*Int. J. Indust. Entomol.* Vol. 5, No. 1, 2002, pp. 37~43
**Research Article**

**International Journal of *Industrial Entomology***

# Multiple Trait Evaluation of Bivoltine Hybrids of Silkworm (*Bombyx mori* L.)

**M. Ramesh Babu*, Chandrashekharaiah, H. Lakshmi and J. Prasad**
*Andhra Pradesh State Sericulture Research and Development Institute (APSSRDI), Kirikera 515 211, Hindupur, India.*

*(Received 19 May 2002; Accepted 13 August 2002)*

**Eighteen new bivoltine silkworm (*Bombyx mori* L.) hybrids developed at Andhra Pradesh State Sericulture Research and Development Institute, Hindupur are evaluated for 10 economic traits by following two multiple trait index methods, *i.e.,* Subordinate Function and Evaluation Index for their economic merit. The hybrid genotype, APS6 × APS11 with highest Subordinate Function value of 8.2432 and highest average Evaluation Index of 61.67 ranked first. This hybrid is adjudicated as most promising hybrid and recommended for commercial use. Further, applicability of Subordinate Function Index Method is tested and recommended for application of multiple trait evaluation similar to Evaluation Index Method as the results obtained are comparable. Further, both these methods can be applied for confirmation of results.**

**Key words**: Silkworm, Bivoltine, Multiple traits, Evaluation index, Subordinate function

## Introduction

Widespread utilization of hybrids towards achieving sustainability and quality oriented increased production is well established in plants and animals in general and silkworm in particular as it is the only animal where hybrids are used compulsorily (Yokoyama, 1976). Inspite of quantitative increase in the overall silk production in India over years through the development and use of productive silkworm hybrids on commercial scale (Sengupta *et al.*, 1971; Sudhakar Rao *et al.*, 2001), there remains a wide quantitative and qualitative yield gap that is mainly attributed to the dearth for potential silkworm hybrids suitable for Indian tropical conditions necessitating the need for more potential silkworm hybrids. Realizing the need for increased qualitative silk production, due emphasis is being laid towards the development of suitable and qualitatively superior bivoltine hybrids for prevailing tropical conditions of the country in general and region and season specific in particular. In this direction, unstinted efforts by the silkworm breeders at Andhra Pradesh State Sericulture Research and Development Institute (APSSRDI), Hindupur over the last 3 years resulted in the development of a few productive and qualitatively superior bivoltine hybrids. Since, the genetic improvement of multiple traits being the objective of evolving the productive hybrids, many breeders (Naseema Begum *et al.*, 2000; Ramesh Babu *et al.*, 2001; Sudhakar Rao *et al.*, 2001; Vidyunmala *et al.*, 1998) followed the Evaluation Index method of Mano *et al.* (1993) to adjudicate the relative merit of the hybrids. In the present investigation an attempt has been made to evaluate the overall merit of the developed hybrids and identification of most promising hybrids by an alternate method, the Subordinate Function Index Method (Gower, 1971) and compared its applicability with that of the Evaluation Index Method for confirmation of the results.

## Materials and Methods

A total of eighteen hybrid combinations (9 each of oval × peanut and peanut × oval type) involving six parents namely APS5, APS11, APS13 (oval), APS2, APS6, APS8 (peanut) developed at APSSRDI constituted the study materials. All the combinations were brushed as composite in 3 replicates each. Each composite laying with about 1000 eggs represented by 10 – 12 different mother broods. From each replication, 300 larvae were retained after third moult. The rearings were conducted as per the standard

*To whom correspandence should be addressed.
Andhra Pradesh State Sericulture Research and Development Institute (APSSRDI), Kirikera-515 211, Hindupur, Andhra Pradesh, India. Tel: 08556-47428; Fax: 08556-47505 E-mail: babu_apssrdi@rediffmail.com

rearing methods as detailed by Bhargava *et al.* (1993). Data was accruded for 10 economic traits namely fecundity, cocoon yield/weight, pupation rate (viable), cocoon weight, cocoon shell weight, shell ratio, filament length, raw silk recovery (quantitative), reelability and neatness (qualitative). The data was analyzed as per Subordinate Function and Evaluation Index methods as detailed below and relative rankings are assigned.

**Subordinate Function Index Method (Gower, 1971)**

The Subordinate Function values character wise were calculated using the following formula.

Xu = (Xi X min) / (X max X min)

Where, Xu = Subordinate Function

Xi = Measurement of character of a tested genotype

X max = The maximum value of the character from all the tested genotypes

X min = The minimum value of the character among all the tested genotypes.

The highest cumulative Subordinate Function value is assigned first rank and subsequent ranks are assigned in the descending order.

**Evaluation Index Method (Mano *et al.*, 1993)**

The Evaluation Index values character wise are calculated by using the formula.

$$\text{Evaluation Index} = \frac{A - B}{C} \times 10 + 50$$

Where,

A = Value obtained for a trait for a hybrid

B = Mean of a trait of all the hybrids for the trait

C = Standard deviation of all the hybrids for a trait

10 = Standard unit

50 = Fixed value

The average cumulative index value over a number of traits analyzed was arranged in descending order. The hybrids with average Evaluation Index (E. I.) value above 50 were considered to possess the economic merit. The hybrid with highest average Evaluation Index was adjudicated to be the most promising one.

## Results and Discussion

Wide and sudden micro-climatic fluctuations coupled with poor quality mulberry and management practices by the farmers under tropical conditions require more flexible genotypes. It is well established that, silk yield in silkworm is contributed by more than 21 characters (Thiagarajan *et al.*, 1993). It is therefore obvious that the superiority of the hybrid genotype is to be assessed by a number of economic traits. In the present study, 10 important primary economic traits (3 viable, 5 quantitative and 2 qualitative) are considered and analysed so as to find out the superiority and relative merit of the eighteen newly developed bivoltine hybrids.

The mean performance of the eighteen hybrid genotypes for ten traits of economic importance is presented in Table 1. The Subordinate Function and E. I. values calculated for all the ten traits combination-wise are given in Tables 2 and 3 respectively. The relative ranks assigned to the test hybrids based on their overall superiority in both the methods are shown in Table 4 and compared.

In the Evaluation Index Method, out of the eighteen hybrid combinations, 9 combinations (APS6 × APS11; APS8 × APS11; APS6 × APS5; APS5 × APS2; APS5 × APS8; APS11 × APS8; APS11 × APS2; APS2 × APS11 and APS8 × APS5) recorded cumulative index values above 50 (Table 4) suggesting that these combinations possessing economic merit. Among them, the hybrid, APS6 × APS11 recorded highest average index of 61.67 while APS8 × APS5 recorded the lowest (50.33). Based on the average cumulative index, relative ranks are assigned in the descending order with APS6 × APS11 figuring in first place.

In the Subordinate Function Method, the cumulative values ranged from a maximum of 8.2432 (APS6 × APS11) to a minimum of 1.7806 (APS8 × APS13). The hybrid, APS6 × APS11 with highest Subordinate Function value is assigned first rank while the subsequent ranks for the remaining test hybrids are assigned in the descending order.

The scrutiny of the data present that the performance of the eighteen different hybrid genotypes exhibited superiority in different individual characters and no single hybrid combination excelled in all the ten analyzed characters put together. These observations confirm the established fact that superiority in one or a couple of characters may not reflect the overall merit of the hybrid (Vidyunmala *et al.*, 1998). However, a few breeders (Singh *et al.*, 1993; Udupa and Gowda, 1988) used selection index method for identification of promising hybrids based on only few characters. Since the comprehensive merit of the hybrid over a range of traits depends on relative superiority of many individual traits selection need to be based on multiple trait analysis comprising viable, quantitative and qualitative traits. As such, it is highly imperative to consider the contribution of various traits contributing to overall silk out put as opined by Singh and Subba Rao (1993). It is absolute must for the breeder to adopt reliable methods for identification of potential hybrids exercising

**Table 1.** Mean performance of new bivoltine silkworm hybrids

| Sl no. | Hybrid combination | Fecundity (no.) | Yld/wt. (kg) | Pupation rate (%) | Cocoon wt. (g) | Shell wt. (g) | Shell ratio (%) | Filament length (m) | Raw silk (%) | Reelability (%) | Neatness (p) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | APS13 × APS2 | 440 | 17.070 | 92.00 | 1.790 | 0.370 | 20.59 | 850 | 14.27 | 75.37 | 82.3 |
| 2 | APS13 × APS8 | 540 | 18.470 | 93.77 | 1.890 | 0.420 | 22.05 | 815 | 15.13 | 74.83 | 85.3 |
| 3 | APS13 × APS6 | 437 | 18.670 | 94.77 | 1.870 | 0.410 | 21.99 | 850 | 15.24 | 76.03 | 83.7 |
| 4 | APS5 × APS2 | 409 | 20.170 | 93.00 | 2.120 | 0.480 | 22.84 | 874 | 15.93 | 76.50 | 84.3 |
| 5 | APS5 × APS8 | 563 | 19.800 | 94.50 | 1.960 | 0.420 | 21.50 | 922 | 14.92 | 75.53 | 86.3 |
| 6 | APS5 × APS6 | 622 | 16.570 | 93.30 | 1.860 | 0.400 | 21.46 | 711 | 13.73 | 74.13 | 86.3 |
| 7 | APS11 × APS2 | 456 | 19.200 | 90.00 | 1.910 | 0.450 | 23.45 | 768 | 15.62 | 75.97 | 90.7 |
| 8 | APS11 × APS8 | 574 | 17.370 | 92.00 | 1.870 | 0.440 | 23.33 | 798 | 16.20 | 75.83 | 89.0 |
| 9 | APS11 × APS6 | 521 | 18.800 | 88.77 | 1.910 | 0.430 | 22.66 | 704 | 14.39 | 73.83 | 88.7 |
| 10 | APS2 × APS13 | 511 | 17.000 | 92.77 | 1.910 | 0.420 | 21.92 | 652 | 13.23 | 73.20 | 86.0 |
| 11 | APS2 × APS5 | 655 | 19.270 | 92.27 | 2.050 | 0.470 | 22.86 | 620 | 13.71 | 68.43 | 85.3 |
| 12 | APS2 × APS11 | 414 | 19.670 | 90.27 | 2.030 | 0.500 | 24.35 | 684 | 15.10 | 72.60 | 84.7 |
| 13 | APS8 × APS13 | 510 | 17.600 | 89.27 | 1.690 | 0.350 | 20.90 | 615 | 14.20 | 73.13 | 83.3 |
| 14 | APS8 × APS5 | 605 | 16.600 | 86.77 | 1.980 | 0.440 | 22.44 | 773 | 16.03 | 78.57 | 88.0 |
| 15 | APS8 × APS11 | 490 | 19.470 | 90.33 | 1.980 | 0.460 | 23.34 | 791 | 18.30 | 77.90 | 89.7 |
| 16 | APS6 × APS13 | 408 | 17.300 | 92.77 | 1.960 | 0.420 | 21.46 | 694 | 16.10 | 72.87 | 86.3 |
| 17 | APS6 × APS5 | 461 | 19.300 | 89.27 | 2.190 | 0.460 | 20.85 | 930 | 17.17 | 76.52 | 91.0 |
| 18 | APS6 × APS11 | 485 | 19.470 | 93.77 | 2.080 | 0.500 | 24.16 | 910 | 17.37 | 80.80 | 89.0 |
| | Average | 506 | 18.433 | 91.64 | 1.947 | 0.436 | 22.34 | 776 | 15.37 | 75.11 | 86.7 |
| | S. D. | 75 | 1.204 | 2.23 | 0.120 | 0.040 | 1.12 | 102 | 1.37 | 2.71 | 2.58 |

**Table 2.** Subordinate function values of new bivoltine silkworm hybrids

| Sl no. | Hybrid combination | Fecundity (no.) | Yld/wt. (kg) | Pupation rate (%) | Cocoon wt. (g) | Shell wt. (g) | Shell ratio (%) | Filament length (m) | Raw silk (%) | Reelability (%) | Neatness (p) | Cumulative index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | APS13 × APS2 | 0.1296 | 0.1389 | 0.6538 | 0.2000 | 0.1333 | 0.0000 | 0.7442 | 0.2051 | 0.5610 | 0.0000 | 2.7659 |
| 2 | APS13 × APS8 | 0.5344 | 0.5278 | 0.8750 | 0.4000 | 0.4667 | 0.3883 | 0.6343 | 0.3748 | 0.5174 | 0.3460 | 5.0646 |
| 3 | APS13 × APS6 | 0.1174 | 0.5833 | 1.0000 | 0.3600 | 0.4000 | 0.3723 | 0.7442 | 0.3964 | 0.6144 | 0.1546 | 4.7427 |
| 4 | APS5 × APS2 | 0.0040 | 1.0000 | 0.7788 | 0.8600 | 0.8667 | 0.5984 | 0.8203 | 0.5325 | 0.6524 | 0.2307 | 6.3438 |
| 5 | APS5 × APS8 | 0.6275 | 0.8972 | 0.9663 | 0.5400 | 0.4667 | 0.2420 | 0.9736 | 0.3333 | 0.5740 | 0.4614 | 6.0819 |
| 6 | APS5 × APS6 | 0.8664 | 0.0000 | 0.8163 | 0.3400 | 0.3333 | 0.2314 | 0.3055 | 0.0986 | 0.4608 | 0.4614 | 3.9136 |
| 7 | APS11 × APS2 | 0.1943 | 0.7306 | 0.4038 | 0.4400 | 0.6667 | 0.7606 | 0.4842 | 0.4714 | 0.6095 | 0.9619 | 5.7230 |
| 8 | APS11 × APS8 | 0.6721 | 0.2222 | 0.6538 | 0.3600 | 0.6000 | 0.7287 | 0.5803 | 0.5858 | 0.5982 | 0.7693 | 5.7704 |
| 9 | APS11 × APS6 | 0.4575 | 0.6194 | 0.2500 | 0.4400 | 0.5333 | 0.5505 | 0.2812 | 0.2288 | 0.4365 | 0.7313 | 4.5286 |
| 10 | APS2 × APS13 | 0.4170 | 0.1194 | 0.7500 | 0.4400 | 0.4667 | 0.3537 | 0.1173 | 0.0000 | 0.3856 | 0.4233 | 3.4731 |
| 11 | APS2 × APS5 | 1.0000 | 0.7500 | 0.6875 | 0.7200 | 0.8000 | 0.6037 | 0.0159 | 0.0947 | 0.0000 | 0.3426 | 5.0143 |
| 12 | APS2 × APS11 | 0.0243 | 0.8611 | 0.4375 | 0.6800 | 1.0000 | 1.0000 | 0.2199 | 0.3688 | 0.3371 | 0.2699 | 5.1986 |
| 13 | APS8 × APS13 | 0.4130 | 0.2861 | 0.3125 | 0.0000 | 0.0000 | 0.0824 | 0.0000 | 0.1913 | 0.3800 | 0.1153 | 1.7806 |
| 14 | APS8 × APS5 | 0.7976 | 0.0083 | 0.0000 | 0.5800 | 0.6000 | 0.4920 | 0.5011 | 0.5523 | 0.8197 | 0.6540 | 5.0050 |
| 15 | APS8 × APS11 | 0.3320 | 0.8056 | 0.4450 | 0.5800 | 0.7333 | 0.7314 | 0.5571 | 1.0000 | 0.7656 | 0.8466 | 6.7965 |
| 16 | APS6 × APS13 | 0.0000 | 0.2028 | 0.7500 | 0.5400 | 0.4667 | 0.2314 | 0.2516 | 0.5661 | 0.3589 | 0.4614 | 3.8288 |
| 17 | APS6 × APS5 | 0.2146 | 0.7583 | 0.3125 | 1.0000 | 0.7333 | 0.0691 | 1.0000 | 0.7771 | 0.6540 | 1.0000 | 6.5190 |
| 18 | APS6 × APS11 | 0.3117 | 0.8056 | 0.8750 | 0.7800 | 1.0000 | 0.9495 | 0.9355 | 0.8166 | 1.0000 | 0.7693 | 8.2432 |

**Table 3.** Evaluation index values of new bivoltine hybrids

| Sl no. | Hybrid combination | Fecundity (no.) | Yld / wt. (kg) | Pupation rate (%) | Cocoon wt. (g) | Shell wt. (g) | Shell ratio (%) | Filament length (m) | Raw silk (%) | Reelability (%) | Neatness (p) | Average evaluation index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | APS13 × APS2 | 41.29 | 38.68 | 51.60 | 36.88 | 33.68 | 34.31 | 57.28 | 41.96 | 50.95 | 33.21 | 41.99 |
| 2 | APS13 × APS8 | 54.56 | 50.30 | 59.54 | 45.23 | 46.13 | 47.39 | 53.88 | 48.25 | 48.95 | 44.83 | 49.91 |
| 3 | APS13 × APS6 | 40.90 | 51.97 | 64.03 | 43.56 | 43.64 | 46.85 | 57.28 | 49.06 | 53.39 | 38.40 | 48.91 |
| 4 | APS5 × APS2 | 37.18 | 64.42 | 56.09 | 64.42 | 61.06 | 54.46 | 59.64 | 54.10 | 55.12 | 40.96 | 54.75 |
| 5 | APS5 × APS8 | 57.61 | 61.35 | 62.82 | 51.07 | 46.13 | 42.46 | 64.39 | 46.72 | 51.54 | 48.70 | 53.28 |
| 6 | APS5 × APS6 | 65.44 | 34.53 | 57.43 | 42.72 | 41.15 | 42.10 | 43.68 | 38.01 | 46.37 | 48.70 | 46.01 |
| 7 | APS11 × APS2 | 43.42 | 56.37 | 42.62 | 46.89 | 53.59 | 59.93 | 49.22 | 51.84 | 53.16 | 65.52 | 52.26 |
| 8 | APS11 × APS8 | 59.07 | 41.17 | 51.60 | 43.56 | 51.11 | 58.85 | 52.20 | 56.08 | 52.65 | 59.05 | 52.53 |
| 9 | APS11 × APS6 | 52.04 | 53.05 | 37.09 | 46.89 | 48.62 | 52.85 | 42.93 | 42.84 | 45.26 | 57.77 | 47.93 |
| 10 | APS2 × APS13 | 50.72 | 38.10 | 55.05 | 46.89 | 46.13 | 46.22 | 37.85 | 34.35 | 42.93 | 47.43 | 44.57 |
| 11 | APS2 × APS5 | 69.82 | 56.95 | 52.81 | 58.58 | 58.57 | 54.64 | 34.71 | 37.87 | 25.31 | 44.71 | 49.40 |
| 12 | APS2 × APS11 | 37.84 | 60.27 | 43.83 | 56.91 | 66.04 | 67.99 | 41.03 | 48.03 | 40.72 | 42.27 | 50.49 |
| 13 | APS8 × APS13 | 50.58 | 43.08 | 39.34 | 28.54 | 28.71 | 37.09 | 34.21 | 41.45 | 42.67 | 37.08 | 38.28 |
| 14 | APS8 × APS5 | 63.19 | 34.77 | 28.12 | 52.74 | 51.11 | 50.88 | 49.75 | 54.84 | 62.77 | 55.17 | 50.33 |
| 15 | APS8 × APS11 | 47.93 | 58.61 | 44.10 | 52.74 | 56.08 | 58.94 | 51.48 | 71.44 | 60.29 | 61.64 | 56.33 |
| 16 | APS6 × APS13 | 37.05 | 40.59 | 55.05 | 51.07 | 46.13 | 42.10 | 42.01 | 55.35 | 41.71 | 48.70 | 45.98 |
| 17 | APS6 × APS5 | 44.08 | 57.20 | 39.34 | 70.26 | 56.08 | 36.64 | 65.21 | 63.17 | 55.20 | 66.79 | 55.40 |
| 18 | APS6 × APS11 | 47.27 | 58.61 | 59.54 | 61.08 | 66.04 | 66.29 | 63.22 | 64.64 | 71.01 | 59.05 | 61.67 |

**Table 4.** Comparative ranking of hybrids

| Sl. no. | Hybrid v | Cumulative subordinate function Index | Average Evaluation Index (E. I.) |
|---|---|---|---|
| 1 | APS6 × APS11 | 8.2432 | 61.67 |
| 2 | APS8 × APS11 | 6.7965 | 56.33 |
| 3 | APS6 × APS5 | 6.5190 | 55.40 |
| 4 | APS5 × APS2 | 6.3438 | 54.75 |
| 5 | APS5 × APS8 | 6.0819 | 53.28 |
| 6 | APS11 × APS8 | 5.7704 | 52.53 |
| 7 | APS11 × APS2 | 5.7230 | 52.26 |
| 8 | APS2 × APS11 | 5.1986 | 50.49 |
| 9 | APS13 × APS8 | 5.0646 | 49.91 |
| 10 | APS2 × APS5 | 5.0143 | 49.40 |
| 11 | APS8 × APS5 | 5.0050 | 50.33 |
| 12 | APS13 × APS6 | 4.7427 | 48.91 |
| 13 | APS11 × APS6 | 4.5286 | 47.93 |
| 14 | APS5 × APS6 | 3.9136 | 46.01 |
| 15 | APS6 × APS13 | 3.8288 | 45.98 |
| 16 | APS2 × APS13 | 3.4731 | 44.57 |
| 17 | APS13 × APS2 | 2.7659 | 41.99 |
| 18 | APS8 × APS13 | 1.7806 | 38.28 |

due weightage to all the economic traits considered. For such selection strategies, different index methods are in vogue used for both plants and livestock breeding programmes (Arunachalam and Bandhyopadhyay, 1984; Naseema Begum *et al.*, 2000; Ramesh Babu *et al.*, 2001; Sudhakar Rao *et al.*, 2001; Vidyunmala *et al.*, 1998). Multiple Trait Evaluation Index Method of Mano *et al.* (1993) has become a very useful tool for evaluation and identification of promising silkworm breeds/hybrids and is widely being applied by many silkworm breeders across the country (Ramesh Babu *et al.*, 2001; Sudhakara Rao *et al.*, 2001) and the same is applied in the present study also. The analysis present that the hybrid genotype, APS6 × APS11 with highest index value of 61.67 and ranked first among the rest of the 17 hybrids. In addition to this, the findings emanated from the Evaluation Index Method are compared with the Subordinate Function Index (Gower, 1971) a relatively less applied but equally effective method for confirmation of results. The results indicate that the hybrid combination APS6 × APS11 being the best among the 18 hybrids tested scoring highest Subordinate Function value (8.2432). The relative ranks assigned for all the test hybrids are in confirmity with all the hybrids scoring average E. I. above 50 except for APS8 × APS5 and ranked 11$^{th}$ instead of 9$^{th}$ rank as for Subordinate Function values. Rest of the ranks assigned is similar in both the methods. These results not only confirm the applicability of Subordinate Function Index Method for multiple trait analysis of silkworm breeds/hybrids and subsequent identification of promising silkworm hybrids but also its comparability with widely applied E. I. Method. These conclusions are in agreement with those of Ramesh Babu *et al.* (2001).

In light of the above observations, the new hybrid genotype, APS6 × APS11 that ranked first in both the methods is adjudicated as most promising hybrid and recommended for commercial use. Further, application of relatively less known Subordinate Function Method is recommended for multiple trait evaluation on par with the E. I. Method that is very popular with the silkworm breeders. This method can serve as an alternate method for E. I. Method. So also, both these methods can be used together for selection of promising silkworm breeds/hybrids for confirmation of results.

## References

Arunachalam, V. and A. Bandyopadyay (1984) A method to make decision jointly on a number of independent characters. *Indian J. Genet.* **44**, 419-424.

Bhargava, S. K., V. Thiagarajan, M. Ramesh Babu and M. K. Majumdar (1993) Impact of silkworm hybrids on reeling parameters. *Textile J.* **104**, 77-89.

Gower, J. C. (1971) A general coefficient of similarity and some of its properties. *Biometrics* **27**, 857-871.

Krishnaswamy, S. (1976) New Technology of silkworm rearing. *Bulletin No.* 2. Central Silk Board, Bangalore.

Mano, Y., S. Nirmal Kumar, H. K. Basavaraja, N. Mal Reddy and R. K. Datta (1993) A new method to select promising silkworm breeds/combinations. *Indian Silk* **31**, 53.

Nagaraju, J., R. Urs and R. K. Datta (1996) Cross breeding and heterosis in silkworm, (*Bombyx mori* L.) - A review. *Sericologia* **36**, 1-20.

Naseema Begum, A., H. K. Basavaraja, P. Sudhakar Rao, M. Rekha and M. M. Ahsan (2000) Identification of bivoltine silkworm hybrids suitable for tropical climate. *Indian J. Seric.* **30**, 24-29.

Ramesh Babu, M., Chandrashekharaiah, H. Lakshmi and J. Prasad (2001) Silkworm (*Bombyx mori* L.) genetic stocks an evaluatory analysis. *Bull. Indian Acad. Seric.* **5**, 9-17.

Sengupta, K., R. K. Datta, S. N. Biswas and B. D. Singh (1971) Heterosis in multivoltine silkworm (*Bombyx mori* L.) Yield performance of F1 hybrids of Nistari and four evolved multivoltine breeds. *Indian. J. Seric.* **10**, 6-13.

Singh, T. and G. Subba Rao (1993) Multiple trait evaluation Index to select useful silkworm (*Bombyx mori* L.) hybrid genotypes. *Italian Entomol.* **6**, 370-382.

Sudhakar Rao, P., R. Singh, G. V. Kalpana, V. Nishita Naik, H. K. Basavaraja, G. N. Ramaswamy and R. K. Datta (2001)

Evaluation and Identification of promising bivoltine hybrids of silkworm (*Bombyx mori* L.) for tropics. *Int. J. Indust. Entomol.* **3**, 31-35.

Thiagarajan, V., S. K. Bhargava, M. Ramesh Babu and B. Nagaraju (1993) Differences in seasonal performance of twenty six strains of silkworm, *Bombyx mori* L. (Bombycidae). *J. Lepidopter. Soc. America* **47**, 331-337.

Udupa, S. and B. L. V. Gowda (1988) Heterotic expression in silk productivity of different crosses of silkworm (*Bombyx mori* L.). *Sericologia* **28**, 395-400.

Vidyunmala, S., B. Narasimha Murthy and N. Sivarami Reddy (1998) Evaluation of new mulberry silkworm (*Bombyx mori* L.) hybrids (multivoltine x bivoltine) through multiple trait evaluation index. *J. Entomol. Res.* **22**, 49-53.

Yokoyama, T. (1976) Breeding of silkworm. *Sci. Tech. Seric.* **15**, 58-61.