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Production and Evaluation of Silkworm Hybrids Using Diallel Genetic Design

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ABSTRACT: Hayman's analysis of variance was used to analyze several characters of importance of a 8 x 8 diallel cross of silkworms. Significant differences were observed for additive, dominance and epistatic effects. Significant differences between reciprocal crosses indicated presence of maternal effects. Further analysis using Wr/Vr relationship indicated that dominance was partial for all characters.

Race 14 had the highest mean shell weight and cocoon shell percentage while races 40 and 36 showed highest mean values for cocoon weight.

Heterosis was observed for all 3 characters. Since dominance was partial, hybrid vigour was probably due to epistatic effects.

The results indicated that those parents having high general combining ability also gave the best hybrids in combination. Although dominance was for increasing alleles, since it was partial and also highly significant additive effects were observed, superior recombinant inbred lines could be extracted from crosses using parents with the highest combining abilities.

INTRODUCTION

The first attempt to establish the Sericulture Industry in Sri Lanka was made in the late seventeenth century in the Jaffna area, with a further attempt in the 1900's in the Kandy area. In the period of 1943 – 1956 a serious attempt was made by the Department of Cottage Industries to establish a special unit to deal with Sericulture within the Department of Minor Export Crops, envisaging the subsequent

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1. Silkworm Breeding Centre, Nilambe

establishment of a statutory authority with responsibility for Sericulture Development.

The Government of Sri Lanka has noted repeatedly the great potential for the industry in view of favourable agroclimatic factors and the plentiful availability of rural labour at low cost, with a relatively high level of education and literacy. The tropical climate permits sericulture to be practiced throughout the year with continuous growth of Mulberry enabling multiple cropping and year – round production of cocoon.

The national silkworm breeding stock comprises of forty six pure lines, including multivoltine, bivoltine and univoltine races introduced from India, China and Italy. The stocks have been maintained by the silkworm breeding centre at Nillambe under Silk and Allied Products Development Authority (SAPDA).

It was observed that the large number of available races provided a considerable genetic base for the Development of improved commercial hybrids. At present Sri Lanka Silk Industry uses one commercial hybrid which is a cross between race 7 (Chinese Origin) and race 12 (Japanese Origin). This hybrid has been used for around 15 years. However, it is not suitable to meet technological and economical requirements of sericulture industry, because the characteristics of this hybrid (cocoon weight, shell percentage, reelability) were found to be inferior compared to standard requirements. At present the silk industry requires high productive commercial hybrids or pure lines to be used in the self employed cottage industry in Sri Lanka. Studies were therefore undertaken to produce and evaluate silkworm hybrids, and pure lines and study the genetic basis of some economically important characteristics. The diallel genetic design was used for this purpose. In this study, only the performance of F1 hybrids were studied.

MATERIALS AND METHODS

Eight silkworm races consisting of 4 Japanese and 4 Chinese were used in the diallel method of crossing. These races were selected based on data maintained for many years at the silkworm breeding centre, Nillambe. The characters studied for selection were cocoon weight, cocoon shell weight and cocoon shell percentage. The races selected and their characteristics are given below:

(1) 18,000 – (18) bivoltine Japanese race, larvae prominently marked, cocoons white and spindle shaped. (2) 40,000 – (40) univoltine Japanese race, larvae marked, cocoon white and spindle shaped, (3) 53,000 – (53) bivoltine Japanese race, larvae marked, cocoon white and spindle shaped. (4) 10,000 – (10) bivoltine Japanese race, larvae marked, cocoon white and spindle shaped. (5) 14,000 – (14) bivoltine Chinese race, larvae plain, cocoon white and oval shaped. (7) 52,000 – (52) bivoltine Chinese race, larvae plain, cocoon white and oval shaped. (8) 30,000 – (30) bivoltine Chinese race, larvae plain, cocoons white and oval shaped.

These 8 races were maintained at the silkworm breeding centre for about 15 years by submating.

These 8 races were crossed in all possible combinations including reciprocals (full diallel) giving 56 F1 hybrids and reciprocal hybrids. These hybrids as well as the parents were reared during March – April 1990 using standard methods of rearing at the silkworm breeding centre, Nillambe.

Each hybrid and parental family consisted of 250 individuals replicated 2 times in 2 blocks (racks). Each family was reared in a tray and its position in the rack changed daily.

The characters presented in this study are cocoon shell weight, cocoon weight and cocoon shell ratio. The data was analysed using Hayman's analysis of variance (Hayman, 1954) to estimate additive genetic effect (a), Non-additive genetic effect (b), Mean dominance effect (b1), Additional dominance effect (b2), Residual dominance effect (b3), Average (c), and specific (d), maternal effect. The Covariance/Variance (Wr/Vr) analysis (Jinks, 1954) was used to identify the type of dominance operating.

RESULTS

Shell weight

The external shell from which the silk fibre is reeled off, constitutes the economically useful part, of the cocoon. The mean values for this character (average of 40 random cocoons) and reciprocal averages are given in Table 1. The results of analysis of variance of shell weight are presented in Table 4.

Analysis of variance indicated significant additive effect (Table 4). The parents showing highest shell weight were 14 (0.38 g) and 36 (0.36 g). An overall significant directional dominance was observed for increasing shell weight. Heterosis was observed in 40 x 53, 40 x 14, 53 x 14 and 14 x 36 hybrids. The race 14 showed the highest mean value for shell weight and was a parent in 3 of the above heterotic hybrids. Directional dominance was significant between hybrids indicating significant difference in specific combining ability (SCA) effect. Significant average maternal effect (c) as well as specific maternal effects (d) were observed (Table 1). Highest differences in reciprocal crosses were detected in 53 x 10, 14 x 10, 14 x 40, 30 x 52 and 36 x 40 hybrids. The presence of significant additive genetic effect and the fact that dominance was partial indicates the recombinant inbred lines superior to the hybrids and parents could be extracted from these crosses for cocoon shell weight.

Figure 1 shows the relationship between parent-offspring Covariance (Wr) on Variance (Vr) of the same array. The graph indicates partial dominance for shell weight. Race 36 carried comparatively large number of dominant genes, for this character. While race 30 has the largest no. of recessive genes.

Cocoon weight

Silk cocoon is the silk capsule formed by silkworm larvae in which it spends the pupal stage. This could perhaps be a good measure of the vigour of the insects and was calculated as the mean of 40 cocoons selected at random from each population.

Mean values and Reciprocal averages for cocoon weight are given in Table 2. Analysis of variance indicated significant additive effect (Table 4). The parents showing highest cocoon weight are 36 (1.68 g) and 40 (1.65 g). An Overall significant directional dominance was observed for increasing cocoon weight. Heterosis was observed in hybrid 52 x 40, 14 x 40, 53 x 14, 36 x 52, 53 x 30 and 40 x 30. The family 40 and 53 showed the higher mean values for cocoon weight and were

Table 1. Mean values of cocoon shell weight.

♀ \ ♂	18	40	53	10	14	36	52	30
	COCOON SHELL WEIGHT (g)							
18	0.18	0.29 (0.28)	0.27 (0.27)	0.29 (0.27)	0.29 (0.29)	0.30 (0.29)	0.26 (0.26)	0.25 (0.26)
40	0.28	0.32	0.38 (0.38)	0.34 (0.33)	0.39 (0.40)	0.39 (0.37)	0.35 (0.33)	0.34 (0.35)
53	0.28	0.38	0.33	0.42 (0.37)	0.42 (0.41)	0.37 (0.36)	0.36 (0.34)	0.34 (0.36)
10	0.26	0.33	0.32	0.27	0.35 (0.38)	0.36 (0.37)	0.34 (0.33)	0.34 (0.35)
14	0.30	0.42	0.41	0.41	0.38	0.42 (0.41)	0.39 (0.33)	0.39 (0.38)
36	0.28	0.35	0.36	0.38	0.40	0.36	0.35 (0.33)	0.36 (0.37)
52	0.26	0.32	0.33	0.32	0.38	0.35	0.31	0.33 (0.35)
30	0.27	0.36	0.38	0.36	0.38	0.38	0.37	0.27

The figures within parenthesis are reciprocal averages.

Table 2. Mean values of cocoon weight.

♀ \ ♂	COCOON WEIGHT (g)							
	18	40	53	10	14	36	52	30
18	1.19	1.57 (1.57)	1.47 (1.54)	1.62 (1.58)	1.50 (1.52)	1.59 (1.56)	1.46 (1.46)	1.51 (1.51)
40	1.58	1.65	1.88 (1.88)	1.72 (1.73)	1.77 (1.83)	1.92 (1.85)	1.80 (1.78)	1.77 (1.81)
53	1.61	1.89	1.56	2.05 (1.84)	1.82 (1.79)	1.82 (1.75)	1.79 (1.73)	1.80 (1.82)
10	1.55	1.75	1.63	1.46	1.67 (1.74)	1.75 (1.78)	1.76 (1.74)	1.68 (1.72)
14	1.55	1.90	1.77	1.81	1.59	1.90 (1.82)	1.79 (1.80)	1.79 (1.76)
36	1.53	1.79	1.68	1.82	1.74	1.68	1.74 (1.74)	1.78 (1.81)
52	1.46	1.77	1.68	1.72	1.81	1.75	1.53	1.75 (1.77)
30	1.52	1.85	1.85	1.76	1.73	1.84	1.79	1.54

The figures within parenthesis are reciprocal averages.

Table 4. Analysis of variance.

Items	df	Cocoon shell weight	Cocoon weight	Shell percentage
a+	7	**	**	**
b	28	**	**	**
b^1	1		*	
b^2	7	**	**	**
b^3	20	**	**	**
c	7	**	**	**
d	21	**	**	**

a+ – Additive genetic effect.

b – Non-additive genetic effect.

b^1 – Mean dominance effect.

b^2 – Additional dominance effect.

b^3 – Residual dominance effect.

c, d – Average and specific maternal effects respectively.
Each main effect was tested against its own block interaction.

*, ** – Significant at 5% and 1% levels respectively.

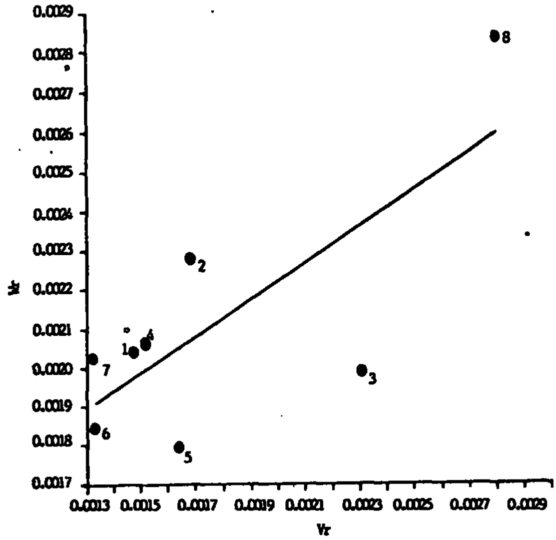

Fig. 1. Relationship between Wr and Vr for cocoon shell weight.
Parental Symbols - 1-18, 2-40, 3-53, 4-10, 5-14, 6-36, 7-52, 8-30.

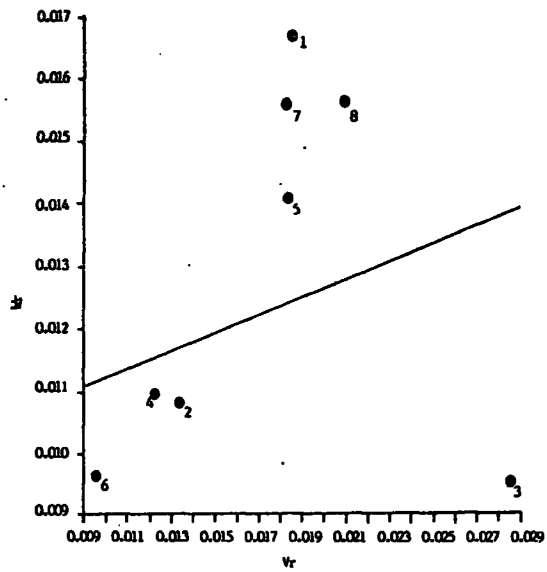

Fig. 2. Relationship between Wr and Vr for cocoon weight.
Parental Symbols - 1-18, 2-40, 3-53, 4-10, 5-14, 6-36, 7-52, 8-30.

parents of above heterotic hybrids. Directional dominance was significant between hybrids. Remaining non additive effect (b3) were also significant. Significant average (c) and specific (d) material effects were observed (Table 2). Highest differences of reciprocal means were detected in hybrids 10 x 53, 14 x 40 and 36 x 14.

The Wr/Vr regression line (Figure 2) indicates partial dominance for cocoon weight. Race 36 carried the greater number of dominant genes for this character and race 30 carried more recessive genes.

As in cocoon shell weight highly significant additive genetic effect and partial dominance indicates the potential to produce superior recombinant inbred lines from these crosses for cocoon weight.

Shell percentage

Ratio of shell weight to cocoon weight expressed as a percentage. Mean values and reciprocal averages are given in Table 3. Analysis of variance is given in Table 4. Additive genetic effects were highly significant. The parents showing highest shell percentage were race 14 (24.14%) race 36 (21.38%). An overall significant directional dominance was observed for increasing shell percentage, Heterosis was observed in 10 x 30. The parents 14 and 53 showed the highest mean values for shell percentage. Directional dominance was significant between hybrids. Remaining non additive effects (b3) were significant indicating possible effects of epistasis.

Significant average maternal effects as well as specific maternal effects were observed (Table 3). Highest differences of reciprocal means were detected in 10 x 40 and 14 x 10. These results are similar to those of the other 2 characters.

The graph (Figure 3) indicates partial dominance for shell percentage. Race 52 carried comparatively large amount, of dominance genes for this character. While race 53 has the largest amount of recessive allels.

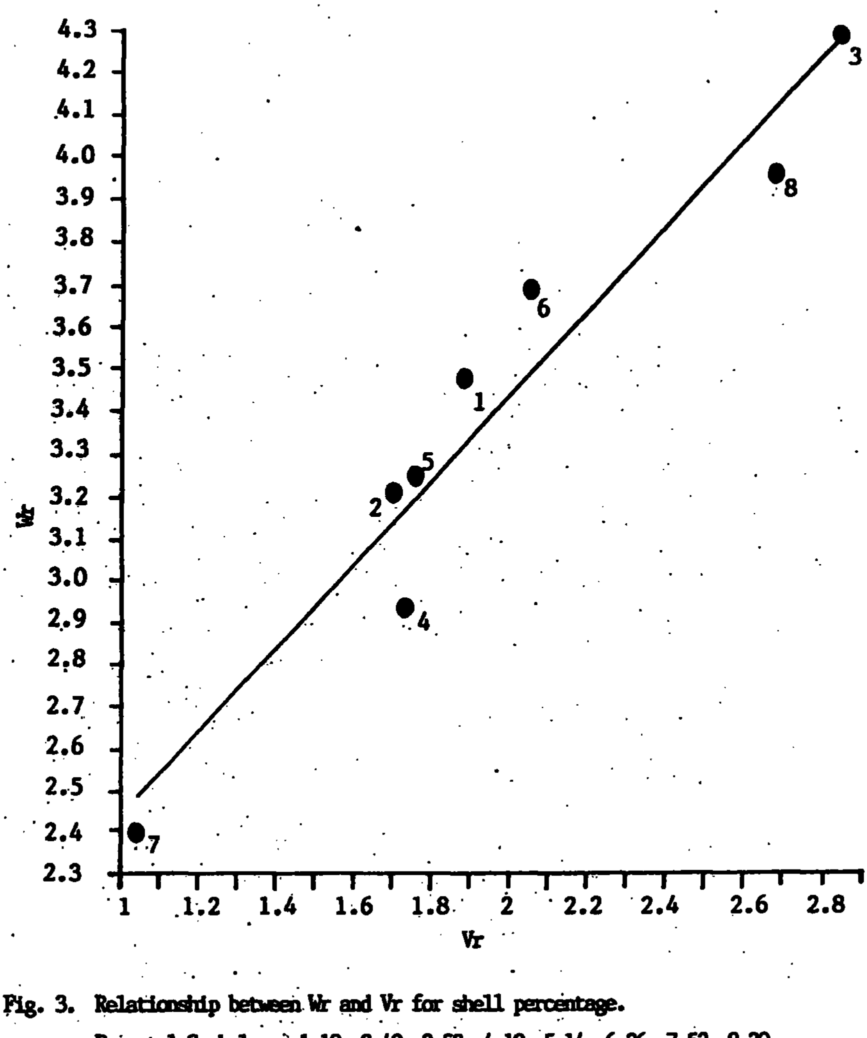

Fig. 3. Relationship between Wr and Vr for shell percentage.
Parental Symbols — 1-18, 2-40, 3-53, 4-10, 5-14, 6-36, 7-52, 8-30.

Table 3. Mean values of cocoon shell percentage.

♂ / ♀	COCOON SHELL PERCENTAGE (%)							
	18	40	53	10	14	36	52	30
18	15.55	18.59 (18.14)	18.60 (18.09)	18.40 (17.85)	19.70 (19.82)	19.10 (18.86)	18.00 (18.05)	16.80 (17.36)
40	7.70	19.80	20.22 (20.23)	20.13 (19.41)	22.35 (22.31)	20.53 (20.45)	19.77 (19.24)	16.88 (18.28)
53	17.59	20.24	21.38	20.69 (20.33)	23.71 (23.52)	20.58 (21.14)	20.61 (20.10)	19.54 (20.00)
10	17.30	18.69	19.98	19.32	21.04 (22.14)	20.95 (20.52)	19.57 (19.40)	19.74 (20.10)
14	19.94	22.28	23.33	23.25	24.14	22.58 (23.01)	22.15 (21.75)	21.85 (21.94)
36	18.62	20.37	21.70	20.89	23.44	21.52	20.56 (20.41)	21.03 (21.05)
52	18.10	18.71	19.60	19.24	21.35	20.27	20.29	19.04 (19.89)
30	17.93	19.69	20.47	20.47	22.03	21.07	20.74	17.53

The figures within parenthesis are reciprocal averages.

DISCUSSION

For all the three characters, the mean of the hybrids is consistently greater than the mean of parents. It is clear from Tables 1 to 3 that most of the hybrids excel the best parent in respect of shell weight andcocoon weight. The ranking of the races in respect of shell weight agrees closely with their ranking in respect of cocoon weight (Krishnaswami *et al.*, 1964). It is important to select high cocoon shell weight as it is effective to breed high silk yielding varieties when considering shell weight and cocoon yield (Shon *et al.*, 1987).

Significant additive genetic effects, dominance and reciprocal differences were detected for all 3 characters. Race 14 and 36 were the parents that had highest cocoon shell weight. The best F1 hybrids were 53 x 14 and 14 x 36. These hybrids were made up of highest scoring parents indicating that those parents with highest GCA gave the best F1 hybrids in combination for cocoon shell weight. Dominance effect was detected to be partial indicating that heterosis was possibly due to epistatic effects. The regression of Wr/Vr had a coefficient less than unity indicating again the possibility of epistatic effects. Significant reciprocal differences indicated presence of specific maternal effects.

Significant additive, dominance and reciprocal differences were obtained for cocoon weight and shell percentage.

The inbred parent 36 as well as the hybrid 40 x 53 gave the highest cocoon weight. Many other hybrids too showed heterosis for cocoon weight. Since dominance was partial, heterosis was possibly due to epistatic or some other non-additive effects.

The parent 14 showed the highest shell percentage (24.14%). The hybrid 14 x 53 had similar values (23.52%). Dominance observed for this character was partial. The regression coefficient of Wr Vs Vr was close to unity indicating absence of epistasis.

These results indicated that the 2 Chinese races 36 and 14 and 2 Japanese races 40 and 53 performed best with regard to combining ability. Therefore, these crosses can be used to extract superior recombinant pure lines in the future, since significant additive effects were identified and dominance was partial.

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