect of genes)	19.019**±6.625	4.093**±0.865	63.191**±7.711	51.610**±11.731
$\hat{F}$ (Mean Fr over arrays)	-3.603±8.145	0.834±1.063	28.137*±9.480	-7.192±14.423
$\hat{h}^2$	1.686± 4.438	0.076± 0.579	26.137** ±5.165	-0.031±7.859
$\hat{E}$ (Environmental component)	1.452±1.104	0.203±0.144	0.751 ±1.285	1.327±1.955
$(\hat{H}_1/\hat{D})^{1/2}$ (Mean degree of dominance)	2.952	3.553	2.486	1.011
$\hat{H}_2/4\hat{H}_1$ (Proportion of genes with+/- effects in parent)	0.250	0.205	0.181	0.182
$(4\hat{D}\hat{H}_1)^{1/2}+\hat{F}/(4\hat{D}\hat{H}_1)^{1/2}-\hat{F}$ (Proportion of dominant and recessive genes in parents)	0.563	1.846	2.339	0.902
$\hat{h}^2/\hat{H}_2$ (No. of gene groups)	0.089	0.019	0.414	-0.001
R (correlation coefficient)	0.770	0.029	0.059	0.730
t^2	40.987**	6.249	0.267	0.817
byx	0.228	0.013	0.072	0.579
(1-b/SEb)	-2.211	0.920	0.843	-1.824
a (Intercept)	0.557	-0.004	-1.244	14.828

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

Table 2. 2: Estimates of genetic components of variation and their related statistics for 12 characters in 9x9 diallel cross of bottle gourd

Components of variation and related statistics	Fruit circumference (cm)	Fruit weight (kg)	No. of fruits per plant	Fruit yield per plant (kg)
1	2	3	4	5
$\hat{D}$ (Additive effect)	27.897**±2.174	0.011*±0.003	0.803±0.610	1.638±0.782
$\hat{H}_1$ (Dominance effect)	20.505**±4.799	0.032** ±0.007	6.131**±1.346	7.010**±1.727
$\hat{H}_2$ (Dominance indicating asymmetry of +/- effect of genes)	11.633*± 4.125	0.024**±0.006	5.157**±1.157	5.719**±1.485
$\hat{F}$ (Mean Fr over arrays)	29.706**±5.072	0.009±0.008	0.475±1.422	1.412 ±1.825

$\hat{h}^2$	5.951±2.763	-0.001±0.004	0.261±0.775	0.255±0.995
$\hat{E}$ (Environmental component)	0.393±0.688	0.002±0.001	0.110±0.193	0.098±0.247
$(\hat{H}_1/\hat{D})^{1/2}$ (Mean degree of dominance)	0.857	1.719	2.763	2.069
$\hat{H}_2/4\hat{H}_1$ (Proportion of genes with+/- effects in parent)	0.142	0.187	0.210	0.204
$(4\hat{D}\hat{H}_1)^{1/2}+\hat{F}/(4\hat{D}\hat{H}_1)^{1/2}-\hat{F}$ (Proportion of dominant and recessive genes in parents)	4.277	1.632	1.246	1.527
$\hat{h}^2/\hat{H}_2$ (No. of gene groups)	0.512	-0.040	0.051	0.045
r (correlation coefficient)	0.933	0.361	0.114	-0.264
t^2	0.713	3.080	4.524	19.530**
byx	0.832	0.201	0.055	-0.075
(1-b/SEb)	-5.876	-0.026	0.696	1.721
a (Intercept)	2.493	0.001	0.203	0.617

*-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.

There was preponderance of non-additive gene action in the inheritance of all the traits studied.

Proportion of genes ($\hat{H}_2/4\hat{H}_1$) in the parents were less than 0.25 for most of the traits indicating asymmetrical distribution of alleles at loci showing dominance.

Over dominance was observed for all the character except node number to first male flower appearance and fruit circumference which showed incomplete dominance.

The ratio of ($\hat{h}^2/\hat{H}_2$) which estimates the number of gene groups, usually provides no information about groups of gene exhibiting little or no dominance. The no major gene group was exhibited for any of the characters studied.

The positive correlation coefficient (r) between parental orders of dominance (Wr+Vr) in parental measurement (Yr) for majority of traits indicated the direction of dominance towards negative side.

Thus, on the basis of gene action obtained which showed preponderance of non-additive gene action.

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