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Genetic Architecture of Yield in Bottle Gourd (*Lagenaria siceraria* (Mol.) Standl.)

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Abstract

The genetic architecture of yield was studied in a five parent half diallel cross of bottle gourd at the experimental field of Olericulture Division, Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur during the winter season of 2016-17. The values of mean square for GCA (general combining ability) and SCA (specific combining ability) were highly significant which suggested the presence of both additive and non-additive genetic variance in the population. But the higher magnitude of GCA compared to SCA indicated predominance of additive genetic variance. In most of the cases, the cross between poor and poor parents showed positive SCA effect for fruit yield, which indicated the higher yield. The estimates of mid parent heterosis ranged from −19.0 to 31.8 percent and the better parent heterosis ranged from −28.4 to 20.5 percent. Analysis for genetic components of variation suggested that additive components were more important in the inheritance of fruit yield. This character was observed being controlled by two to three pairs of genes or groups of genes. Narrow sense heritability was 55 percent indicating probability of selection in generations. The graphical analysis also indicated wide genetic diversity among the parents.

Keywords

Bottle Gourd, *Lagenaria siceraria* (Mol.) Standl., Combining Ability, Heterosis, Yield, Genetic Architecture

1. Introduction

Bottle gourd (*Lagenaria siceraria* (Mol.) Standl.) is one of the most important, widely cultivated popular winter vegetables in Bangladesh. But it is cultivated

around the tear due to its taste and demand to the consumers. It occupies an area of about 7217 ha with a total production of 85,267 tons. The average yield is only 11.81 tons per hectare [1], which is very low as compared to that in other tropical countries. Though a large number of farmers are using their local varieties/cultivars, most of them lost their potentiality due to its cross-pollinated nature. Besides this, limited progressive farmers also using commercial hybrid varieties viz., Dalisa, Barsha etc., but these hybrid varieties are not available to the farmers due to high price. Thus a well-planned and dynamic bottle gourd breeding research programme is needed to meet the required demand of bottle gourd production.

Furthermore hybrid varieties may play a vital role in satisfying the interest of producers and consumers. The understanding of the nature and magnitude of gene action is an important factor in developing an effective breeding programme. The diallel analysis provides an efficient means of rapidly obtaining an overall picture of the genetic control of a character in a set of parents in the early generations [2]. In Bangladesh context, the information on this aspect of bottle gourd is not sufficient. This study would be very important in developing hybrid varieties for Bangladesh agricultural conditions. Therefore, the present investigation was undertaken to investigate the genetic architecture of yield in bottle gourd.

2. Materials and Methods

The experiment was conducted at the experimental field of Olericulture Division, Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur during the winter season of 2016-17. The experimental field was at 23.9920˚N Latitude and 90.4125˚E Longitudes having an elevation of 8.2 m from sea level. The seeds of ten F_1, crosses (P1 × P2, P1 × P3, P1 × P4, P1 × P5, P2 × P3, P2 × P4, P2 × P5, P3 × P4, P3 × P5 and P4 × P5) of bottle gourd in a diallel set (excluding reciprocals) involving 5 parents (P1 = BGN1-4, P2 = BGN2-1, P3 = BGN2-3, P4 = BGN2-5 and P5 = BGN3-5) (Table 1) were sown in the polybag on 15th September 2016 and twenty days old seedlings (5 - 6 leaf stage) were transplanted in the main field on 05 October 2016. The experiment was laid out in Randomize Complete Block (RCB) design with three replications. The unit plot size was 10.0 × 2.5 m maintaining 2.0 × 2.5 m spacing.

Table 1. Characters of parents.

Parents code	Fruit shape with fruit colour
P1	Cylindrical shape with Deep Green + White Spot colour
P2	Oblong shape with Light Green colour
P3	Medium Cylindrical shape + Swelling at bottom with Light Green colour
P4	Cylindrical shape with Green + White Spot colour s
P5	Medium Cylindrical shape with Light Green colour

The land was fertilized with cowdung (organic fertilizer), nitrogen (N), phosphorus (P), potassium (K), sulphur (S), boron (B) and zinc (Zn) @ 10,000, 80, 45, 88, 25, 1.8 and 4.5 kg/ha, respectively. Half of cowdung and all of S, Zn and B each of P and K @ 30 kg/ha will be applied during final land preparation. Rest of cowdung and P and K @ 15 kg/ha will be applied as basal in pit. Rest of N and K will be applied after 20 days of transplanting in 4 equal installments at 20 days interval of starting. The intercultural operations (weeding and irrigation etc.) were done as and when necessary. Data on yield (t/ha) was recorded from three randomly selected plants per entry per replication. The data were analysed following [3] [4] [5]. Weather report of experimental area during Sep 2016-Mar 2017 is mentioned in Table 2. In the analysis of variance (ANOVA) the F test was used at the 5% and 1% levels of probability. The trait means were compared by the Tukey test at the 5% level of probability.

2.1. Estimates of GCA and SCA Effects

The GCA and SCA effects were estimated according to [6] by the following formula:

$$\text{GCA effects } (Gi) \ = \ gi \ = 1/p + 2[\Sigma \ (Yi. + Yii) - 2/pY$$

$$\text{SCA effects } (Sij) \ = \ Yij - 1/p + 2(Yi. - Yii + Y.j + Yjj + (2/(p+1)(p+2))Y$$

2.2. Estimation of Heterosis

For estimation of heterosis in each character the mean values of the 21 F_1's have been compared with better parent (BP) for heterobeltiosis. Percent heterosis was calculated as

$$H \ (BP) = \left[(F_1 - BP/100) \times BP \right] \ \left[\text{when BP for better parent, H for heterosis} \right]$$

The significance test for heterosis was done by using standard error of the value of better parent as

$$SE \ (BP) = \text{sqrt} \left[3/2 \times (MSE)/r \right] \ \left[\text{MSE for Mean Squared Error} \right]$$

Table 2. Weather report of experimental area during Sep 2016-Mar 2017.

Year	Month	Temp ˚C (max)	Temp ˚C (min)	Temp ˚C (Av)	Av. RH (%)
2016	Sep	34	26	30	79
	Oct	34	21	28	76
	Nov	34	20	26	74
	Dec	30	17	24	71
2017	Jan	31	13	22	61
	Feb	33	16	25	61
	Mar	32	19	26	69

3. Results and Discussion

3.1. Combining Ability

The values of mean sum of square for both GCA (general combining ability) and SCA (specific combining ability) were highly significant for yield per hectare, which suggests the presence of both additive and non-additive genetic variance in the population (Table 3). But the higher magnitude of GCA compared to SCA indicated predominance of additive genetic variance. The GCA component is primarily a function of the additive genetic variance. GCA of parents plays a significant role in the choice of parents. A parent with higher positive significant GCA effects is considered as a good general combiner for yield. The magnitude and direction of the significant effects for the five parents provide meaningful comparisons and would give indications to the future breeding programme.

3.2. GCA Effect

In the present study, parent P1 also showed the greatest relative GCA effect (2.78**) followed by P3 (2.22**) for yield (Table 4). The parent P5 (−2.28**) was however a poor combiner for yield. KBG-16 was the best general combiner for total yield per vine [7]. Parent L13 showed high GCA effects for the average yield per plant [8]. Almost similar trends of additive and non-additive gene actions have been reported previously by other research groups [9].

Table 3. Analysis of variance of general and specific combining abilities and heterosis for fruit yield in bottle gourd.

Source of variation	Mean sum of square for combining ability	Source of variation	Mean sum of square for heterosis
GCA	37.75**	Genotype	68.96**
SCA	17.09**	Replication	23.81**
Error	1.39	Error	4.16

*Significant at 5% level; **Significant at 1% level.

Table 4. Combining ability effects (SCA and GCA) for yield per hectare of bottle gourd.

Parent			SCA			GCA
♂ ♀	P1	P2	P3	P4	P5	
P1		1.03	7.49**	−2.09*	−2.02*	2.78**
P2			4.13**	2.95**	0.69	−1.28**
P3				−5.20**	−0.12	2.22**
P4					4.03**	−1.47**
P5						−2.28**
S.E. (Sij)			0.813			
S.E. (Gi)						0.399
LSD (0.05)			1.642			0.806
LSD (0.01)			2.195			1.077

*Significant at 5% level; **Significant at 1% level.

3.3. SCA Effect

Out of 10 cross combinations 6 crosses showed positive SCA effect for yield, among them 4 crosses exhibited significant positive SCA effect (Table 4). The highest positive significant SCA effects were shown by the hybrid P1 × P3 (7.49**) followed by P2 × P3 (4.13**), P4 × P5 (4.03**) and P2 × P4 (2.95**). Thus P1 × P3 was the best combination (good × good combiner) compare to other three hybrids P2 × P3 (poor × good combiner), P4 × P5 (poor × poor combiner) and P2 × P4 (poor × poor combiner) for yield in bottle gourd. The other higher values of positive SCA effect may be considered as good specific combiner (poor × poor combiner or poor × good combiner) for fruit yield. [9] also found 3 hybrids viz., GH-10 × G-2, GH-9 × PSPL and GH-13 × G-2 exhibited significant specific combining ability effects for fruit yield. [10] reported good SCA for fruit yield. [11] reported that the parents having poor GCA for certain traits when crossed with parents having high GCA for the same traits usually generated high positive SCA effect. Similar trends were also observed in the present study e.g. P2 × P3. The parents like P2 having poor GCA for yield, when crossed with P4 having poor GCA, for this character, gave higher positive SCA effects (P2 × P4). Since a relationship seems to exist between general and specific combining ability effects, it would safely be assumed that P2 would be an outstanding parent contributing to yield through additive gene actions.

3.4. Heterosis

Significant difference between genotype and replication was observed in ANOVA for fruit yield (Table 3). Among ten crosses 6 combinations exhibited significant positive heterotic effect for yield of bottle gourd (Table 5). Percent of mid parent positive heterosis ranged from 7.7% to 31.8%. The highest significant positive heterosis was obtained from the cross P2 × P3 (31.8%). More than 20% mid parent heterosis was observed from 3 crosses. The highest values were observed in P2 × P3 (31.8%), P2 × P4 (25.5%) and P2 × P5 (20.5%). While [12] reported the highest heterosis over mid-parent for yield per plant was recorded in L13 × T1 (117.26%), L9 × T1 (20.68%) manifested heterosis over the standard parent (T3-Pusa Naveen).

In the case of better parent heterosis for this trait 5 crosses showed significant positive better parent heterosis. Percent of significant positive heterosis ranged from 9.4% to 20.5%. The highest significant positive better parent heterosis was exhibited for the hybrid P2 × P5 followed by P2 × P4 (18.5%). While [12] reported the yield per plant of F_1 hybrids L12 × T2 (13.80%) and L9 × T1 (8.08%) manifested heterosis over top parent. [13] stated the highest heterobeltiosis for yield was recorded in cross PSPL × NDBG-1 (106.85%). [14] got 3 best F_1 hybrids (S46 × S54, S10 × S52-7 and S54 × S52-7) showed 84.5%, 80.5% and 80% heterosis, respectively, for yield over the best parental line, S41. [15] stated three best performing F_1 hybrids LA-46 × LA-99, LA-12 × LA-76 and LA-32 × LA-37 also showed 51.8% and 125.9%, 81.8% and 121.1% and 99.1% and 200.1% higher

Table 5. Mean performance and percent heterosis over mid parent (MP) and better parent (BP) for fruit yield in bottle gourd.

Hybrids/Parents	Fruit yield (ton/hectare)		
	Means (ton)	MP	BP
F$_1$ (P1 × P2)	33.6	7.7**	−12.5**
F$_1$ (P1 × P3)	42.0	14.1**	9.4**
F$_1$ (P1 × P4)	30.0	−7.7**	−21.9**
F$_1$ (P1 × P5)	30.0	−3.8*	−21.9**
F$_1$ (P2 × P3)	39.0	31.8**	10.8**
F$_1$ (P2 × P4)	32.0	25.5**	18.5**
F$_1$ (P2 × P5)	28.8	20.5**	20.5**
F$_1$ (P3 × P4)	25.2	−19.0**	−28.4**
F$_1$ (P3 × P5)	30.8	−2.5	−12.5**
F$_1$ (P4 × P5)	30.0	17.6**	11.1**
P1	38.4		
P2	24.0		
P3	35.2		
P4	27.0		
P5	24.0		
S. E		1.44	1.66
LSD (0.05)		2.90	3.41
LSD (0.01)		3.88	4.60

*Significant at 5% level, **Significant at 1% level.

yield over the better parent in kharif and summer seasons, respectively. [14] reported the best performing hybrids for yield were S36-1 × NC59812-1 and S39-1 × S1-3, with 76.4% and 58.1% heterosis over better parents, respectively. The yield per plant exhibited appreciably high amount of heterosis over the better parent, top parent and commercial control [16].

3.5. Genetic Components of Variation

The components of variation along with the derived genetic ratios for fruit yield (Table 6) showed that the D and H components, which measure additive and dominance variation, respectively were significant. This indicated the importance of both additive and dominance components for the inheritance of all the genotypes in bottle gourd. However, the magnitude of dominance was higher than the additive component. These results agree with that reported by [17]. The H$_2$ representing dominance deviation due to relative frequency of positive and negative genes was significant.

The proportion of positive effects as indicated by F value was non-significant

Table 6. Estimates of genetic components of variation and their ratios for different characters in bottle gourd.

Source of variation	Fruit yield	Source of variation	Fruit yield
D	$23.2^* \pm 5.4$	$(H_1/D)^{1/2}$	1.8
H_1	$74.7^* \pm 14.5$	$H_2/4H_1$	0.22
H_2	$66.3^* \pm 13.2$	$\dfrac{(4DH_1)^{1/2} + F}{(4DH_1)^{1/2} - F}$	1.1
F	5.0 ± 13.4	h^2/H_2	0.45
h^2	$29.6^* \pm 8.9$	b (heritability)	0.80
E	0.00 ± 2.2	h^2 (narrow sense)	0.55

for fruit yield, suggesting greater frequency of dominant alleles governing this character.

The net dominance effect, obtained by the estimate h^2 expressed as the algebraic sum over all loci in heterozygous condition in all crosses, was significant. This revealed that substantial contribution of dominance effects was due to heterogeneity of loci.

The environmental component E, exhibited non-significant values, indicating no influence of environmental factors in the expression. However, the magnitude of E was definitely lower due to no value than the respective value of D and H_1. This also indicated that the characters were influenced less by the environment.

The average degree of dominance as indicated by the proportion $(H_1/D)^{1/2}$ was more than unity, suggesting that over dominance was operating in the expression for fruit yield of bottle gourd. [18] and [19] also found over-dominance in graphic analysis.

The ratio of $H_2/4H_1$ provides an estimate of the average frequency of positive and negative alleles in all the parents. A value of this ratio smaller than 0.25 studied suggested asymmetrical distribution of only the negative alleles.

The ratio of $[(4DH_1)^{1/2} + F/(4DH_1)^{1/2} - F]$ estimates the relative proportion of dominant and recessive alleles in the parents. In the present study the ratio for all the characters were greater than unity, suggesting excess of dominant alleles and minority of recessive alleles *i.e.*, asymmetrical distribution for dominant alleles in the parents.

The estimated number of effective factors (h^2/H_2) was less than unity for all the attributes studied. The proportion of genes or group of genes showing dominance was very less, which could be owing to the predominant concealing effects of positive and negative effects of genes or to non-isodirectional distribution of polygene [20].

Heritability in narrow sense was higher for fruit yield, indicating that this character was highly heritable. These results agree with that reported by [17].

3.6. Graphical Analysis

Graphical analysis of parent-offspring covariances (Wr) on array variances (Vr) is shown in Figure 1. It was observed from the Wr/Vr graph that the slope of the regression line for fruit yield was significantly below 1.0 (0.39 ± 0.15), suggesting significant non-allelic interaction for this character. The regression line intersected the Wr axis above the origin, suggested incomplete dominance to partial dominance in addition to the interaction. Here all the Wr, Vr points lay within the boundary of the limiting parabola. The relative values of Wr and Vr showed that the parent P4, P5 had the lowest value and hence contained the most dominant alleles while the parent P3 had the highest Wr, Vr values and have the most recessive alleles. The other parents fell in between suggested that the equal frequency of dominant and recessive alleles.

All the Wr, Vr points were fall within the boundary of the limiting parabola and here the parents also clustered into two distinct groups on the regression line showing diversity in the parents for this trait.

4. Conclusion

The cross between poor and poor parents showed positive SCA effect for fruit yield, which indicated the higher yield. The estimates of mid parent heterosis ranged from −19.0 to 31.8 percent and the better parent heterosis ranged from −28.4 to 20.5 percent. Analysis for genetic components of variation suggested that additive components were more important in the inheritance of fruit yield. This character was observed being controlled by two to three pairs of genes or groups of genes. Narrow sense heritability was 55 percent indicating probability of selection in generations. The graphical analysis also indicated wide genetic diversity among the parents.
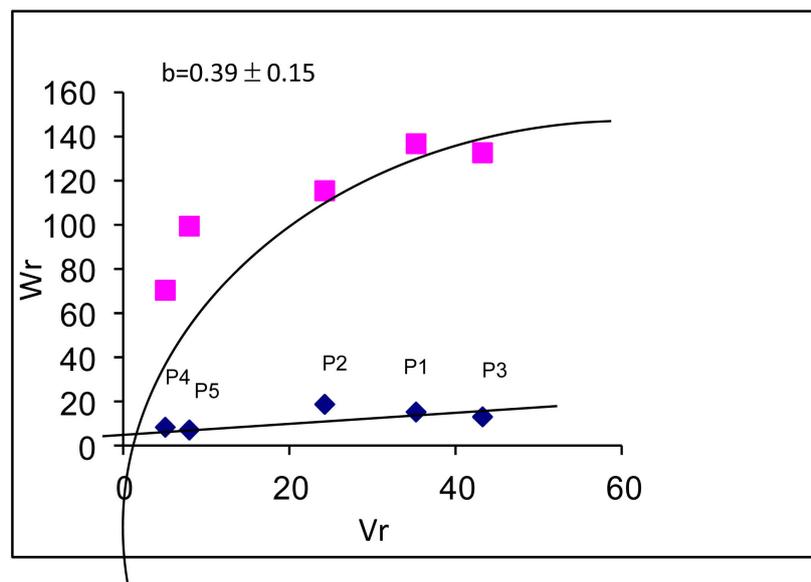

Figure 1. Wr/Vr regression line and limiting parabola for fruit yield.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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