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Genetic Analysis of Fruit Yield and its Components in Bottle Gourd [*Lagenaria siceraria* (Mol.) Standl.]

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ABSTRACT

Background: The choice of parents to be incorporated in hybridization is a crucial step for breeders for the improvement of complex quantitative characters, such as fruit yield and its components. It requires extensive and detailed genetic assessment of existing germplasm and newly developed promising lines. The magnitude and type of gene action serves as criteria for selection of parents, which after hybridization are likely to produce the best recombinants for desirable traits.

Methods: Forty five bottle gourd genotypes comprising 36 hybrids and 9 parents were evaluated in four different environments. Genetic components of variation were estimated for 12 different characters including fruit yield per plant.

Result: The additive as well as dominant components were significant for fruit yield per plant and its components, revealing equal importance of both additive as well as non-additive gene effects. However, fruit yield per plant is under the control of dominance variance. Over dominance type of gene action, considerable degree of gene symmetry over all the loci, excess of dominant alleles in parents and high narrow sense heritability was found for most of the traits studied.

Key words: Additive, Bottle gourd, Dominant, Gene effects, Heritability, Non-additive.

INTRODUCTION

Bottle gourd [*Lagenaria siceraria* (Mol.) Standl. 2n=2x=22], is one of humankind's first domesticated plants. It is an important cucurbitaceous vegetable crop belonging to the family *Cucurbitaceae*. The *Lagenaria siceraria* is the only annual and monoecious cultivated species of bottle gourd, while other species are wild, perennial and dioecious.

The choice of parents to be incorporated in hybridization is a crucial step for breeders for the improvement of complex quantitative characters, such as fruit yield and its components. It requires extensive and detailed genetic assessment of existing germplasm and newly developed promising lines, which could be used in future breeding programme or could be directly released as a variety after thorough testing. The magnitude and type of gene action serves as criteria for selection of parents, which after hybridization are likely to produce the best recombinants for desirable traits. Diallel analysis, as developed by Hayman (1954) and Jinks (1954) provides a systematic approach for the selection of parents and crosses superior for the traits under investigation.

MATERIALS AND METHODS

The experimental materials comprised of 45 entries includes nine parents (ABG 1, Punjab Long, NDBG 132, Arka Bahar, Pusa Naveen, DBG 5, Samrat, DBG 6 and Santosh), their 36 F_1s developed through half diallel mating design. The genotypes were evaluated in a RBD with three replications over four environments (Environments were created by two different date of sowing during *kharif* 2018 and *summer* 2019 *i.e.* E_1= July 24, 2018; E_2= August 24, 2018; E_3= February 24, 2019 and E_4= March 24, 2019) at Sagdividi Farm, Department of Seed Science and Technology, Junagadh Agricultural University, Junagadh. Each entry was sown in a single row plot of 10 m length keeping 2 m × 1 m spacing. The recommended package of practices and plant protection measures of Gujarat state were followed to raise a healthy crop of bottle gourd. Five competitive plants per genotype in each replication and in each environment were selected randomly for recording observations on different characters *viz*., number of node bearing first female flower, number of node bearing first male flower, vine length (cm), days to first picking, fruit length (cm), fruit equatorial diameter (cm), number of fruits per plant, average fruit weight per plant (kg), days to last picking and fruit yield per plant (kg). Genetic components of variation were estimated according to method suggested by Hayman (1954) as described in detail by Singh and Chaudhary (1985).

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RESULTS AND DISCUSSION

The genetic components of variance were worked out for different characters for individual environments (Table 1-4), as suggested by Hayman (1954) as described in detail by Singh and Chaudhary (1985). Validity of hypothesis according to Hayman (1954) was tested by t^2 values. Non-significant values of t^2 for all the characters in individual environments except for days to first opening male flower and vine length in E_2 number of fruits per plant and days to last picking in E_1 and E_3 and for fruit yield per plant in E_1, E_2 and E_3 environments, suggested the adequacy of additive - dominant model to explain the variation in almost all the traits studied.

The additive as well as dominant components were significant for all the characters studied except for additive (D) component in number of nodes bearing first female flower in E_4 environment, vine length in E_3 and E_4 number of fruits per plant in E_4 and fruit yield per plant in E_3 and E_4; for dominance components (H_1) in vine length, days to first picking and number of fruits per plant in E_1 average fruit weight per plant in E_3 and days to last picking in E_2 and E_3; and for dominant component (H_2) in days to first opening female flower and days to last picking in E_2, fruit length in E_1 and average fruit weight per plant in E_3 environment.

These results revealing equal importance of both additive as well as non-additive gene effects for the traits studied. However, the relative magnitude of dominant components were found to be higher than additive components for fruit yield per plant indicated the preponderance of dominant (non-additive) gene action, while for the remaining traits studied with few exceptions, the preponderance of additive gene action. The preponderance of dominance components for fruit yield per plant in bottle gourd was reported earlier by Quamruzzaman and Ahmad (2010), Ray *et al.* (2015), Adarsh *et al.* (2017), Mishra *et al.* (2019) and Quamruzzaman *et al.* (2019). Preponderance of additive gene action was also reported in bottle gourd for various traits. Sirohi *et al.* (1986) reported that additive gene action was responsible for the inheritance of days to first male and female flower opening and fruit length; Ray *et al.* (2015) for fruit length and Adarsh *et al.* (2017) for days to first fruit harvest and fruit girth in bottle gourd.

Significance of h^2 for number of node bearing first male flower in E_2, E_3 and E_4, vine length in E_1, days to first picking in E_2, fruit equatorial diameter in E_1, E_3 and E_4 number of fruits per plant in E_1, E_2 and E_4 and number of node bearing first female flower, average fruit weight per plant and fruit yield per plant in all the environments, indicated unidirectional dominant gene action, which revealed that substantial contribution of dominance effects was due to heterogeneity of loci. For the remaining traits in the respective environments, bidirectional dominant gene action prevailed. The results are in accordance with the findings of Quamruzzaman and Ahmad (2010) for fruit yield in bottle gourd.

The covariance between additive and dominants effects (F) was found to be non-significant in all the environments for number of node bearing first female flower, vine length, number of fruits per plant, average fruit weight per plant, days to last picking and fruit yield per plant; in E_1 and E_2 for days to first opening female flower; in E_2, E_3 and E_4 for days to first opening male flower and fruit equatorial diameter; in E_1, E_3 and E_4 for number of node bearing first male flower; and in E_1 and E_4 environments for days to first picking and fruit length; indicating equal distribution of dominant and recessive alleles for these traits in respective environments. The results are in accordance with the findings of Quamruzzaman *et al.* (2019) for fruit yield in bottle gourd.

Environmental component (E) was significant for all the traits studied in all the environments except in E_2 and E_4 for number of node bearing first male flower and in E_4 for fruit equatorial diameter, manifesting the pivotal role of environment in the expression of traits studied.

The average degree of dominance $(H_1/D)^{1/2}$ indicated over dominance type of gene action all four environments for all the traits studied except for days to first opening female flower and days to first opening male flower in E_1, E_2 and E_3; for vine length and fruit length in E_1; for days to first picking in E_1 and E_3; for fruit equatorial diameter, number of fruits per plant and average fruit weight per plant in E_1 and E_2; and for days to last picking in all the environments. Over dominance for fruit yield per plant and important yield components in bottle gourd was reported earlier by Quamruzzaman and Ahmad (2010), Ray *et al.* (2015) and Quamruzzaman *et al.* (2019).

The distribution of genes with positive and negative effects ($H_2/4H_1$) in the parents was observed nearly symmetrical in all the environments for fruit yield per plant and the other characters studied except in E_2 and E_4 for days to first opening female flower; in E_1 for days to first opening male flower; in E_3 for number of node bearing first female flower; in E_2 and E_3 for number of node bearing first male flower and days to last picking; in E_1, E_2 and E_3 for fruit length; in E_3 and E_4 for fruit equatorial diameter and in E_4 for number of fruits per plant; indicating considerable degree of gene symmetry over all the loci for the studied traits.

The estimates of K_D/K_R ratio was more than unity indicated the excess of dominant alleles in parents for all the characters studied in all the environments except for days to first opening male flower in E_4; for vine length in E_2 and E_4; for fruit equatorial diameter in E_1; for number of fruits per plant in all environments; for average fruit weight per plant E_1 and E_2; for days to last picking in E_2 and E_3 and for fruit yield per plant in E_1, E_2 and E_3; which indicated more number of dominant genes than recessive genes in the parents. The present findings are in accordance with those of Mishra *et al.* (2019) and Quamruzzaman *et al.* (2019), who reported that ratio of dominant and recessive alleles was more than unity or fruit yield and its components indicating presence of excess of dominant alleles.

In the present investigation, the ratio of h^2/H_2, estimating the number of gene groups indicated that there was one group of genes responsible for number of node bearing first

Table 1: Estimates of genetic components of variances for days to first opening female flower, days to first opening male flower and number of node bearing first female flower in bottle gourd.

Parameters	Days to first opening female flower				Days to first opening male flower				Number of node bearing first female flower			
	E_1	E_2	E_3	E_4	E_1	E_2	E_3	E_4	E_1	E_2	E_3	E_4
D	25.21**±	12.60**±	26.25**±	23.19**±	24.33**±	10.40**±	17.06**±	10.29**±	0.35**±	0.26**±	0.34**±	0.17±
	2.17	1.93	2.29	3.66	1.49	1.43	1.47	1.81	0.04	0.04	0.07	0.11
H_1	13.45**±	8.37*±	13.60**±	25.10**±	10.72**±	7.49*±	9.59**±	14.82**±	0.36**±	0.34**±	0.66**±	1.20**±
	4.79	4.27	5.05	8.07	3.28	3.15	3.26	4.00	0.09	0.10	0.15	0.24
H_2	12.65**±	7.09±	11.88**±	17.81**±	7.98**±	6.53*±	8.90**±	15.16**±	0.34**±	0.30**±	0.51**±	1.03**±
	4.11	3.67	4.34	6.94	2.82	2.71	2.80	3.44	0.01	0.08	0.13	0.21
F	7.85±	7.60	10.66*±	16.44*±	13.59**±	4.72±	5.66±	-0.15±	0.17±	0.10±	0.29±	0.05±
	5.06	4.51	5.33	8.53	3.47	3.33	3.44	4.23	0.10	0.10	0.15	0.26
h^2	-0.43±	2.03	0.59±	1.43±	-0.77±	-0.44±	0.25±	3.95±	0.22**±	0.13**±	0.34**±	0.69**±
	2.76	2.46	2.91	4.65	1.89	1.81	1.87	2.31	0.05	0.06	0.08	0.14
E	2.57**±	2.43**	2.65*±	2.44*±	1.95**±	1.88**±	1.95**±	2.05**±	0.03**±	0.03**±	0.08**±	0.08**±
	0.68	0.61	0.72	1.16	0.47	0.45	0.47	0.57	0.01	0.01	0.02	0.03
$(H_1/D)^{1/2}$	0.73	0.82	0.72	1.04	0.66	0.85	0.75	1.20	1.01	1.14	1.39	2.62
$H_2/4H_1$	0.23	0.12	0.22	0.18	0.19	0.22	0.23	0.26	0.23	0.23	0.20	0.21
K_D/K_R	1.54	2.17	1.79	2.03	2.45	1.73	1.57	0.99	1.61	1.40	1.90	1.13
h^2/H_2	-0.03	0.29	0.05	0.08	-0.10	-0.07	0.03	0.26	0.67	0.43	0.66	0.67
Heritability (%)	61.30	42.80	60.60	50.40	63.10	48.60	59.10	46.40	47.40	47.00	30.50	30.20
Narrow sense												
t^2	0.93	1..09	0.18	0.03	1.33	4.91*	1.01	0.11	0.91	0.11	3.73	2.19

*, ** Indicates significance at P=0.05 and P=0.01 levels, respectively.

Table 2: Estimates of genetic components of variances for number of node bearing first male flower, vine length (m) and days to first picking in bottle gourd.

Parameters	Number of node bearing first male flower				Vine length (m)				Days to first picking			
	E_1	E_2	E_3	E_4	E_1	E_2	E_3	E_4	E_1	E_2	E_3	E_4
D	0.33**±	1.37**±	0.23**±	0.72**±	0.59**±	0.21**±	0.17±	0.11±	14.16**±	7.80**±	11.55**±	15.74**±
	0.04	0.09	0.05	0.22	0.07	0.08	0.09	0.12	1.91	1.03	1.82	4.30
H_1	0.43**±	1.45**±	0.36**±	2.01**±	0.23±	0.55**±	1.15**±	0.95**±	8.27±	8.31**±	8.06*±	32.51**±
	0.10	0.19	0.11	0.49	0.13	0.17	0.20	0.26	4.23	2.28	4.02	9.49
H_2	0.39**±	0.79**±	0.29**±	1.74**±	0.29**±	0.47**±	1.12**±	0.84**±	7.49*±	6.98**±	7.17*±	28.60**±
	0.09	0.17	0.09	0.42	0.11	0.15	0.17	0.22	3.63	1.96	3.45	8.15
F	0.17±	1.71**±	0.14±	0.85±	0.01±	-0.27±	0.11±	-0.01±	8.71±	5.23*±	7.21*±	11.57±
	0.11	0.21	0.11	0.52	0.01	0.18	0.21	0.28	4.47	2.41	4.25	10.03
h^2	0.08±	0.25*±	0.45**±	0.71**±	0.33**±	0.05±	-0.005±	0.01±	-1.03±	2.81*±	-0.52±	-1.05±
	0.06	0.11	0.06	0.28	0.08	0.10	0.11	0.15	2.43	1.31	2.31	5.46
E	0.05**±	0.05±	0.14**±	0.13±	0.12**±	0.12**±	0.13**±	0.13**±	3.41**±	3.33*±	3.33**±	3.55*±
	0.01	0.03	0.01	0.07	0.01	0.02	0.03	0.04	0.06	0.33	0.57	1.36
$(H_1/D)^{1/2}$	1.14	1.03	1.25	1.67	0.63	1.60	2.62	2.94	0.77	1.03	0.84	1.44
$H_2/4H_1$	0.23	0.14	0.20	0.22	0.30	0.21	0.24	0.22	0.22	0.21	0.22	0.22
K_D/K_R	1.58	4.07	1.64	2.09	1.03	0.43	1.28	0.97	2.34	1.96	2.19	1.69
h^2/H_2	0.21	0.31	1.53	0.41	1.19	0.10	-0.004	0.001	-0.13	0.40	-0.07	-0.04
Heritability (%)	39.80	39.30	26.80	11.60	56.80	53.10	8.00	29.90	37.10	27.80	33.80	27.40
Narrow sense												
t^2	0.65	1.33	0.40	2.47	0.02	14.03**	0.07	1.54	0.02	0.05	0.02	0.75

*, ** Indicates significance at P=0.05 and P=0.01 levels, respectively.

Table 3: Estimates of genetic components of variances for fruit length (cm), fruit equatorial diameter (cm) and number of fruits per plant in bottle gourd.

Parameters	Fruit length (cm)				Fruit equatorial diameter (cm)				Number of fruits per plant			
	E_1	E_2	E_3	E_4	E_1	E_2	E_3	E_4	E_1	E_2	E_3	E_4
D	18.27**±	16.96**±	16.84**±	10.12**±	0.94**±	0.65**±	0.79**±	0.68**±	1.80**±	2.13**±	0.90**±	0.38±
	2.34	2.58	3.70	4.05	0.05	0.04	0.06	0.15	0.29	0.32	0.30	0.30
H_1	10.37*±	18.63**±	38.74**±	42.16**±	0.29*±	0.23*±	0.84**±	1.20**±	1.17±	1.75*±	1.75**±	2.45**±
	5.17	5.69	8.16	8.94	0.11	0.10	0.14	0.32	0.65	0.72	0.66	0.66
H_2	8.11±	14.15**±	31.49**±	39.90**±	0.31**±	0.22*±	0.68**±	0.94**±	1.23*±	1.68**±	1.74**±	1.72**±
	4.44	4.89	8.16	7.68	0.09	0.09	0.12	0.28	0.56	0.62	0.66	0.57
F	8.13±	12.06*±	16.91*±	7.07±	0.001±	0.005±	0.46**±	0.42±	-1.13±	-0.52±	-1.25±	-0.99±
	5.47	6.01	8.63	9.45	0.12	0.05	0.14	0.34	0.69	0.76	0.70	0.70
h^2	3.68±	0.47±	-0.57±	7.32±	0.10**±	-0.02±	0.31**±	0.37*±	1.30**±	1.49**±	-0.04±	1.52**±
	2.98	3.28	4.70	5.15	0.06	0.06	0.08	0.19	0.37	0.41	0.38	0.38
E	5.04**±	5.05**±	5.05**±	5.50**±	0.05**±	0.06**±	0.06**±	0.06±	0.54**±	0.55**±	0.55**±	0.55**±
	0.74	0.81	1.17	1.28	0.01	0.01	0.02	0.05	0.09	0.10	0.09	0.09
$(H_1/D)^{1/2}$	0.75	1.05	1.52	2.04	0.55	0.60	1.03	1.33	0.80	0.91	1.39	2.54
$H_2/4H_1$	0.19	0.19	0.20	0.24	0.28	0.23	0.20	0.20	0.27	0.24	0.25	0.18
K_D/K_R	1.83	2.03	1.99	1.41	1.00	1.01	1.79	1.61	0.43	0.76	0.33	0.32
h^2/H_2	0.45	0.03	-0.02	0.18	0.32	-0.07	0.46	0.39	1.04	1.36	-0.02	0.88
Heritability (%)	46.70	35.30	21.70	14.60	77.40	74.80	51.60	46.30	62.60	58.50	52.20	51.70
Narrow sense												
t^2	1.06	0.25	1.19	0.003	0.10	0.29	0.004	0.15	6.99**	0.58	26.89**	2.14

*, ** Indicates significance at P=0.05 and P=0.01 levels, respectively.

Table 4: Estimates of genetic components of variances for average fruit weight per plant (kg), days to last picking and fruit yield per plant (kg) in bottle gourd.

Parameters	Average fruit weight per plant (kg)				Days to last picking				Fruit yield per plant (kg)			
	E_1	E_2	E_3	E_4	E_1	E_2	E_3	E_4	E_1	E_2	E_3	E_4
D	0.010*±	0.001*±	0.005**±	0.007**±	21.65**±	16.21**±	12.28**±	15.31**±	0.50*±	0.52**±	0.17±	0.17±
	0.0001	0.001	0.001	0.002	2.56	3.15	1.90	1.68	0.20	0.19	0.29	0.25
H_1	0.005**±	0.005**±	0.001±	0.026*±	14.26**±	5.95±	6.01±	12.72**±	1.83**±	1.94**±	2.32**±	2.83**±
	0.001	0.001	0.002	0.005	5.65	6.96	4.18	3.70	0.46	0.43	0.64	0.55
H_2	0.006**±	0.006**±	0.001±	0.021**±	17.04**±	9.68±	8.93**±	11.03**±	1.83**±	1.87**±	2.13**±	2.36**±
	0.001	0.001	0.002	0.004	4.85	5.98	3.60	3.18	0.39	0.37	0.55	0.48
F	-0.001±	-0.001±	0.002±	0.001±	1.68±	-2.84±	-3.64±	2.91±	-0.87±	-0.57 ±	-0.13±	0.08±
	0.001	0.001	0.002	0.005	5.97	7.36	4.42	3.91	0.48	0.45	0.68	0.59
h^2	0.006**±	0.006**±	0.007**±	0.011**±	-1.85±	0.46±	1.42±	2.85±	2.79**±	2.54**±	0.97*±	2.15**±
	0.0001	0.001	0.001	0.003	325	4.00	2.41	2.13	0.26	0.25	0.37	0.32
E	0.001**±	0.001**±	0.001**±	0.001**±.	9.65**±	9.23**±	8.84**±	9.60**±	0.44**±	0.34**±	0.29**±	0.19*±
	0.0001	0.0001	0.0001	0.0001	0.81	0.10	0.60	0.53	0.06	0.06	0.09	0.08
$(H_1/D)^{1/2}$	0.80	0.80	1.35	1.91	0.81	0.61	0.70	0.91	1.93	1.94	3.69	4.03
$H_2/4H_1$	0.27	0.27	0.23	0.21	0.30	0.41	0.37	0.22	0.25	0.24	0.23	0.21
K_D/K_R	0.86	0.84	1.27	1.94	1.10	0.75	0.65	1.23	0.37	0.55	0.81	1.12
h^2/H_2	1.12	1.01	0.80	0.53	-0.11	0.05	0.16	0.26	1.51	1.36	0.46	0.91
Heritability (%)	60.50	60.90	37.40	17.30	38.20	39.70	37.00	36.30	43.20	41.70	23.10	26.50
Narrow sense												
t^2	1.50	1.26	0.02	0.004	4.29*	1.43	5.52*	2.39	9.59**	6.57*	18.84**	0.13

*, ** Indicates significance at P=0.05 and P=0.01 levels, respectively.

male flower in E_3 environment; for days to last picking and vine length in E_1 and for number of fruits per plant average fruit weight per plant and fruit yield per plant in E_1 and E_2 environments. For all the remaining traits in respective environments, number of group of genes control the particular characters exhibit dominance. Quamruzzaman and Ahmad (2010) and Quamruzzaman *et al.* (2019) observed number of gene group, which exhibits dominance was less than one for most of the traits in bottle gourd.

In the present study, high estimates of narrow sense heritability were depicted for days to first opening female flower, days to first opening male flower, number of node bearing first female flower, fruit equatorial diameter, number of fruits per plant and days to last picking in all the environments, for number of node bearing first male flower, vine length, fruit length and fruit yield per plant in E_1 and E_2; for days to first picking in E_1 and E_3 and for average fruit weight per plant in E_1, E_2 and E_3; medium for number of node bearing first male flower, fruit length and fruit yield per plant in E_3 and E_4, vine length in E_4, for days to first picking in E_2 and E_4 and for average fruit weight per plant in E_4 environment and low for vine length in E_3 environment. In general, the characters under investigation were having high heritability indicating that the characters studied were highly heritable. The results are in accordance with the findings of Ray *et al*. (2015) and Quamruzzaman *et al.* (2019) reported in bottle gourd for fruit yield and its components.

CONCLUSION

The present study revealed the importance of dominant gene action in the improvement of fruit yield per plant. The dominance genetic components could be exploited by heterosis breeding or by intermating the selected progenies in early segregating generations which would results in the accumulation of favourable genes for increasing fruit yield. Hence, biparental mating followed by pedigree selection may give fruitful results for genetic improvement of yield in bottle gourd.

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