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# An Analysis of Genetic Variation and Divergence on Silk Fibre Characteristics of Multivoltine Silkworm (*Bombyx mori* L.) Genotypes

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**The nature of genetic variation and diversity among the 65 multivoltine silkworm genotypes was evaluated for 16 post cocoon characters. The components of genetic variation revealed higher PCV (60.487%) and GCV (44.56%) for evenness (variation 1) followed by cohesion (PCV=55.38%, GCV=40.36%) and non-broken filament length (PCV=32.05%, GCV=31.28%). The higher heritability ($h^2$ in broad sense) was observed for boil-off loss (95.6%) followed by non-broken filament length (95.22%). The both genotypic and phenotypic correlation indicated significant positive correlation of filament length with non-broken filament length, silk recovery, raw silk, neatness, and low neatness; and negative correlation with denier, renditta and silk waste. The principal component analysis (PCA) revealed 75.381% of total variance from the five principal components extracted. On the basis of Mahalonobis' $D^2$ values (Ward's minimum variance), the sixty-five multivoltine silkworm genotypes were classified in to 9 clusters with substantial inter and intra cluster distances. Number of genotypes included in different clusters varied from 3 to 17. The results indicated that the optimum distance obtained in cluster VII (15.059) along with higher cluster mean values especially for filament length, non broken filament length, renditta, silk recovery, silk waste, and raw silk emphasized the utilization of these genotypes in the conventional silkworm breeding programme for improvement of multivoltine silk fibre quality. The possibility of exploiting genetic variation in post cocoon traits for efficient breeding programme is discussed.**

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**Key words**: *Bombyx mori* L., Multivoltine, Genetic variation, Divergence, Silk fibre characters

## Introduction

Silk is referred to as the 'Queen of textiles fibres' over the years for its elegant textile quality. The main object of the Indian silk industry is to produce raw silk for the preparation of fabrics. Generally, the structural characteristics and the size of the cocoon filaments are notable characteristics in post cocoon technology since they determine the final nature of the silk (Akai, 1998). India, the second largest producer of silk, only next to China is also the second largest importer and consumer of silk only next to USA. The present production of raw silk in India is about 16,500 MT against an estimated internal demand of 26000 MT. The production formed only 67.50% of the availability and the gap is met by imports. About 95% of the silk produced in the country comes from either cross breeds of multi × bi or pure multivoltine cocoons (Obitsu, 1994). At present the Central Sericultural Germplasm Resources Centre (CSGRC), Hosur, Tamil Nadu, India conserves 71 multivoltine silkworm germplasm with wide genetic diversity comprising 61 indigenous and 10 exotic collections of various potential resources, which could provide the raw materials for improving the silk productivity and fibre quality (Kumaresan *et al.*, 2005). The recognition of biodiversity in different races and lines of silkworm (*Bombyx mori* L.) is very useful for breeding programmes and production of high efficiency hybrids (Etebari *et al.*, 2005). The genetic analysis of growth and reproductive traits of silkworm races has been carried out by a number of researchers (Krishnaswami *et al.*, 1964; Sen *et al.*, 1976; Rahman *et al.*, 1978; Rahman *et al.*, 1984; Murakami *et al.*, 1989; Govinda *et al.*, 1990; Saleh *et al.*, 1990; Mukherjee *et al.*, 1999; Kumaresan *et al.*, 2000, 2002, 2003). But such a kind of reports is scanty in case of

**Table 1.** Mean performance of sixty-five multivoltine silkworm genotypes for silk reeling and quality traits

| Sl.No. | Race name | FL | NBF | DEN | REEL | REND | S_REC | WASTE | R_SILK | NEAT | BOIL | CLEAN | EVEN_V1 | TENA | ELONG | COHE | L_NEAT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | PURE MYSORE | 324.00 | 243.50 | 2.44 | 75.90 | 12.00 | 47.25 | 32.50 | 8.38 | 71.50 | 22.30 | 51.00 | 40.00 | 3.15 | 17.00 | 22.00 | 62.50 |
| 2 | SARUPAT | 332.00 | 287.00 | 2.21 | 81.55 | 12.70 | 46.00 | 30.00 | 7.85 | 85.00 | 23.10 | 53.00 | 30.00 | 3.45 | 17.20 | 65.50 | 80.00 |
| 3 | MORIA | 445.00 | 349.50 | 2.22 | 83.65 | 10.80 | 55.10 | 31.65 | 9.25 | 89.00 | 22.60 | 85.00 | 20.00 | 3.75 | 17.70 | 80.00 | 82.50 |
| 4 | TAMILNADU WHITE | 425.00 | 339.50 | 2.32 | 79.00 | 10.40 | 58.65 | 24.40 | 9.68 | 93.00 | 26.20 | 71.00 | 20.00 | 3.50 | 15.30 | 50.00 | 85.00 |
| 5 | C.NICHI | 257.00 | 196.50 | 1.71 | 70.85 | 18.40 | 42.65 | 43.30 | 5.45 | 49.50 | 17.70 | 57.50 | 30.00 | 3.30 | 13.60 | 14.50 | 47.50 |
| 6 | HOSA MYSORE | 523.00 | 435.00 | 2.17 | 79.50 | 10.35 | 55.95 | 26.65 | 9.65 | 87.00 | 22.50 | 81.00 | 40.00 | 3.65 | 15.80 | 45.50 | 80.00 |
| 7 | MYSORE PRINCESS | 371.00 | 277.50 | 2.01 | 77.30 | 18.05 | 50.40 | 36.00 | 5.55 | 88.50 | 26.90 | 66.00 | 70.00 | 3.55 | 17.50 | 64.00 | 82.50 |
| 8 | KOLAR GOLD | 554.00 | 448.50 | 1.64 | 73.60 | 13.10 | 48.20 | 30.95 | 7.65 | 93.00 | 18.00 | 81.00 | 30.00 | 3.55 | 17.10 | 86.00 | 91.50 |
| 9 | KOLLEGAL JAWAN | 684.00 | 578.00 | 1.64 | 82.35 | 12.65 | 45.90 | 28.35 | 7.90 | 85.00 | 18.60 | 71.00 | 20.00 | 3.60 | 16.60 | 35.50 | 80.00 |
| 10 | MY-1 | 523.00 | 403.50 | 1.14 | 74.25 | 18.45 | 37.30 | 30.00 | 5.40 | 68.00 | 21.40 | 37.00 | 70.00 | 3.25 | 15.90 | 47.50 | 60.00 |
| 11 | P2D1 | 510.00 | 345.00 | 1.95 | 72.80 | 12.50 | 55.35 | 30.95 | 8.00 | 90.50 | 23.05 | 77.00 | 20.00 | 3.30 | 15.00 | 69.50 | 87.50 |
| 12 | RONG DAZAO | 294.00 | 225.00 | 2.10 | 71.00 | 15.35 | 40.45 | 27.50 | 6.50 | 72.00 | 21.60 | 66.00 | 50.00 | 3.25 | 16.10 | 20.00 | 65.00 |
| 13 | GUANGNONG PLAIN | 412.00 | 235.00 | 1.33 | 64.75 | 14.80 | 40.25 | 40.00 | 6.80 | 75.50 | 18.90 | 77.00 | 60.00 | 3.35 | 13.30 | 25.00 | 70.00 |
| 14 | OS-616 | 614.00 | 440.00 | 1.35 | 70.80 | 13.15 | 60.80 | 23.65 | 7.63 | 89.00 | 20.20 | 57.00 | 40.00 | 3.45 | 18.60 | 25.50 | 87.50 |
| 15 | RAJ | 512.00 | 340.00 | 1.25 | 67.70 | 14.65 | 46.15 | 27.50 | 6.85 | 92.00 | 21.70 | 67.00 | 30.00 | 3.40 | 15.60 | 44.00 | 90.00 |
| 16 | G | 568.00 | 460.00 | 1.28 | 76.90 | 13.20 | 49.25 | 30.00 | 7.58 | 89.00 | 25.10 | 89.00 | 40.00 | 3.55 | 17.20 | 78.00 | 85.00 |
| 17 | NISTARI | 421.00 | 303.00 | 1.91 | 75.95 | 13.65 | 52.40 | 32.00 | 7.33 | 83.50 | 21.10 | 48.50 | 90.00 | 3.20 | 13.70 | 22.00 | 72.50 |
| 18 | NISTARI (M) | 294.00 | 211.00 | 2.70 | 73.65 | 13.45 | 52.40 | 30.00 | 7.44 | 77.50 | 22.00 | 74.00 | 55.00 | 3.20 | 16.50 | 31.00 | 62.50 |
| 19 | NISTARI (P) | 385.00 | 317.50 | 1.98 | 73.10 | 12.40 | 55.65 | 29.35 | 8.07 | 87.00 | 20.10 | 71.00 | 60.00 | 3.45 | 16.60 | 43.00 | 82.50 |
| 20 | ZPN (SL) | 300.00 | 239.00 | 2.09 | 79.55 | 15.15 | 43.80 | 45.00 | 6.61 | 63.50 | 23.00 | 54.00 | 20.00 | 3.15 | 19.40 | 11.00 | 50.00 |
| 21 | CB5 | 562.60 | 511.00 | 2.16 | 85.64 | 10.01 | 68.09 | 17.27 | 10.00 | 71.00 | 20.10 | 95.00 | 40.00 | 3.08 | 14.10 | 69.50 | 66.50 |
| 22 | KW2 | 392.90 | 178.60 | 2.21 | 66.48 | 11.35 | 63.45 | 23.50 | 8.82 | 82.00 | 24.30 | 75.00 | 40.00 | 3.25 | 12.40 | 41.00 | 72.50 |
| 23 | M2 | 519.00 | 288.00 | 2.61 | 48.55 | 11.25 | 62.50 | 19.50 | 8.90 | 84.00 | 23.50 | 93.00 | 40.00 | 3.20 | 13.00 | 46.00 | 78.00 |
| 24 | A23 | 442.10 | 306.10 | 2.40 | 76.72 | 12.05 | 57.70 | 25.20 | 8.30 | 74.00 | 24.20 | 95.50 | 60.00 | 2.88 | 14.20 | 48.00 | 67.50 |
| 25 | A25 | 610.00 | 342.00 | 2.01 | 67.20 | 12.76 | 53.40 | 25.00 | 7.95 | 84.00 | 21.50 | 85.00 | 40.00 | 3.55 | 18.20 | 31.00 | 82.50 |
| 26 | OVAL | 528.30 | 310.80 | 2.57 | 66.93 | 10.51 | 65.05 | 22.54 | 9.54 | 79.50 | 20.60 | 93.00 | 50.00 | 2.89 | 11.10 | 76.00 | 70.50 |
| 27 | O | 526.28 | 404.83 | 2.62 | 77.98 | 8.96 | 76.15 | 16.95 | 11.17 | 76.50 | 20.50 | 57.00 | 30.00 | 3.30 | 12.70 | 94.50 | 62.50 |
| 28 | M83(C) | 402.30 | 311.00 | 2.49 | 74.66 | 10.53 | 68.92 | 19.96 | 9.51 | 63.00 | 19.10 | 72.00 | 40.00 | 3.08 | 14.60 | 11.00 | 50.00 |
| 29 | B | 563.00 | 433.00 | 1.79 | 78.00 | 11.50 | 66.60 | 23.40 | 8.68 | 85.00 | 20.70 | 87.00 | 30.00 | 3.26 | 15.50 | 114.00 | 81.50 |
| 30 | GNM | 518.85 | 324.28 | 2.83 | 65.60 | 7.86 | 77.27 | 14.32 | 12.73 | 26.00 | 19.20 | 67.00 | 40.00 | 3.12 | 11.50 | 24.50 | 20.00 |
| 31 | A14DY | 470.00 | 366.30 | 2.50 | 76.55 | 10.30 | 64.14 | 23.15 | 9.70 | 68.00 | 20.50 | 96.50 | 30.00 | 3.50 | 15.80 | 47.00 | 60.00 |
| 32 | A4E | 560.00 | 310.00 | 2.63 | 50.05 | 14.04 | 48.05 | 38.68 | 7.10 | 81.50 | 25.40 | 84.00 | 20.00 | 2.70 | 12.40 | 26.50 | 80.00 |

**Table 1.** Continued

| Sl.No. | Race name | FL | NBF | DEN | REEL | REND | S_REC | WASTE | R_SILK | NEAT | BOIL | CLEAN | EVEN_V1 | TENA | ELONG | COHE | L_NEAT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 33 | PA12 | 516.70 | 303.90 | 2.78 | 54.08 | 9.07 | 76.80 | 19.58 | 10.99 | 82.50 | 25.60 | 82.00 | 20.00 | 2.53 | 12.40 | 39.00 | 70.00 |
| 34 | AP12 | 605.00 | 385.00 | 2.70 | 45.82 | 9.95 | 72.50 | 21.80 | 10.00 | 82.00 | 25.20 | 87.00 | 20.00 | 2.65 | 13.50 | 20.00 | 70.00 |
| 35 | A13 | 343.00 | 171.00 | 2.07 | 50.00 | 19.44 | 34.28 | 28.00 | 5.12 | 80.00 | 19.70 | 93.00 | 30.00 | 3.85 | 18.00 | 52.50 | 71.50 |
| 36 | PMX | 280.00 | 185.50 | 2.74 | 66.00 | 16.02 | 41.40 | 30.00 | 6.22 | 63.00 | 17.00 | 82.00 | 30.00 | 3.45 | 11.50 | 62.00 | 40.00 |
| 37 | PMS2 | 378.00 | 295.00 | 2.80 | 73.80 | 12.30 | 52.85 | 26.80 | 8.15 | 63.00 | 19.90 | 93.00 | 60.00 | 3.50 | 12.80 | 37.50 | 55.00 |
| 38 | MU-1 | 396.00 | 308.00 | 2.15 | 70.55 | 12.95 | 56.30 | 27.50 | 7.75 | 90.00 | 23.75 | 36.00 | 40.00 | 3.50 | 17.90 | 81.50 | 87.50 |
| 39 | MU-11 | 413.00 | 344.00 | 2.30 | 78.55 | 12.05 | 52.75 | 33.75 | 8.30 | 75.00 | 19.60 | 95.00 | 60.00 | 3.40 | 15.10 | 61.50 | 67.50 |
| 40 | WAI-1 | 440.00 | 300.00 | 2.50 | 64.45 | 12.25 | 53.95 | 28.40 | 8.20 | 67.00 | 21.20 | 97.50 | 30.00 | 3.45 | 15.50 | 44.50 | 62.50 |
| 41 | WAI-4 | 500.70 | 357.70 | 2.44 | 78.09 | 9.68 | 66.24 | 15.23 | 10.34 | 80.00 | 15.50 | 85.00 | 30.00 | 3.07 | 14.90 | 44.00 | 76.50 |
| 42 | MY23 | 340.00 | 240.00 | 2.30 | 62.30 | 12.00 | 59.50 | 22.60 | 8.30 | 88.50 | 23.30 | 80.00 | 30.00 | 3.12 | 14.20 | 33.00 | 85.00 |
| 43 | MW13 | 593.88 | 494.90 | 2.30 | 73.23 | 8.64 | 74.30 | 11.94 | 11.60 | 83.50 | 18.40 | 73.00 | 10.00 | 3.25 | 11.50 | 23.00 | 79.00 |
| 44 | MHMP (W) | 401.70 | 138.50 | 2.51 | 53.85 | 11.15 | 64.80 | 24.89 | 9.00 | 80.00 | 26.30 | 71.00 | 40.00 | 3.10 | 14.10 | 33.00 | 72.50 |
| 45 | MHMP (Y) | 495.00 | 329.00 | 2.40 | 65.45 | 11.15 | 57.15 | 23.90 | 8.95 | 55.00 | 18.00 | 96.00 | 40.00 | 3.60 | 15.70 | 38.50 | 50.00 |
| 46 | P4D3 | 344.00 | 148.00 | 2.25 | 40.25 | 14.70 | 46.50 | 51.20 | 6.80 | 82.00 | 18.30 | 98.50 | 20.00 | 3.35 | 13.50 | 69.50 | 80.00 |
| 47 | NISTID (Y) | 367.50 | 226.90 | 2.85 | 44.87 | 11.90 | 68.78 | 34.41 | 8.64 | 65.50 | 25.50 | 93.00 | 20.00 | 3.06 | 12.20 | 22.00 | 59.00 |
| 48 | NISTID (W) | 427.00 | 224.70 | 2.16 | 57.47 | 12.71 | 54.99 | 28.92 | 7.87 | 81.50 | 21.00 | 64.00 | 20.00 | 2.98 | 13.60 | 35.00 | 72.50 |
| 49 | NK4 | 360.00 | 314.00 | 1.96 | 71.75 | 13.10 | 54.33 | 31.00 | 7.73 | 83.00 | 27.20 | 72.00 | 40.00 | 3.45 | 15.20 | 70.50 | 72.50 |
| 50 | CAMBODG | 451.00 | 340.00 | 2.35 | 72.15 | 9.70 | 70.50 | 16.50 | 10.35 | 81.50 | 18.70 | 91.00 | 40.00 | 3.28 | 13.00 | 55.00 | 77.50 |
| 51 | DAIZO | 301.00 | 167.00 | 2.10 | 50.10 | 12.25 | 61.05 | 39.75 | 8.10 | 84.00 | 29.40 | 85.00 | 20.00 | 2.52 | 12.30 | 28.50 | 75.00 |
| 52 | LMP | 399.00 | 356.00 | 2.34 | 84.60 | 10.35 | 68.00 | 16.20 | 9.70 | 81.50 | 19.85 | 90.00 | 40.00 | 3.25 | 14.40 | 51.00 | 77.50 |
| 53 | DMR | 432.40 | 196.60 | 2.59 | 58.88 | 9.70 | 65.85 | 19.09 | 10.30 | 67.00 | 18.90 | 91.00 | 40.00 | 2.87 | 11.90 | 48.50 | 66.00 |
| 54 | LMO | 567.45 | 315.15 | 1.84 | 76.37 | 10.14 | 76.37 | 17.75 | 9.88 | 86.00 | 23.20 | 94.00 | 20.00 | 3.58 | 13.10 | 48.50 | 83.00 |
| 55 | MY1 (SL) | 422.00 | 272.50 | 2.24 | 55.50 | 11.90 | 53.99 | 28.00 | 8.40 | 58.00 | 20.70 | 91.50 | 30.00 | 3.40 | 16.50 | 50.00 | 35.00 |
| 56 | PM (SL) | 419.00 | 210.00 | 2.80 | 61.30 | 11.10 | 60.40 | 18.85 | 8.95 | 85.00 | 25.20 | 91.00 | 30.00 | 3.15 | 17.90 | 30.50 | 72.50 |
| 57 | BL23 | 320.00 | 188.70 | 2.55 | 60.01 | 17.10 | 35.90 | 44.10 | 5.86 | 82.00 | 22.80 | 96.00 | 120.00 | 3.75 | 17.60 | 44.50 | 75.00 |
| 58 | BL24 | 268.80 | 178.60 | 2.91 | 62.24 | 17.05 | 38.37 | 61.85 | 5.82 | 60.50 | 20.20 | 95.00 | 60.00 | 3.60 | 17.10 | 61.00 | 50.00 |
| 59 | MU303 | 333.00 | 221.70 | 2.91 | 65.65 | 13.17 | 53.25 | 52.78 | 7.55 | 76.50 | 20.85 | 87.00 | 80.00 | 3.53 | 16.20 | 27.00 | 67.50 |
| 60 | MU520 | 408.20 | 357.65 | 2.57 | 81.70 | 11.87 | 57.67 | 31.42 | 8.44 | 79.00 | 20.50 | 94.00 | 40.00 | 3.75 | 17.70 | 24.00 | 67.50 |
| 61 | MU10 | 389.40 | 300.95 | 2.28 | 72.50 | 13.80 | 48.40 | 49.60 | 7.25 | 78.50 | 20.40 | 96.00 | 60.00 | 4.00 | 18.80 | 35.50 | 65.00 |
| 62 | TW×SK6×SK1 | 265.00 | 232.55 | 2.20 | 86.50 | 18.80 | 50.60 | 47.90 | 5.30 | 56.50 | 22.95 | 91.00 | 80.00 | 3.75 | 18.50 | 25.00 | 45.00 |
| 63 | SK6×SK1×TW | 253.30 | 219.45 | 2.35 | 86.10 | 16.90 | 53.85 | 49.30 | 5.90 | 56.00 | 21.75 | 93.00 | 50.00 | 3.60 | 17.60 | 30.50 | 45.00 |
| 64 | BL43 | 425.59 | 328.47 | 2.72 | 77.12 | 11.23 | 51.28 | 45.31 | 8.92 | 66.50 | 20.68 | 88.00 | 80.00 | 3.79 | 19.00 | 29.50 | 62.50 |
| 65 | APM-1 | 658.67 | 544.21 | 2.33 | 80.73 | 8.92 | 65.63 | 16.08 | 11.21 | 85.00 | 21.74 | 85.00 | 90.00 | 3.64 | 18.50 | 22.50 | 77.50 |

post cocoon characteristics of silk filament and fibre quality of silkworm genetic resources. Hence, the present investigation has been carried out to evaluate the nature of genetic variation present in the 16 essential post cocoon characteristics of 65 multivoltine silkworm genotypes.

## Materials and Methods

Sixty-five multivoltine silkworm (*B.mori* L.) genotypes (10 geographical races and 55 evolved breeds) were used for the present study. Three replications with 300 larvae retained after third moult out were considered for the study. The standard rearing techniques recommended were followed (Krishnaswamy, 1978; Kumaresan *et al.*, 2004). Sixteen post cocoon characters of economic importance was used for the present study *viz.*, Filament length (m) (FL), Non-broken filament length (m) (NBF), Denier (d) (DEN), Reelability (%) (REEL), Renditta (Kg) (REND), Silk recovery (%) (S_REC), Silk waste (%) (WASTE), Raw silk (%) (R_SILK), Neatness (points) (NEAT), Boil-off loss (%) (BOIL), Cleanness (%) (CLEAN), Evenness (variation 1) (EVEN_V1), Tenacity (g/d) (TENA), Elongation (%) (ELONG), Cohesion (# strokes) (COHE) and Low neatness (points) (L_NEAT). The silk reeling and quality parameters were evaluated as per the standard procedures of mulberry silk reeling technology (Anonymous, 1972).

To ascertain the genetic diversity through Mahalonobis' distance ($D^2$); and to estimate the genetic parameters such as genotypic coefficient of variation (GCV%), phenotypic coefficient of variation (PCV%), heritability ($h^2$ in broad sense), genetic advancement (GA%), correlation coefficient (genotypical and phenotypical) among the traits and principal component analysis (PCA), the computer packages developed by Indostat Service Pvt. Ltd., Hyderabad, India were used.

## Results and Discussion

The mean performance of the genotypes for silk reeling and quality traits is presented in Table 1. The data were evaluated by variance analysis (ANOVA) and correlation coefficients between tested traits and characteristics were calculated. The results revealed highly significant variation ($P<0.001$) among the genotypes for all the traits studied (Table 2). Quantitative characters are cause to vary by a combination of underlying genetic variation and by the environment. In a population, if variability largely is of genetic nature with least environmental effect, the probability of isolating superior genotype is high (Petkov and Yolov, 1980). The existence of genetic variability in economic characters is obviously a resource for breeding (Frankel and Brown, 1983; Frey *et al.*, 1983; Dalton, 1987). The components of genetic variation such as variances of environment, genotype and phenotype together with their coefficient of variation, heritability ($h^2$ in broad

**Table 2.** Variability in post cocoon traits of multivoltine silkworm genotypes

| Sl.No. | Parameter | Mean | Minimum | Maximum | SD | SE | CV | ANOVA (F-value) |
|---|---|---|---|---|---|---|---|---|
| 1 | Filament length (m) | 436.29 | 253.30 | 684.00 | 106.49 | 13.31 | 24.41 | 28.10*** |
| 2 | Non-broken filament length (m) | 307.01 | 138.50 | 578.00 | 97.22 | 12.15 | 31.67 | 40.84*** |
| 3 | Denier (d) | 2.25 | 1.13 | 2.91 | 0.42 | 0.05 | 18.77 | 20.01*** |
| 4 | Reelability (%) | 69.54 | 40.25 | 86.50 | 11.13 | 1.39 | 16.00 | 20.39*** |
| 5 | Renditta (Kg) | 12.60 | 7.86 | 19.43 | 2.68 | 0.33 | 21.23 | 39.49*** |
| 6 | Silk recovery (%) | 56.21 | 34.28 | 77.27 | 10.74 | 1.34 | 19.11 | 14.94*** |
| 7 | Silk waste (%) | 29.44 | 11.93 | 61.85 | 10.59 | 1.32 | 35.99 | 20.87*** |
| 8 | Raw silk (%) | 8.27 | 5.12 | 12.72 | 1.65 | 0.21 | 19.98 | 32.49*** |
| 9 | Neatness (points) | 76.75 | 26.00 | 93.00 | 12.32 | 1.54 | 16.06 | 2.96*** |
| 10 | Boil-off loss (%) | 21.68 | 15.50 | 29.40 | 2.75 | 0.34 | 12.68 | 44.42*** |
| 11 | Cleanness % | 79.85 | 36.00 | 98.50 | 15.47 | 1.93 | 19.38 | 3.78*** |
| 12 | Evenness (V1) | 41.77 | 10.00 | 120.00 | 21.15 | 2.64 | 50.63 | 3.37*** |
| 13 | Tenacity (g/d) | 3.33 | 2.52 | 3.99 | 0.31 | 0.04 | 9.29 | 8.27*** |
| 14 | Elongation % | 15.27 | 11.10 | 19.40 | 2.26 | 0.28 | 14.78 | 3.81*** |
| 15 | Cohesion (# strokes) | 44.41 | 11.00 | 114.00 | 21.52 | 2.69 | 48.45 | 3.27*** |
| 16 | Low neatness (points) | 69.35 | 20.00 | 91.50 | 14.37 | 1.80 | 20.72 | 3.16*** |

***Significance at $P<0.001$

**Table 3.** Genetic variability and heritability (broad sense) in silk reeling and quality traits of multivoltine silkworm genotypes

| Parameter | Variance | | | Coefficient of Variance (%) | | | $h^2$ (%) (b.s.) | GA % of Mean (selection intensity at) | |
|---|---|---|---|---|---|---|---|---|---|
| | Env. | Geno. | Pheno. | Env. | Geno. | Pheno. | | 5% | 1% |
| Filament length (m) | 809.44 | 10969.76 | 11779.19 | 6.53 | 24.05 | 24.92 | 93.13 | 47.81 | 61.27 |
| Non-broken filament length (m) | 462.84 | 9220.88 | 9683.73 | 7.01 | 31.28 | 32.05 | 95.22 | 62.87 | 80.57 |
| Denier | 0.02 | 0.17 | 0.19 | 5.93 | 18.29 | 19.23 | 90.48 | 35.85 | 45.94 |
| Reelability (%) | 12.15 | 117.81 | 129.96 | 5.01 | 15.61 | 16.39 | 90.65 | 30.61 | 39.23 |
| Renditta (Kg) | 0.36 | 6.98 | 7.34 | 4.78 | 20.96 | 21.50 | 95.06 | 42.10 | 53.96 |
| Silk recovery (%) | 15.45 | 107.68 | 123.13 | 6.99 | 18.46 | 19.74 | 87.45 | 35.56 | 45.57 |
| Silk waste (%) | 10.76 | 106.86 | 117.61 | 11.14 | 35.11 | 36.84 | 90.85 | 68.94 | 88.36 |
| Raw silk (%) | 0.17 | 2.65 | 2.82 | 4.96 | 19.67 | 20.29 | 94.03 | 39.29 | 50.36 |
| Neatness (points) | 102.59 | 100.54 | 203.13 | 13.20 | 13.06 | 18.57 | 49.50 | 18.93 | 24.27 |
| Boil-off loss (%) | 0.34 | 7.38 | 7.72 | 2.69 | 12.54 | 12.82 | 95.60 | 25.25 | 32.35 |
| Cleanness (%) | 126.68 | 176.06 | 302.74 | 14.09 | 16.62 | 21.79 | 58.16 | 26.10 | 33.45 |
| Evenness (variation 1) | 282.14 | 335.09 | 617.23 | 40.89 | 44.56 | 60.48 | 54.29 | 67.64 | 86.69 |
| Tenacity (g/d) | 0.02 | 0.08 | 0.11 | 4.57 | 8.71 | 9.84 | 78.43 | 15.89 | 20.37 |
| Elongation (%) | 2.68 | 3.76 | 6.43 | 10.71 | 12.69 | 16.61 | 58.41 | 19.98 | 25.61 |
| Cohesion (# strokes) | 283.61 | 321.35 | 604.96 | 37.92 | 40.36 | 55.38 | 53.12 | 60.59 | 77.66 |
| Low neatness (points) | 130.71 | 141.09 | 271.81 | 16.48 | 17.13 | 23.77 | 51.91 | 25.42 | 32.58 |

sense) and genetic advancement are presented in Table 3. The Evenness (variation 1) showed higher PCV (60.487%) and GCV (44.56%) followed by cohesion (PCV=55.38%, GCV=40.36%), Silk waste % (PCV=36.84%, GCV=35.11%) and non-broken filament length (PCV=32.05%, GCV= 31.28%), respectively. A fundamental quantity in quantitative genetics is heritability. This is a description of the amount of total phenotypic variance in characters that is genetic. The general heritability ($h^2$ in broad sense) estimated among the post cocoon traits showed the range from 49.50% in neatness to 95.60% in boil-off loss. The higher heritability (>90%) was recorded in many traits such as non-broken filament length (95.22%), renditta (95.06%), raw silk % (94.03%), filament length (93.13%), silk waste (90.85%), reelability (90.65%) and denier (90.48%). The high heritability along with high genetic advancement was observed for filament length, which was corroborated with the earlier report (Islam *et al.*, 2003). The results indicated that the filament length could be considered for measuring the phenotypic stability of silkworm genotypes in the varying environments as it has correlation with many traits of economic importance (Kumaresan *et al.*, 2005[a]). This suggests that selection based on above characters will be highly effective for improvement (Narasimharaju *et al.*, 1990; Kumaresan *et al.*, 2000). The characters like neatness and low neatness have showed less GCV %, PCV % and heritability under study indicating that the environmental effect was more in the expression of those traits.

Correlation coefficient was performed to determine the inter relationship between traits. In silkworm most of the correlation between different characters has been worked out by selection experiments (Ooi *et al.*, 1970). Genotypic and phenotypic correlations co-efficient among the selected characters are presented in Table 4. The result indicates in general, the genotypic correlation among the characters to be slightly higher than the phenotypic correlation. This suggests the fact that in spite of strong inherent phenotypic association between various characters studied; the environment may modify the full expression of the genotypes. The both genotypic and phenotypic correlation indicated significant positive correlation of filament length with non-broken filament length, silk recovery, raw silk, neatness, and low neatness; and negative correlation with denier, renditta, silk waste and evenness (V1). The raw silk has shown significant positive correlation with filament length, non-broken filament length, denier, and silk recovery; and negative correlation with renditta, silk waste, evenness, tenacity and elongation. The denier has shown almost negative correlation with many traits such as filament length, non-broken filament length, reelability, renditta, neatness, elongation and low neatness, but for few traits, which showed significant positive correlation *viz.*, silk recovery, raw silk and cleanness. Increasing in reelabity is attributed to the better swelling and softening degree of sericin of all the filament layers and filament cross over points in the cocoon shell. The silk quality trait such as cleanness has showed positive correlation with

**Table 4.** Genotypic and phenotypic correlation coefficient among the silk reeling and quality traits

| Variable | FL | NBF | DEN | REEL | REND | S_REC | WASTE | R_SILK | NEAT | BOIL | CLEAN | EVEN | TENA | ELONG | COHE | L_NEAT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FL | – | 0.831 | −0.256 | 0.069 | −0.559 | 0.481 | −0.601 | 0.566 | 0.424 | −0.085 | 0.002 | −0.337 | −0.138 | −0.154 | 0.232 | 0.497 |
| NBF | 0.825 | – | −0.326 | 0.508 | −0.439 | 0.325 | −0.469 | 0.450 | 0.351 | −0.204 | −0.090 | −0.116 | 0.148 | 0.168 | 0.275 | 0.407 |
| DEN | −0.267 | −0.340 | – | −0.269 | −0.341 | 0.333 | −0.004 | 0.362 | −0.457 | 0.057 | 0.456 | 0.019 | −0.215 | −0.300 | −0.194 | −0.535 |
| REEL | 0.057 | 0.501 | −0.263 | – | −0.057 | 0.005 | −0.089 | 0.065 | 0.041 | −0.228 | −0.233 | 0.322 | 0.48 | 0.499 | 0.204 | 0.051 |
| REND | −0.538 | −0.418 | −0.347 | −0.034 | – | −0.842 | 0.701 | −0.968 | −0.148 | 0.006 | −0.161 | 0.442 | 0.369 | 0.452 | −0.073 | −0.164 |
| S_REC | 0.443 | 0.297 | 0.338 | −0.009 | −0.832 | – | −0.681 | 0.879 | 0.02 | 0.104 | 0.143 | −0.421 | −0.471 | 0.572 | 0.041 | 0.048 |
| WASTE | −0.584 | −0.451 | −0.015 | −0.079 | 0.684 | −0.673 | – | −0.737 | −0.216 | 0.075 | 0.111 | 0.426 | 0.363 | 0.466 | −0.144 | −0.244 |
| R_SILK | 0.539 | 0.427 | 0.368 | 0.048 | −0.968 | 0.869 | −0.720 | – | 0.015 | −0.054 | 0.135 | −0.419 | −0.358 | −0.495 | 0.048 | 0.050 |
| NEAT | 0.268 | 0.223 | −0.264 | −0.014 | −0.117 | 0.028 | −0.165 | 0.026 | – | 0.424 | −0.189 | −0.079 | 0.008 | 0.237 | 0.475 | 0.974 |
| BOIL | −0.070 | −0.181 | 0.033 | −0.203 | 0.009 | 0.098 | 0.063 | −0.054 | 0.289 | – | −0.099 | −0.066 | −0.294 | 0.063 | −0.029 | 0.319 |
| CLEAN | 0.022 | −0.052 | 0.366 | −0.179 | −0.156 | 0.168 | 0.049 | 0.141 | −0.029 | −0.080 | – | 0.099 | 0.132 | −0.128 | 0.138 | −0.208 |
| EVEN | −0.228 | −0.094 | 0.015 | 0.190 | 0.308 | −0.317 | 0.326 | −0.301 | −0.085 | −0.051 | 0.017 | – | 0.497 | 0.474 | −0.159 | −0.074 |
| TENA | −0.105 | 0.133 | −0.192 | 0.390 | 0.321 | −0.401 | 0.302 | −0.310 | 0.027 | −0.263 | 0.117 | 0.295 | – | 0.742 | 0.206 | 0.013 |
| ELONG | −0.118 | 0.089 | −0.190 | 0.329 | 0.332 | −0.410 | 0.319 | −0.360 | 0.085 | 0.029 | −0.054 | 0.294 | 0.594 | – | −0.096 | 0.197 |
| COHE | 0.182 | 0.197 | −0.153 | 0.118 | −0.055 | 0.022 | −0.088 | 0.032 | 0.264 | −0.035 | 0.065 | −0.082 | 0.139 | 0.016 | – | 0.484 |
| L_NEAT | 0.322 | 0.264 | −0.323 | −0.002 | −0.126 | 0.034 | −0.171 | 0.043 | 0.941 | 0.230 | −0.011 | −0.110 | 0.026 | 0.063 | 0.252 | – |

Above: Genotypic correlations; Below: Phenotypic correlations; Correlation is significance at 1% if r => 325; 5% if r => 0.250.
Where, FL=Filament length (m), NBF=Non-broken filament length (m), DEN=Denier, REEL=Reelability, REND=Renditta, S_REC=Silk recovery %, WASTE=Silk waste %, R_SILK=Raw silk %, NEAT=Neatness %, BOIL=Boil-off loss, CLEAN=Cleanness, EVEN=Evenness, TENA=Tenacity, ELONG=Elongation, COHE=Cohesion, L_NEAT=Low neatness.

denier only. The tenacity has shown positive correlation with reelability, renditta, silk waste, evenness and elongation. The boil-off loss has shown positive correlation with neatness and negative correlation with tenacity indicates importance of degumming process for production of strong and quality raw silk. The renditta is negatively correlated with quantitative traits *viz.*, filament length, non broken filament length, denier, silk recovery, raw silk and positively correlated with silk quality traits such as silk waste, evenness, tenacity, and elongation indicates the contributing factors for production of quality raw silk. The positive correlation between these characters suggest the scope of using one set of variables as selection markers to control the expression of other correlated variables. The results concur with the earlier observations (Kumaresan *et al.*, 2000). Uniformity characteristics of raw silk influence significantly the performance of raw silk during preparatory and weaving operations and appearance of the fabrics (Warren, 1922). Uniformity of raw silk is determined by the size deviation and evenness variation of raw silk. These properties are influenced by reelability of cocoons, reeling speed and denier (Narayanan, 1967; Lewin, 1983). In general, the post cocoon characters are mostly influenced by the abiotic factors such as high temperature and high humidity during spinning, and reeling technology adopted besides the racial characters (Naik and Somashekar, 2003). The filament length has significant negative correlation with denier, which indicates that selection for filament length will change the filament size in the reverse direction. This is in agreement with the earlier observation (Lin *et al.*, 1995).

The structure of genetic variation among the populations based on all the 16 post cocoon traits was analyzed using principal component analysis (PCA). In statistical practices, the method of principal component analysis is used to find the linear combinations with large variance (Kumaresan *et al.*, 2003[a]). The PCA was carried out considering all the 16 post cocoon parameters, the character which explained eigen values (total variance) lower than 1.067 in the principal component was rejected according to the criteria pro-

**Table 5.** Variance of principal components (PC) and the cumulative contribution to the total variance

| Components | Initial Eigen values | | | Extraction Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| PC1 | 4.678 | 29.239 | 29.239 | 4.678 | 29.239 | 29.239 |
| PC2 | 2.900 | 18.127 | 47.366 | 2.900 | 18.127 | 47.366 |
| PC3 | 2.028 | 12.674 | 60.040 | 2.028 | 12.674 | 60.040 |
| PC4 | 1.388 | 8.672 | 68.712 | 1.388 | 8.672 | 68.712 |
| PC5 | 1.067 | 6.668 | 75.381 | 1.067 | 6.668 | 75.381 |

**Table 6.** Correlation coefficients between principal component (PC) and the set of traits

| Sl.No. | Characters | Components | | | | |
|---|---|---|---|---|---|---|
| | | PC1 | PC2 | PC3 | PC4 | PC5 |
| 1 | Filament length (m) | 0.712 | 0.444 | 0.097 | −0.106 | −0.121 |
| 2 | Non-broken filament length (m) | 0.544 | 0.636 | 0.369 | −0.099 | 0.005 |
| 3 | Denier (d) | 0.174 | −0.703 | 0.090 | 0.492 | 0.173 |
| 4 | Reelability (%) | −0.005 | 0.511 | 0.579 | −0.064 | 0.276 |
| 5 | Renditta (Kg) | −0.913 | 0.116 | −0.125 | −0.161 | −0.147 |
| 6 | Silk recovery (%) | 0.867 | −0.236 | 0.068 | 0.093 | 0.165 |
| 7 | Silk waste (%) | −0.826 | −0.081 | −0.079 | 0.158 | −0.027 |
| 8 | Raw silk (%) | 0.920 | −0.159 | 0.203 | 0.119 | 0.136 |
| 9 | Neatness (points) | 0.223 | 0.610 | −0.635 | 0.261 | 0.084 |
| 10 | Boil-off loss (%) | 0.014 | −0.041 | −0.620 | 0.025 | 0.542 |
| 11 | Cleanness (%) | 0.113 | −0.223 | 0.065 | 0.768 | −0.295 |
| 12 | Evenness (V1) | −0.445 | 0.098 | 0.258 | 0.239 | 0.376 |
| 13 | Tenacity (g/d) | −0.429 | 0.479 | 0.425 | 0.395 | −0.036 |
| 14 | Elongation (%) | −0.458 | 0.471 | 0.237 | 0.262 | 0.342 |
| 15 | Cohesion (# strokes) | 0.128 | 0.390 | −0.080 | 0.231 | −0.479 |
| 16 | Low neatness (points) | 0.245 | 0.637 | −0.608 | 0.231 | 0.028 |

**Table 7.** Cluster information derived from Mahalnobis' Euclidean2 distance based on Ward's minimum variance

| Cluster | No.of Genotypes | Name of the Genotypes |
|---|---|---|
| I | 9 | Pure Mysore, Sarupat, Moria, T. N. White, Nistari (M), A23, MY23, NK4, ZPN (SL). |
| II | 17 | P2D1, A25, MU1, G, Nistari, Nistari (P), A14DY, MU11, MU520, Hosa Mysore, BL43, PMS2, WAI-1, MHMP (Y), MY1 (SL), MU303, MU10. |
| III | 9 | Rong Dazao, PMX, GNP, Raj, P4D3, Oval, Nistid (W), DMR, LMO. |
| IV | 4 | KW2, MHMP (W), PM(SL), Daizo. |
| V | 5 | M2, Nistid (Y), PA12, AP12, A4e. |
| VI | 9 | Kolar Gold, Kollegal Jawan, CB5, OS-616, B, M83 (c), LMP, Cambodg, WAI-4. |
| VII | 4 | MW13, APM-1, O, GNM. |
| VIII | 3 | C. nichi, MY1, A13. |
| IX | 5 | BL23, BL24, TW × SK6 × SK1, SK6 × SK1 × TW, Mysore Princess. |

posed by Joliffe (1973). The first five principal components representing 75.381% of the total variance was extracted and presented in Tables 5 & 6. The highest positive correlation coefficient value was obtained for raw silk % (0.920) in PC1, low neatness (0.637) in PC2, reelability (0.579) in PC3, cleanness (0.768) in PC4 and boil-off loss (0.542) in PC5, respectively. Similarly, the highest inverse (negative) relation was recorded for renditta (–0.913) in PC1, denier (–0.703) in PC2, neatness (–0.635) in PC3, filament length (–0.106) in PC4 and cohesion (–0.479) in PC5.

Several attempts have been made to classify the germplasm stocks by using Hierarchical agglomerative clustering (UPGMA methods) for identification of genetically diverged parents to develop higher heterotic combination based on bio-chemical aspects, yield attributes and cocoon size & weight variables (Jolly *et al.*, 1989; Chatterjee and Datta, 1992; Ramamohana Rao and Nakada, 1998; Kumaresan and Sinha, 2002). On the basis of Mahalonobis' $D^2$ values (Ward's minimum variance), the sixty-five multivoltine silkworm genotypes were classified in to 9 clusters with substantial inter and intra cluster distances (Table 7 and Fig. 1). Number of genotypes included in different clusters varied from 3 to 17. Maximum number of genotypes (17) have included in cluster II, where except Nistari all of them are evolved breeds; where the genotypes BL43 and MHMP (Y) have showed strong filament characters. The clusters I, III and VI included 9 genotypes each, where, cluster I included 3 genotypes of geographical origin *viz.*, Pure Mysore, Sarupat and Moria. The cluster VI included 9 genotypes, where Kolar Gold and Kollegal Jawan are considered for their fibroin quality because it showed low level of boil-off loss and cohesion in fibre quality. The cluster V included 5 genotypes, where two genotypes PA12 and AP12 have showed thick denier silk fibre. The cluster IX included 5 genotypes, where the genotypes TW × SK6 × SK1 and SK6 × SK1 × TW have showed their strong fibre quality because it showed higher tenacity, cohesion and elongation. Cluster VII

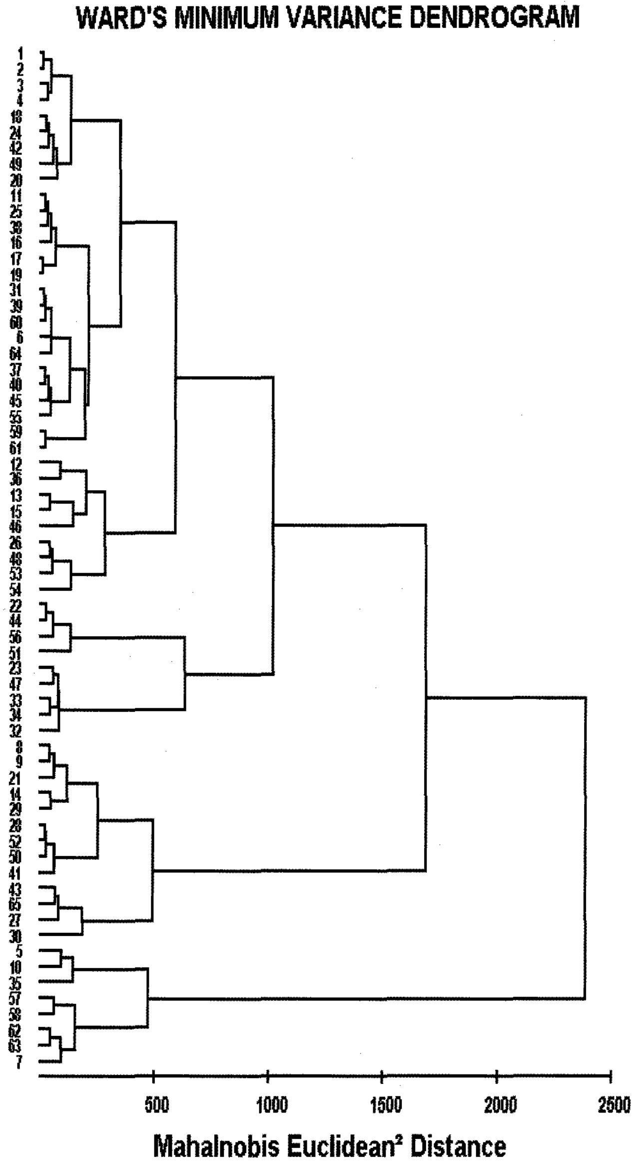


**Fig. 1.** Dendrogram based on Ward's minimum variance showing the genetic divergence in 65 multivoltine silkworm genetic resources for 16 post cocoon traits.

**Table 8.** Inter and Intra cluster distances between clusters based on Ward's minimum variance

| Cluster | I | II | III | IV | V | VI | VII | VIII | IX |
|---|---|---|---|---|---|---|---|---|---|
| I | 10.275 | 12.815 | 16.998 | 15.684 | 18.941 | 18.626 | 23.996 | 29.548 | 23.343 |
| II | | 11.03 | 15.955 | 20.074 | 18.297 | 14.583 | 20.404 | 26.602 | 21.774 |
| III | | | 15.759 | 19.965 | 20.45 | 18.837 | 23.491 | 23.929 | 22.589 |
| IV | | | | 12.111 | 19.827 | 26.786 | 30.646 | 32.748 | 26.127 |
| V | | | | | 11.568 | 22.696 | 22.422 | 26.766 | 21.768 |
| VI | | | | | | 12.654 | 18.309 | 26.845 | 26.087 |
| VII | | | | | | | 15.059 | 26.544 | 27.365 |
| VIII | | | | | | | | 15.512 | 20.146 |
| IX | | | | | | | | | 13.454 |

**Table 9.** Mean values of each cluster for silk reeling and quality traits

| Cluster | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | 366.34 | 281.07 | 2.29 | 76.01 | 12.41 | 52.75 | 30.26 | 8.17 | 80.56 | 23.77 | 70.61 | 33.89 | 3.29 | 16.30 | 45.67 | 71.94 |
| II | 444.29 | 330.94 | 2.27 | 72.19 | 12.22 | 54.34 | 32.03 | 8.25 | 76.32 | 21.14 | 83.65 | 49.41 | 3.54 | 16.32 | 45.03 | 68.82 |
| III | 413.57 | 242.31 | 2.09 | 63.26 | 13.17 | 53.00 | 29.39 | 7.86 | 77.61 | 20.13 | 81.39 | 35.56 | 3.24 | 13.30 | 47.61 | 70.78 |
| IV | 382.40 | 173.52 | 2.40 | 57.93 | 11.46 | 62.42 | 26.75 | 8.72 | 82.75 | 26.30 | 80.50 | 32.50 | 3.00 | 14.17 | 33.25 | 73.12 |
| V | 516.64 | 302.76 | 2.71 | 48.67 | 11.24 | 65.72 | 26.79 | 9.13 | 79.10 | 25.04 | 87.80 | 22.00 | 2.83 | 12.70 | 30.70 | 71.40 |
| VI | 527.34 | 419.47 | 2.02 | 77.76 | 11.18 | 62.58 | 21.28 | 9.08 | 81.00 | 18.97 | 81.00 | 34.44 | 3.29 | 15.42 | 54.61 | 76.50 |
| VII | 573.92 | 442.05 | 2.52 | 74.38 | 8.59 | 73.34 | 14.82 | 11.67 | 67.75 | 19.96 | 70.50 | 36.25 | 3.32 | 13.55 | 41.12 | 59.75 |
| VIII | 388.17 | 257.00 | 1.63 | 65.03 | 18.76 | 38.08 | 33.77 | 5.32 | 65.83 | 19.60 | 62.50 | 43.33 | 3.47 | 15.83 | 38.17 | 59.67 |
| IX | 283.20 | 219.36 | 2.40 | 74.43 | 17.58 | 45.82 | 47.83 | 5.68 | 68.70 | 22.92 | 88.20 | 76.00 | 3.65 | 17.66 | 45.00 | 59.50 |

Where, 1=Filament length (m), 2=Non-broken filament length (m), 3=Denier, 4=Reelability, 5=Renditta, 6=Silk recovery %, 7=Silk waste %, 8=Raw silk%, 9=Neatness %, 10=Boil-off loss, 11=Cleanness, 12=Evenness, 13=Tenacity, 14=Elongation, 15=Cohesion, 16=Low neatness.

included 4 genotypes; where MW13, APM-1 and GNM have showed their good fibre quality, as they showed low renditta, maximum silk recovery and maximum reelability, filament length along with good evenness with less variation. The cluster VIII included 3 genotypes, where the genotype MY1 has showed very fine denier. The cluster IV included 4 genotypes, where the genotype Daizo has showed high neatness indicates presence of high sericin content in their cocoon shell. This result further implies that when an initial choice of parents has to be made to obtain heterosis it is important to ascertain the level of parental divergence (Jolly *et al.,* 1989).

Arunachalam *et al.* (1984) emphasized that there is an optimum level of genetic divergence between parents to obtain heterosis in $F_1$ generation and it may not be logical to advocate the use of extreme diverge parents to obtain heterotic combination. The genetic distances for inter and intra clusters is presented in Table 8. The intra cluster distance revealed that the genotype included in cluster III has showed maximum genetic distance (15.759), which is minimum in cluster I (10.275). The inter cluster distance indicates the maximum genetic distance between cluster IV and VIII (32.748), whereas the cluster between II and I showed minimum distance (12.815). The mean performance of each cluster for all the ten economic traits is presented in Table 9. The results indicated that the optimum distance obtained in cluster VII (15.059) along with higher cluster mean values especially for filament length, non broken filament length, silk recovery, raw silk; and lower mean values for renditta and silk waste of cocoon characters emphasized the utilization of these genotypes in the conventional silkworm breeding programmes for improvement of silk fibre quality in multivoltine silkworm breeds.

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