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# Evaluation of Polyvoltine Hybrids Based on Silk Productivity in Silkworm, *Bombyx mori* L.

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**Polyvoltine silkworm breeds/hybrids play an important role in tropical sericulture. In the process of synthesizing more potential polyvoltine hybrids (polyvoltine × bivoltine) of superior quantity and quality, the Andhra Pradesh State Sericulture Research and Development Institute (APSSRDI) has developed 8 promising polyvoltine breeding lines (SDMG2, APM16, APM15, APM14, APM5, RM2, APM3, APM13). In order to study their hybrid vigour and performance, these breeds were crossed with 4 potential bivoltine testers (SDD1, SDD2, SDD3, APS8), and 32 different hybrid combinations were prepared and evaluated for their mid parent heterosis (MPH) and better parent heterosis (BPH) of silk productivity. Since silk is the ultimate product required for commercial purpose, based on silk productivity and its heterosis, three superior polyvoltine hybrid combinations namely RM2 × APS8 (24.3%), APM3 × APS8 (12.4%) and APM15 × SDD2 (10.8%) were adjudicated as potential heterotic hybrid combinations of superior silk yield and hence recommended for further large scale field trails and commercial exploitation.**

**Key words**: Polyvoltine, Hybrid, Silk productivity, heterosis, MPH, BPH

## Introduction

In recent times, the trend of global silk production is centered mainly on tropical countries. India is one among them ranking second in the world in the production of silk, next only to China. In spite of continuous efforts for the development of sericulture through various conventional silkworm breeding programmes, still there is a wide gap exists between domestic requirement and production in India. To fulfill the gap and to face global competitiveness in silk production, there is a need to develop more productive breeds/hybrids with improved quality of silk. This may be possible through proper exploitation of hybrid vigour. Heterosis or hybrid vigour are synonyms refer to luxuriance or increased growth over parents which occurs due to complementary action of parental genes. The purpose of hybrid preparation or crossing in silkworm is to produce a heterotic effect rather than to provide genetic variation for selection. Heterosis has been exploited for the improvement of productivity and quality of desired characters both in animals and plants by crossing the various pure lines of different genetic diversity and geographical origin (Griffing, 1956; Kurian and Peter, 1995). In silkworms, exploitation of hybrid vigour had started in Japan as early as first decade of last century (Toyoma, 1906; Osawa and Harada, 1944). It is reported in silkworms high degree of heterosis for various quantitative traits was observed during the spring season compared to that of autumn and the difference observed in the expression of heterosis of various traits is due to the influence of environment on gene action (Harada, 1961; Griffing and Zsiros, 1971). The main aim of the silkworm breeding is not only to synthesize new genotypes but also to provide the productive hybrid for commercial exploitation. Good number of hybrids has been developed through conventional breeding *viz.*, PM × C. Nichi, PM × $NB_4D_2$, Nistari × $NB_4D_2$, BL24 × $NB_4D_2$, APM1 × APS8, BL67 × CSR101, etc. Many of them failed to perform in the field and few of them became successful at farmers level due to various reasons (Kalpana *et al.*, 1998). Among them many polyvoltine hybrids produce poor quality of silk (Datta, 1984). There is a great need to

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develop silkworm hybrids with superior and gradable quality of silk.

Exploitation of heterosis has played a vital role in increasing the silk production to a great extent in the world. Attempts have been made earlier by many scientists to identify the most productive and promising hybrids by estimating combining ability and heterosis in silkworm, *Bombyx mori* L. (Sengupta *et al.*, 1971; Subba Rao and Sahai, 1989; Bhargava *et al.*, 1993; Singh *et al.*, 2000; Datta *et al.*, 2001; Narayanaswamy *et al.*, 2002; Raghavendra Rao *et al.*, 2002a, 2002b; Singh *et al.*, 2002; Chandrashekaraiah and Ramesh Babu, 2003; Rao *et al.*, 2004). Since silk is the ultimate product play important economic role, some breeders have paid attention on the estimation of hybrid vigour in silkworms with special reference to silk productivity (Udupa and Gowda, 1988; Singh *et al.*, 1994; Singh and Subba Rao 1994; Bhargava *et al.*, 1996; Ramesh Babu *et al.*, 2001). Keeping the need in view, the present study was aimed to identify the potential polyvoltine hybrid combinations based on increased silk productivity by estimating heterosis of the traits that contribute to silk yield *i.e.*, survival and silk productivity.

## Materials and Methods

Eight promising polyvoltine silkworm breeds (SDMG2, APM16, APM15, APM14, APM5, RM2, APM3, APM13) were developed in the polyvoltine laboratory of APSSRDI through conventional breeding methods. The lines are found to be genetically divergent in expressing their quantitative traits and silk productivity. These parental lines possess the slender/small plain larvae with oval type cocoons, greenish dark/light yellow cocoon colour with fine/medium grains. Four bivoltine tester (SDD1, SDD2, SDD3, APS8) of Japanese origin were selected. The larval and cocoon characters of these lines are presented in Table 1. By utilizing these eight polyvoltine lines and four testers, 32 hybrid combinations were prepared and rearing was conducted during September - October 2003. These $F_1$ hybrids were reared along with polyvoltine parents and bivoltine testers in three replications. After the 3rd moult, 300 larvae were retained and reared at standard rearing conditions consists of optimum temperature, relative humidity, air current, rearing space, germ free conditions and with high nutritive fresh mulberry leaves (Krishnaswami, 1978). The rearing performance of each hybrid combination along with lines and testers were recorded and analyzed.

The silk productivity is mainly imply on the effective rate of rearing percentage (ERR%), cocoon shell weight and larval duration of 5th instar of the silkworm. The silk productivity is calculated by using the following formulae (Udupa and Gowda, 1988).

$$\text{Single cocoon shell weight (cg)} = \frac{\text{Wt. of 25 male (cg)} + \text{25 female cocoon shells (cg)}}{50}$$

$$\text{ERR (\%)} = \frac{\text{Total no. of cocoons harvested}}{\text{(Effective Rate of Rearing)}} \times 100$$

(Larvae retained after 3rd moult – Uzi infested cocoons)

Table 1. Larval and cocoon characteristics of parental lines

| Sl. no. | Breed | Larval characters | Cocoon characters |
|---|---|---|---|
| Polyvoltine Parents | | | |
| 1 | SDMG2 | Small, blueish white,Plain | Greenish dark yellow, Oval,Medium grains |
| 2 | APM16 | Slender, blueish white,Plain | Greenish light yellow, Oval, Fine grains |
| 3 | APM15 | Slender, blueish white,Plain | Greenish dark yellow, Oval,Medium grains |
| 4 | APM14 | Robust, blueish white,Plain | Greenish light yellow, Oval, Fine grains |
| 5 | APM5 | Small, blueish white,Plain | Greenish dark yellow, Oval,Medium grains |
| 6 | RM2 | Slender, blueish white,Plain | Greenish dark yellow, Oval, Fine/medium grains |
| 7 | APM3 | Robust, blueish white,Plain | Greenish light yellow, Oval, Fine/medium grains |
| 8 | APM13 | Robust, blueish white,Plain | Greenish dark yellow, Oval, Fine/medium grains |
| Bivoltine parents (testers) | | | |
| 1 | SDD1 | Slender, Plain | White dumbbell, Medium grains |
| 2 | SDD2 | Slender, Plain | White dumbbell, Medium grains |
| 3 | SDD3 | Slender, Plain | White dumbbell, Medium grains |
| 4 | APS8 | Slender, Plain | White dumbbell, Medium grains |

$$\text{Silk productivity per day (cg)} = \frac{\text{ERR\%} \times \text{coccon shell weight (cg)}}{5^{th} \text{ instar larval duration (days)}}$$

Mid parent heterosis (MPH) and better parent heterosis (BPH) are calculated as per the procedure followed by Bhargava *et al.* (1993). The percent of MPH and BPH with respect to a particular character is tabulated as follows.

MPH = 100 (A – B)/B
BPH = 100 (A – C)/C

Where, A = Actual performance of hybrid
B = Average performance of the female and male parents
C = Performance of better parent

## Results

The larvae of the breeding lines are slender, bluish white and plain. Cocoons are greenish dark yellow in colour, oval in shape with medium grains (SDMG2, APM15, APM5) greenish light yellow, oval, fine grains (APM14, APM16), dark greenish yellow, oval, fine/ medium grains (RM2, APM3, APM13). In case of bivoltine testers, the larvae are slender, plain and cocoons are white in colour with dumbbell shape and medium grains (Table 1).

### Performance of parental lines

The effective rate of rearing (ERR) of polyvoltines ranged between to a maximum of 95.44% (APM16, APM14, APM5) and to a minimum of 71.22% (RM2). The cocoon shell weight (cg) was ranged between to a maximum of 24.64 (APM13) to a minimum of 19.17 (APM5). Silk productivity per day ranged between a maximum of 4.47 cg (APM3) to a minimum of 3.03 cg (RM2).

In bivoltine parents (testers) ERR percentage was recorded as 91.22% (SDD1), 92.89% (SDD2), 89.78% (SDD3) and 87.44% (APS8). Cocoon shell weight (cg) was recorded highest in SDD3 (41.71) followed by SDD1 (40.33), APS8 (37.70) and SDD2 (35.36). Silk productivity ranged to a maximum of 6.42 cg (SDD3) to a minimum of 5.65 cg (APS8).

### Performance of Hybrids

Among the 32 hybrid combinations, highest ERR% was recorded in APM16 × SDD3 (96.33) followed by APM14 × APS8, APM5 × SDD2 (95.11) and minimum was recorded in APM15 × SDD3 (87.33) followed by APM3 × APS8 (88.56) and APM14 × SDD3 (89.33). Highest shell weight (cg) was recorded in RM2 × APS8 (41.19) followed by APM3 × APS8 (39.44) and SDMG2 × SDD3 (36.77) and lowest was recorded in APM14 × SDD1 (28.25) followed by APM16 × APS8 (29.75). Highest silk productivity was observed in RM2 × APS8 (7.02 cg) hybrid combination where as lowest was noticed in APM5 × SDD3 (4.94 cg) (Table 2).

### Heterosis estimation

Regarding mid parent heterosis (MPH), highest was noticed in APM3 × SDD3 (5.45%) and lowest was observed in RM2 × APS8 (4.34%). Better parent heterosis (BPH), ranged between a maximum of 6.42% (SDMG2 × SDD3, APM16 × SDD3, APM15 × SDD3, APM14 × SDD3, APM5 × SDD3, RM2 × SDD3, APM3 × SDD3, APM13 × SDD3) to a minimum of 5.65% (SDMG2 × APS8, APM16 × APS8, APM15 × APS8, APM14 × APS8, APM5 × APS8, RM2 × APS8, APM3 × APS8) (Table 3). It is concluded that of the results obtained is conformity with the earlier studies of Udupa and Gowda (1988). In the multivoltine × bivoltine crosses, the cocoon characters have invariably failed to exceed the better parent values. The most of the $F_1$ hybrid combination shown negative or non-beneficial heterosis might be due to the superiority of bivoltine male parent over the female parents with respect to the cocoon characters (Gowda *et al.*, 1993).

Heterosis of MPH% and BPH% in 32 hybrid combinations for silk productivity is presented in the Table 3. Out of 32 hybrid combinations 2 hybrid combinations (APM14 × SDD1, APM5 × SDD3) expressed negative heterosis for MPH%. 21 hybrid combinations were expressed negative heterosis for BPH%. Among the 11 hybrid combinations of positive BPH%, highest heterosis was noticed in RM2 × APS8 (24.3%) followed by APM3 × APS8 (12.4%), APM15 × SDD2 (10.8%) where as lowest was noticed in APM15 × APS8 (0.8%) followed by APM14 × APS8 (1.1%).

## Discussion

Heterosis is the basis of hybrid development in silkworms. Hybrid vigour is very prominent in silkworms and it has been successfully utilized at commercial level all over the world (Toyoma, 1906; Harada, 1946). Ultimate commercial product of the silkworm is the silk yield and it is a complex trait contributed by different traits of varying degree. In silkworms, all most all the traits that contribute to silk are quantitative in nature and are under the control of polygenic system (Nagaraju, 1994). Silk yield and silk filament length is expressed due to additive action of poly

**Table 2.** Silk productivity of the parents and their hybrids

| Sl. no. | Breeds/ Hybrids | ERR* | Cocoon shell weight (cg) | 5th instar larval period (days) | Silk productivity per day (cg) |
|---|---|---|---|---|---|
| Polyvoltines parents | | | | | |
| 1 | SDMG2 | 95.00 | 23.41 | 5.42 | 4.11 |
| 2 | APM16 | 95.44 | 22.78 | 5.42 | 4.01 |
| 3 | APM15 | 94.11 | 23.06 | 5.17 | 4.20 |
| 4 | APM14 | 95.44 | 24.31 | 5.42 | 4.28 |
| 5 | APM5 | 95.44 | 19.17 | 5.17 | 3.54 |
| 6 | RM2 | 71.22 | 23.01 | 5.42 | 3.03 |
| 7 | APM3 | 94.11 | 23.77 | 5.00 | 4.47 |
| 8 | APM13 | 95.33 | 24.64 | 5.42 | 4.34 |
| Bivoltine parents (testers) | | | | | |
| 1 | SDD1 | 91.22 | 40.33 | 6.00 | 6.13 |
| 2 | SDD2 | 92.89 | 35.36 | 5.58 | 5.88 |
| 3 | SDD3 | 89.78 | 41.71 | 5.83 | 6.42 |
| 4 | APS8 | 87.44 | 37.70 | 5.83 | 5.65 |
| Hybrids | | | | | |
| 1 | SDMG2 × SDD1 | 94.22 | 34.77 | 5.50 | 5.96 |
| 2 | SDMG2 × SDD2 | 94.22 | 32.57 | 5.50 | 5.58 |
| 3 | SDMG2 × SDD3 | 89.22 | 36.77 | 5.67 | 5.79 |
| 4 | SDMG2 × APS8 | 94.44 | 32.10 | 5.50 | 5.51 |
| 5 | APM16 × SDD1 | 93.44 | 30.80 | 5.42 | 5.31 |
| 6 | APM16 × SDD2 | 94.89 | 31.85 | 5.42 | 5.58 |
| 7 | APM16 × SDD3 | 96.33 | 30.15 | 5.42 | 5.36 |
| 8 | APM16 × APS8 | 91.89 | 29.75 | 5.42 | 5.05 |
| 9 | APM15 × SDD1 | 94.00 | 34.82 | 5.17 | 6.33 |
| 10 | APM15 × SDD2 | 93.22 | 36.70 | 5.25 | 6.52 |
| 11 | APM15 × SDD3 | 87.33 | 32.92 | 5.25 | 5.48 |
| 12 | APM15 × APS8 | 93.67 | 31.94 | 5.25 | 5.70 |
| 13 | APM14 × SDD1 | 94.67 | 28.25 | 5.42 | 4.94 |
| 14 | APM14 × SDD2 | 94.11 | 33.99 | 5.25 | 6.09 |
| 15 | APM14 × SDD3 | 89.33 | 35.83 | 5.25 | 6.10 |
| 16 | APM14 × APS8 | 95.11 | 31.53 | 5.25 | 5.71 |
| 17 | APM5 × SDD1 | 93.11 | 37.01 | 5.50 | 6.26 |
| 18 | APM5 × SDD2 | 95.11 | 29.92 | 5.67 | 5.02 |
| 19 | APM5 × SDD3 | 89.00 | 31.43 | 5.67 | 4.94 |
| 20 | APM5 × APS8 | 94.33 | 30.85 | 5.67 | 5.14 |
| 21 | RM2 × SDD1 | 94.78 | 36.62 | 5.67 | 6.12 |
| 22 | RM2 × SDD2 | 94.22 | 32.55 | 5.50 | 5.58 |
| 23 | RM2 × SDD3 | 91.78 | 35.08 | 5.50 | 5.85 |
| 24 | RM2 × APS8 | 93.78 | 41.19 | 5.50 | 7.02 |
| 25 | APM3 × SDD1 | 93.00 | 34.59 | 5.00 | 6.43 |
| 26 | APM3 × SDD2 | 93.67 | 30.69 | 5.08 | 5.65 |
| 27 | APM3 × SDD3 | 94.00 | 31.01 | 5.25 | 5.55 |
| 28 | APM3 × APS8 | 88.56 | 39.44 | 5.50 | 6.35 |
| 29 | APM13 × SDD1 | 94.44 | 35.72 | 5.25 | 6.43 |
| 30 | APM13 × SDD2 | 94.78 | 35.27 | 5.25 | 6.37 |
| 31 | APM13 × SDD3 | 94.00 | 32.81 | 5.67 | 5.44 |
| 32 | APM13 × APS8 | 94.22 | 30.84 | 5.67 | 5.13 |

*ERR: Effective Rate of Rearing.

**Table 3.** MPH and BPH of silk productivity in different polyvoltine hybrids of silkworm

| Sl.no. | Breeds/Crosses | $F_1$ Value | Mid parent value | Better paraent value | *MPH % | #BPH % |
|---|---|---|---|---|---|---|
| 1 | SDMG2 × SDD1 | 5.96 | 5.12 | 6.13 | 16.35 | -2.86 |
| 2 | SDMG2 × SDD2 | 5.58 | 4.99 | 5.88 | 11.71 | -5.16 |
| 3 | SDMG2 × SDD3 | 5.79 | 5.26 | 6.42 | 9.99 | -9.83 |
| 4 | SDMG2 × APS8 | 5.51 | 4.88 | 5.65 | 12.98 | -2.46 |
| 5 | APM16 × SDD1 | 5.31 | 5.07 | 6.13 | 4.73 | -13.35 |
| 6 | APM16 × SDD2 | 5.58 | 4.95 | 5.88 | 12.73 | -5.18 |
| 7 | APM16 × SDD3 | 5.36 | 5.22 | 6.42 | 2.79 | -16.47 |
| 8 | APM16 × APS8 | 5.05 | 4.83 | 5.65 | 4.45 | -10.68 |
| 9 | APM15 × SDD1 | 6.33 | 5.17 | 6.13 | 22.63 | 3.32 |
| 10 | APM15 × SDD2 | 6.52 | 5.04 | 5.88 | 29.26 | 10.77 |
| 11 | APM15 × SDD3 | 5.48 | 5.31 | 6.42 | 3.12 | -14.71 |
| 12 | APM15 × APS8 | 5.70 | 4.93 | 5.65 | 15.68 | 0.83 |
| 13 | APM14 × SDD1 | 4.94 | 5.21 | 6.13 | -5.21 | -19.49 |
| 14 | APM14 × SDD2 | 6.09 | 5.08 | 5.88 | 19.84 | 3.55 |
| 15 | APM14 × SDD3 | 6.10 | 5.35 | 6.42 | 13.92 | -5.03 |
| 16 | APM14 × APS8 | 5.71 | 4.97 | 5.65 | 14.99 | 1.08 |
| 17 | APM5 × SDD1 | 6.26 | 4.84 | 6.13 | 29.53 | 2.18 |
| 18 | APM5 × SDD2 | 5.02 | 4.71 | 5.88 | 6.55 | -14.65 |
| 19 | APM5 × SDD3 | 4.94 | 4.98 | 6.42 | -0.90 | -23.11 |
| 20 | APM5 × APS8 | 5.14 | 4.60 | 5.65 | 11.73 | -9.12 |
| 21 | RM2 × SDD1 | 6.12 | 4.58 | 6.13 | 33.76 | -0.12 |
| 22 | RM2 × SDD2 | 5.58 | 4.45 | 5.88 | 25.20 | -5.21 |
| 23 | RM2 × SDD3 | 5.85 | 4.72 | 6.42 | 23.94 | -8.83 |
| 24 | RM2 × APS8 | 7.02 | 4.34 | 5.65 | 61.89 | 24.28 |
| 25 | APM3 × SDD1 | 6.43 | 5.30 | 6.13 | 21.35 | 4.94 |
| 26 | APM3 × SDD2 | 5.65 | 5.18 | 5.88 | 9.19 | -3.89 |
| 27 | APM3 × SDD3 | 5.55 | 5.45 | 6.42 | 1.93 | -13.53 |
| 28 | APM3 × APS8 | 6.35 | 5.06 | 5.65 | 25.43 | 12.36 |
| 29 | APM13 × SDD1 | 6.43 | 5.23 | 6.13 | 22.78 | 4.81 |
| 30 | APM13 × SDD2 | 6.37 | 5.11 | 5.88 | 24.59 | 8.21 |
| 31 | APM13 × SDD3 | 5.44 | 5.38 | 6.42 | 1.21 | -15.22 |
| 32 | APM13 × APS8 | 5.13 | 4.99 | 5.65 | 2.67 | -9.27 |

*MPH = Mid parent heterosis; #BPH = Better parent heterosis.

genes (Griffing, 1956). After the report of Tazima (1958) many polyvoltine hybrids (cross breeds) have been developed in India by crossing with exogenous bivoltine parents. Hybrid vigour was successfully exploited while developing these hybrids. As a result India has jumped to 2nd position in the world in the quantum of silk production. But in quality of silk it stands far behind. Because many of the polyvoltine cross breeds developed, could not give satisfactory silk yield and gradable quality of silk. The hybrids that are well adopted to tropical climate could not yield superior quality of silk. The hybrids that give good quality of silk could not adjust to the tropical climate of peninsular India. Usually the polyvoltines are poor silk yielders with better survival and adoptability where as bivoltine varieties are good silk yielders with low survival and poor adoptability. Hence, in the present study of hybrid evaluation work, we have targeted silk yield and other traits that contribute to silk yield like effective rate of rearing (ERR), 5th instar larval duration, cocoon shell weight and their heterosis gain obtained. Based on the performance of the traits, positive mid and better parent heterosis of silk productivity, three potential hybrid combinations, namely RM2 × APS8, APM3 × APS8 and APM15 × SDD2 are short-listed (Table 4) from the total

**Table 4.** Hybrids showing positive mid and better parent heterosis of silk yield

| Sl. no. | Breeds/Crosses | $F_1$ Value | Mid parent value | Better paraent value | ^MPH % | #BPH % |
|---|---|---|---|---|---|---|
| 1 | APM15 × SDD1 | 6.33 | 5.17 | 6.13 | 22.63 | 3.32 |
| 2 | APM15 × SDD2* | 6.52 | 5.04 | 5.88 | 29.26 | 10.77 |
| 3 | APM15 × APS8 | 5.70 | 4.93 | 5.65 | 15.68 | 0.83 |
| 4 | APM14 × SDD2 | 6.09 | 5.08 | 5.88 | 19.84 | 3.55 |
| 5 | APM14 × APS8 | 5.71 | 4.97 | 5.65 | 14.99 | 1.08 |
| 6 | APM5 × SDD1 | 6.26 | 4.84 | 6.13 | 29.53 | 2.18 |
| 7 | RM2 × APS8* | 7.02 | 4.34 | 5.65 | 61.89 | 24.28 |
| 8 | APM3 × APS8* | 6.35 | 5.06 | 5.65 | 25.43 | 12.36 |
| 9 | APM3 × SDD1 | 6.43 | 5.30 | 6.13 | 21.35 | 4.94 |
| 10 | APM13 × SDD1 | 6.43 | 5.23 | 6.13 | 22.78 | 4.81 |
| 11 | APM13 × SDD2 | 6.37 | 5.11 | 5.88 | 24.59 | 8.21 |

*Selected hybrids of high silk productivity productivity.
^MPH = Mid parent heterosis; #BPH = Better parent heterosis.

of 32 hybrid combinations. These three hybrids with superior silk productivity are further selected for large scale field trails for commercial exploitation.

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