ISSN 2348 – 7968

Genetic evaluation of silkworm genetic resources to identify cluster groups for conservation of promising silkworm breeds

Ashok Kumar, K., Veeranna Gowda., Balachandran, N., Somasundaram, P., and Kanika Trivedy
Central Sericultural Germplasm Resources Centre, Central Silk Board, Hosur 635 109

ABSTRACT

The genetic evaluation of 72 multivoltine silkworm germplasm resources of different geographical origin maintained at Central Sericultural Germplasm Resources Centre, Hosur were analyzed by cluster analysis. The data showed variation and diversity among the multivolitine genotypes based on 12 economic traits and based on the results of all the 12 economic traits studied, the genotypes were grouped into clusters. It is evident from the results that the single shell weight showed higher genetic variation such as PCV (17.20%) followed by single cocoon weight, shell ratio and matured larval weight. The application of ward's minimum variance statistical tool revealed two distinctive cluster groups encompassing 12 variants within them. The specific genotypes were chosen from these clusters as promising ones for maintenance of unique breeds possessing higher quantitative trait values for conservation and evolution of pre-breed materials. The utility of such promising parental genetic material is discussed in this study.

Key words: Multivoltine genotypes, genetic variation, divergence analysis, cluster mean values.

INTRODUCTION

Great diversity of multivoltine silkworm *Bombyx mori* L. must exist globally, considering the fact that many number of silkworm breeds are evolved by selection or cross breeding and also some of the tropical countries allowed individual farmers to reproduce silkworm eggs (Anonymous, 1997). This diversity is considered to be the result of adaptation during long generation (Murakami, 1994). The genetic variation accumulated through adaptation can be used to measure genetic diversity and therefore, can also be utilized to monitor and promote efficient conservation and utilization of germplasm.

In India, Central Sericultural Germplasm Resources Centre (CSGRC), Central Silk Board, Hosur, Tamil Nadu (latitude: 12˚ 45"N, longitude: 77˚ 51"E, altitude: 942 meter above MSL, average maximum temperature 27-36˚C and average minimum temperature 9-14˚ C with average annual rainfall of 800-1000 mm is the only centre exclusively established during February 1991 for conservation of mulberry (Morus sp.) and silkworm genetic resources (*Bombyx mori* L.) and is maintaining 72 multivoltine silkworm germplasm resources collected from different geographical regions possessing large amount of genetic variability, which could be exploited well for breeding program. Moreover, in silkworm when an initial choice of parents has to be made to obtain heterosis in different hybrid crosses, it is important to ascertain the level of parental divergence (Jolly *et al*., 1989; Chatterjee *et al*., 1993; Mukherjee et al., 1999; Kumaresan *et al*., 2003 and 2003a). The genetic variability included phenotypic coefficient of variation (PCV%), genotypic coefficient of variation (GCV%), environmental coefficient of variation (ECV %), heritability (h^2) and genetic gain (GA) on economically important quantitative traits of silkworm facilitating the choice of characters to be selected for improvement in the breeding program.

The present study was undertaken to ascertain the magnitude of genetic diversity among 72 multivoltine silkworm (*Bombyx mori* L.) genotypes and to estimate the genetic variation for 12 economic traits to augment the utilization of silkworm genetic resources for silkworm breeding programs.

MATERIALS AND METHODS

Seventy two multivoltine genotypes of the silkworm *Bombyx mori* maintained at Central Sericultural Germplasm Resources Centre, Hosur were considered for the present investigation and were used to analyze 12 quantitative traits from the data collected from the rearings of all the genotypes reared together in four consecutive seasons *viz.*, January-March, April-June, July-September and October-December from 2003 to 2005. The standard rearing techniques and methodology of Krishnaswamy (1978) and Datta *et al.,* (1996) were followed for maintenance of germplasm. Three replications during each season for all the genotypes by retaining 300 larvae after third moult were considered during the study. The conservation rearing for maintenance of silkworm germplasm was followed as 'composite population' to avoid inbreeding depression and genetic erosion. Composite laying is defined as collection of known number of eggs from a known number of individual laying sources that represents the whole population. The composite layings are prepared only after pigmentation takes place by taking approximately 50 eggs from each laying of 40 dfls and were divided into two batches *i.e*. 20 dfls of each. All the pieces from 20 laying sources were pasted on a slightly thick brown paper and were wrapped in tissue paper. Thus, each composite laying consists of 20 laying sources with about 1,000 – 1,500 individual eggs. Twelve economically important quantitative traits *viz*., fecundity, weight of 10 matured larvae (g), total larval duration and Vage larval duration (hrs), cocoon yield/10,000 larvae (No.) and (Wt.), single cocoon weight (g), single shell weight (g), shell ratio (%), pupation rate (%), filament length (m), NBFL (m) and neatness (p) were considered. To ascertain the genetic diversity through Mahalnobis' distance (D^2), estimated the phenotypic component analysis (PCV) in respected of all the quantitative traits.

RESULTS AND DISCUSSION

The mean performance and the range of variability among the seventy two multivoltine genotypes for the twelve quantitative traits is presented in Table 1 and 2. The wide variation obtained among the multivoltine genotypes in respect of fecundity with mean value of 439 (12.27%), followed by cocoon yield /10,000 larvae by wt. (25.16kg) and pupation (82.12) facilitates to select for breeding on these principal traits. The existence of genetic variability in economic characters is obviously a resource for breeding (Frankel & Brown, 1983; Dalton, 1987). Analysis of variance indicated significant variation among the multivoltine genotypes for all the economic traits considered for the study (Table 1 and 2). The single shell weight showed higher PCV (16.15%), followed by cocoon weight (11.02%), shell ratio (6.72%) and larval weight (12.79%). The single cocoon weight with higher PCV of 11.02% indicated that the trait could be considered for measuring the phenotypic stability of multivoltine genotypes in the varying environments (Kumaresan *et al.,* 2005). This suggests that selection based on above characters will be highly effective for improvement (Narasimharaju *et a*l., 1990; Kumaresan *et al.,* 2000). The characters like yield / 10000 larvae (No.) and pupation rate have showed less PCV% under the study indicating that the environmental effect was more in the expression of those traits. Though the genetic variation obtained in this study is primarily based on the quantitative traits. Thus, the study needs further confirmation through the DNA profile study like ISSR, RFLP, etc., which is in conformity with the studies of Chatterjee and Mohandas (2003) in the yield traits of some 20 silkworm stocks wherein the genetics of productive traits associated with ISSR markers were studied to explore the association between ISSR markers and yield attributes, such markers needs to be tested for their use in marker-assisted breeding programs for modifying the yield potential of silkworm.

On the basis of Mahalonobis 'D^2' values (Ward's minimum variance), cluster analysis was done and dendogram was drawn using the variables (figure 1). The dendrogram of the seventy two multivoltine silkworm genotypes shows the presence of 2 distinct clusters with substantial inter and intra sub-cluster (7) distincts. Number of multivoltine genotypes included in different clusters varied from 1 to 20. As evident from Table 3, the major cluster I shows maximum number of genotypes (20) is in cluster I(i) followed by six in cluster I(ii), seven in cluster I(iii) and three in cluster I(iv) were included. Other major cluster II contains, 15 genotypes under II(i), 3 in II(ii) and cluster II(iii) with a group of 8 genotypes.

The Present investigation has also helped in understanding the variability that existed in the seventy two multivoltine germplasm resources with regard to the quantitative traits analyzed and also to assess possibilities of clustering all the genotypes on the basis of economic parameters and phenotypic component analysis (PCA) variability.

Table 1: Mean data of performance of multivoltine genotypes for economic traits

Acc.No.	Fecundity	Wt. Of 10 grown larvae (g)	Total larval duration (h)	Vth age larval duration (h)	Yield/10,000 larvae		Cocoon wt. (g)	Shell wt. (g)	SR %	Pupation rate (%)	Filament length (m)	Non-breakable filament length (m)	Neatness %
					By no..	By wt. (kg)							
BMI-0001	457	18.17	626.00	186.00	7410	7.15	1.00	0.14	14.07	72.94	307.00	243.50	71.50
BMI-0002	405	25.21	569.00	149.00	7717	9.02	1.16	0.17	14.85	75.27	350.50	287.00	85.00
BMI-0003	388	26.85	564.00	145.00	8045	9.72	1.13	0.16	14.69	77.07	419.00	349.50	89.00
BMI-0004	429	26.41	566.00	147.00	7876	9.47	1.21	0.19	15.70	79.41	428.50	339.50	93.00
BME-0005	397	20.96	539.00	112.00	7923	8.18	1.00	0.12	11.99	84.55	276.50	196.50	49.50
BMI-0006	498	28.34	559.00	144.00	7435	10.27	1.36	0.21	15.16	82.12	514.50	435.00	87.00
BMI-0007	488	26.16	558.00	144.00	7836	9.62	1.16	0.18	15.84	81.21	326.00	277.50	88.50
BMI-0008	477	27.85	553.00	134.00	8132	10.08	1.26	0.19	15.43	80.24	548.00	448.50	93.00
BMI-0009	480	28.40	549.00	132.00	8241	10.38	1.28	0.19	15.12	87.28	698.50	578.00	85.00
BMI-0010	452	27.23	564.00	146.00	7710	10.63	1.36	0.19	14.01	85.85	544.00	403.50	68.00
BMI-0011	466	29.17	565.00	154.00	8066	10.65	1.31	0.20	15.06	86.03	474.50	345.00	90.50
BME-0012	433	29.27	572.00	168.00	7331	10.64	1.41	0.21	14.57	76.74	265.50	225.00	72.00
BME-0013	417	24.32	558.00	135.00	7592	8.57	1.13	0.17	14.59	81.56	365.00	235.00	75.50
BMI-0014	411	22.96	559.00	141.00	7756	8.13	1.08	0.15	14.13	84.69	621.00	440.00	89.00
BME-0015	383	21.06	578.00	166.00	7511	7.94	1.06	0.15	14.67	82.76	502.00	340.00	92.00
BMI-0016	432	25.37	571.00	149.00	8167	9.58	1.22	0.18	14.44	78.67	598.00	460.00	89.00
BMI-0017	381	20.91	557.00	143.00	7972	7.72	1.02	0.13	13.00	78.94	399.00	303.00	83.50
BMI-0018	392	19.64	559.00	142.00	7871	7.75	0.94	0.13	13.51	81.44	286.50	211.00	77.50
BMI-0019	382	20.58	549.00	134.00	8002	7.75	0.97	0.14	13.99	86.04	432.00	317.50	87.00
BMI-0020	312	21.34	572.00	147.00	7427	7.52	1.00	0.14	13.71	95.94	300.50	239.00	63.50
BMI-0021	407	23.15	560.00	147.00	8503	9.11	1.07	0.17	15.45	80.81	562.60	511.00	71.00
BMI-0022	391	22.14	571.00	150.00	7947	8.49	1.05	0.15	14.62	83.62	392.90	178.60	82.00
BMI-0023	421	20.60	564.00	144.00	8551	8.39	1.00	0.15	14.77	84.91	519.00	288.00	84.00
BMI-0024	423	23.74	559.00	139.00	8225	9.23	1.12	0.16	14.39	86.89	442.10	306.10	74.00
BMI-0025	462	23.51	570.00	150.00	7642	8.91	1.20	0.18	14.73	75.28	520.00	342.00	84.00
BMI-0026	413	23.37	562.00	148.00	7917	8.81	1.12	0.16	14.51	83.18	528.30	310.80	79.50
BMI-0027	411	23.60	570.00	154.00	8352	9.64	1.16	0.17	14.90	78.67	526.28	404.83	76.50
BMI-0028	403	23.42	559.00	138.00	7985	8.07	1.05	0.15	14.26	85.88	402.30	311.00	63.00
BMI-0029	426	21.36	589.00	165.00	7954	8.63	1.09	0.16	15.00	71.20	563.00	433.00	85.00
BME-0030	397	26.35	557.00	144.00	8264	9.69	1.19	0.18	15.21	84.45	518.85	324.28	26.00
BMI-0031	407	26.14	543.00	138.00	8413	9.62	1.17	0.17	14.44	76.42	470.15	366.30	68.00
BMI-0032	444	27.37	569.00	147.00	8237	10.31	1.21	0.18	15.09	83.24	570.00	310.00	81.50

BMI-0033	443	28.01	570.00	147.00	8104	9.95	1.32	0.21	15.96	76.59	516.70	303.90	82.50
BMI-0034	472	30.77	565.00	148.00	8270	11.68	1.40	0.22	15.45	86.52	610.00	385.00	82.00
BMI-0035	475	29.11	569.00	151.00	7786	10.81	1.36	0.21	15.31	87.30	344.00	171.00	80.00
BMI-0036	445	28.03	564.00	147.00	8190	9.73	1.23	0.19	15.72	78.39	281.00	185.50	63.00
BMI-0037	432	25.98	566.00	145.00	8227	9.46	1.20	0.19	15.62	80.35	378.00	295.00	63.00
BMI-0038	467	27.40	564.00	143.00	7896	9.68	1.22	0.19	15.30	82.28	432.50	308.00	90.00
BMI-0039	414	26.82	555.00	135.00	7078	8.32	1.19	0.18	15.21	83.76	413.00	344.00	75.00
BMI-0040	447	27.05	543.00	127.00	7361	8.37	1.19	0.17	14.37	78.04	440.00	300.00	67.00
BMI-0041	381	23.53	555.00	136.00	8251	8.26	1.07	0.15	14.31	78.33	500.70	357.70	80.00
BMI-0042	457	27.99	559.00	141.00	8268	10.45	1.26	0.18	14.68	80.56	350.00	240.00	88.50
BMI-0043	470	28.96	558.00	138.00	7548	9.74	1.33	0.20	14.98	79.54	593.88	494.90	83.50
BMI-0044	407	29.27	562.00	143.00	7301	9.65	1.31	0.19	14.30	74.94	401.70	138.50	80.00
BMI-0045	479	31.50	568.00	151.00	7778	11.22	1.42	0.22	15.48	83.63	495.00	329.00	55.00
BMI-0046	461	27.85	571.00	153.00	7713	9.87	1.34	0.21	16.07	80.40	353.50	148.00	82.00
BME-0047	426	23.77	558.00	143.00	7872	8.66	1.12	0.15	13.60	79.86	367.50	226.90	65.50
BME-0048	408	23.07	557.00	141.00	7821	7.52	1.04	0.14	13.40	78.78	427.00	224.70	81.50
BME-0049	321	21.88	566.00	151.00	7968	8.61	1.03	0.14	13.40	83.82	413.00	314.00	83.00
BME-0050	315	22.19	556.00	139.00	7551	7.94	0.99	0.14	14.20	81.54	448.50	340.00	81.50
BME-0052	393	21.76	564.00	162.00	7062	6.72	0.96	0.13	13.75	76.67	310.50	167.00	84.00
BMI-0053	390	23.33	562.00	147.00	7786	8.43	1.07	0.15	14.54	85.26	401.50	356.00	81.50
BMI-0054	410	24.13	549.00	138.00	7818	8.58	1.06	0.16	14.83	78.99	432.40	196.60	67.00
BMI-0055	439	25.68	566.00	147.00	8566	10.10	1.19	0.17	14.22	84.36	567.45	315.15	86.00
BMI-0056	492	23.98	581.00	153.00	7492	8.30	1.18	0.18	15.16	80.45	423.00	272.50	58.00
BMI-0057	477	26.61	563.00	144.00	7260	8.37	1.23	0.18	14.96	77.71	424.50	210.00	85.00
BMI-0058	491	30.74	559.00	151.00	8191	11.88	1.40	0.23	16.49	76.83	307.80	188.70	82.00
BMI-0059	472	29.07	562.00	148.00	8758	13.10	1.40	0.23	16.13	80.80	274.50	178.60	60.50
BMI-0060	523	27.87	574.00	157.00	8959	11.90	1.34	0.20	14.81	83.67	327.20	221.70	76.50
BMI-0061	456	30.14	549.00	135.00	8812	11.40	1.31	0.20	15.15	78.02	418.90	357.65	79.00
BMI-0062	292	27.76	562.00	145.00	7496	9.33	1.31	0.21	16.15	69.04	402.45	300.95	78.50
BMI-0063	397	23.05	557.00	135.00	8463	9.22	1.06	0.12	11.70	75.18	261.95	232.55	56.50
BMI-0064	486	22.99	547.00	125.00	9159	9.49	1.07	0.13	12.58	80.92	245.75	219.45	56.00
BMI-0065	524	27.46	576.00	152.00	9498	11.99	1.22	0.20	16.33	94.58	414.84	328.47	66.50
BMI-0066	558	30.14	579.00	157.00	9656	13.03	1.40	0.23	16.59	89.01	656.67	544.21	85.00
BMI-0067	511	23.98	637.00	199.00	9494	10.80	1.15	0.17	15.03	87.95	324.63	303.57	62.50
BMI-0068	496	20.10	582.00	160.00	9419	9.86	1.06	0.16	15.34	89.44	345.98	267.09	51.00
BMI-0069	461	21.34	585.00	164.00	9437	10.36	1.12	0.17	15.33	89.39	365.70	285.77	51.50
BMI-0070	540	20.72	585.00	162.00	9660	10.55	1.07	0.16	14.89	91.47	238.64	203.32	58.50
BMI-0071	496	21.94	578.00	159.00	9591	10.25	1.07	0.16	14.90	92.27	405.37	365.94	63.50
BMI-0072	530	22.58	597.00	171.00	9557	11.02	1.17	0.18	15.51	90.94	298.89	226.49	60.50
BMI-0073	537	28.24	528.00	129.00	9477	11.51	1.26	0.22	17.57	91.50	279.92	164.89	35.00
Mean	**439**	**25.16**	**565.39**	**147.24**	**8147**	**9.52**	**1.18**	**0.17**	**14.79**	**82.12**	**424.53**	**302.40**	**74.60**
SD (%)	**53.81**	**3.22**	**16.14**	**12.93**	**669.53**	**1.36**	**0.13**	**0.03**	**0.99**	**5.33**	**107.93**	**95.41**	**13.74**
CV(%)	**12.27**	**12.79**	**2.85**	**8.78**	**8.22**	**14.28**	**11.02**	**16.15**	**6.72**	**6.50**	**25.42**	**31.55**	**18.42**

Table 2: Range of variability among 72 multivoltine genotypes for important economic traits

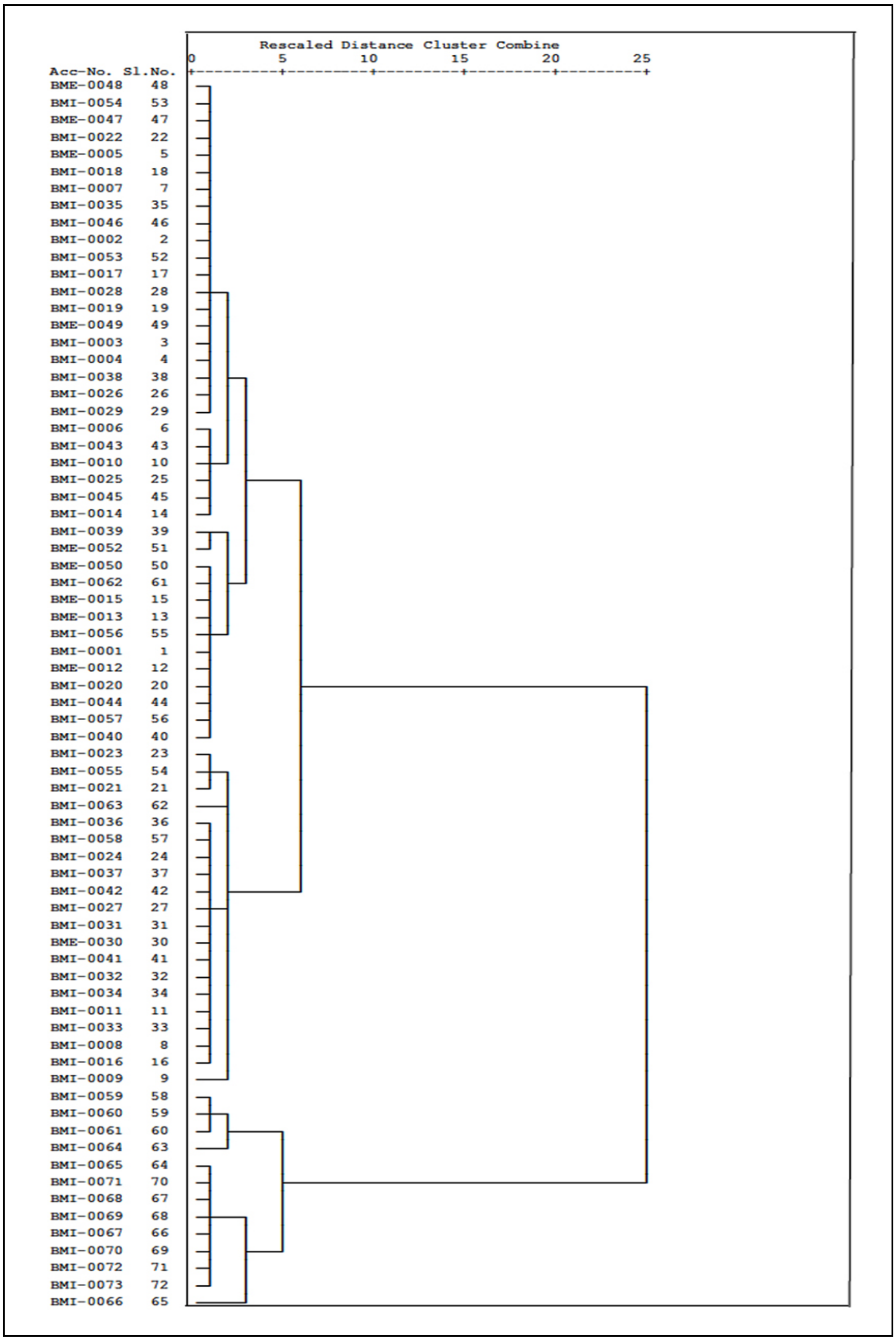
Trait	Minimum	Maximum	Mean	SD (±)	CV (%)
Fecundity (No.)	292 (BMI-0062)	558 (BMI-0066)	439	53.81	12.27
Wt. of 10 larvae (g)	18.17 (BMI-001)	31.50 (BMI-0045)	25.16	3.22	12.79
Total larval duration (hrs)	528 (BMI-0073)	626 (BMI-001)	565.39	16.14	2.85
Fifth larval duration (hrs.)	112 (BME-005)	186 (BMI-001)	147.24	12.93	8.78
Yield/10000 larvae (No.)	7078 (BMI-0039)	9656 (BMI-0066)	8147	669.53	8.22
Yield/10000 larvae (Wt.)	6.72 (BME-0052)	13.10 (BMI-0059)	9.52	1.36	14.28
Cocoon weight (g)	0.94 (BMI-0018)	1.42 (BMI-0045)	1.18	0.13	11.02
Shell weight (g)	0.12 (BMI-0063)	0.23 (BMI-0058, BMI-0059, BMI-0066)	0.17	0.03	16.15
Shell ratio (%)	11.70 (BMI-0063)	17.57 (BMI-0073)	14.79	0.99	6.72
Pupation rate (%)	69.04 (BMI-0062)	94.58 (BMI-0065)	82.12	5.33	6.50
Filament length (m)	238.64 (BMI-0070)	698.50 (BMI-009)	424.53	107.93	25.42
NBFL (m)	349.50 (BMI-003)	578.00 (BMI-009)	302.40	95.41	31.55
Neatness (p)	49.50 (BME-005)	93.00 (BMI-008)	74.60	13.74	18.42

Table 3: Cluster groups showing multivoltine genotypes

Sl. No.	Major cluster	Sub-cluster	No. of genotypes	List of Accessions grouped under sub-clusters
1	I	i	20	BME-0048, BMI-0053, BME-0047, BMI-0022, BME-0005, BMI-0018,BMI-0007,BMI-0035, BMI-0046, BMI-0002, BME-0052, BMI-0017, BMI-0028, BMI-0019, BME-0049, BMI-0003, BMI-0004, BMI-0038, BMI-0026, BMI-0029
		ii	06	BMI-0006, BMI-0043, BMI-0010, BMI-0025, BMI-0045, BMI-0014
		iii	07	BMI-0039, BME-0051, BME-0015, BME-0050, BMI-0061, BME-0015, BME-0013, BMI-0055
		iv	03	BMI0023, BMI-0054, BMI-0021
2	II	i	15	BMI-0036, BMI-0057, BMI-0024, BMI-0037, BMI-0042, BMI-0027, BMI-0031, BME-0030, BMI-0041, BMI-0032, BMI-0034, BMI-0011, BMI-0033, BMI-0008, BMI-0016
		ii	03	BMI-0058, BMI-0059, BMI-0060
		iii	08	BMI-0064, BMI-0070, BMI-0067, BMI-0068, BMI-0066, BMI-0069, BMI-0071, BMI-0072

ISSN 2348 – 7968

Figure 1: Dendrogram obtained from cluster analysis of average estimates of economic traits (between groups)



REFERENCES

Anonymous (1997) Principles and techniques of silkworm breeding. ESCAP, Oxford & IBH Publishing Co. Pvt. Ltd., United Nations, New York, pp. 114

Arunachalam, S., Bandyopadhy, S.N., Nigam, R. W. and Gibbons (1984) Heterosis in relation to genetic divergence and specific combining ability in groundnut (Arachis hypgaea). Euphytica, 33, 33-39.

Chatterjee, S.N. and Mohandas, T.P. (2003) Identification of ISSR markers associated with productivity traits in silkworm Bombyx mori L. Genome, 46 (3), 438-447.

Chatterjee, S.N., Ramamohana Rao, P., Ravindra Singh and Datta, R.K. (1993) Genetic variability in mulberry silkworm Bombyx mori L. breeds with low silk yield. Indian J. Seric. 32, 69- 86.

Dalton, D.C. (1987) An introduction to practical animal breeding. Second Edition, English Language Book Society/Collins, pp. 182.

Datta, R. K., Basavaraja, H. K. and Mano, Y. (1996) In: Manual on rearing, race maintenance and multiplication, CSR&TI, Mysore, India, pp.1-25.

Frankel, O.H. and Brown, A.H.D. (1983) Current plant genetic resources a critical appraisal. In:

Genetics: New Frontiers, Volume IV Applied Genetics, Proceedings XV International Congress of Genetics, New Delhi,

V.L. Chopra, B.C. Joshi, R.P. Sharma and H.C. Bansal, eds.) (New Delhi:Oxford and IBH Publishing Co) pp: 3-13.

Jolly, M.S., Datta, R.K., Noamani, M.K.R., Iyengar,M.N.S., Nagaraj, C.S., Basavaraj, H.K., Kshamarani, G. and Ramamohana Rao, P. (1989)Studies on the genetic divergence in mulberry silkworm Bombyx mori L. Sericologia, 29, 545-559.

Krishnaswamy, S. (1978) new technology of silkworm rearing. CSR&TI., Central Silk Board, Mysore, India, Bullettin No. 2.

Kumaresan, P., Sinha, R.K., Sahni, N.K. and Sekar, S. (2000) Genetic variability and selection indices for economic quantitative traits of multivoltine mulberry silkworm (Bombyx mori L.) genotypes. Sericologia, 40, 595-605.

Kumaresan, P. and Sinha, R.K. (2002) Genetic divergence in multivoltine silkworm germplasm in Relation to cocoon characters. Indian J. Genet. 62,183-184.

Kumaresan, P., Sinha, R.K. and Thangavelu, K. (2003) Heterosis studies in some elite multivoltine

silkworm (Bombyx mori L.) races with popular bivoltine NB4D2. Int. J. Indust. Entomol. 7, 221-229.

Kumaresan, P., Mahadevamurthy, T.S., Thangavelu, K. and Sinha, R.K. (2003a) Further studies on thegenetic divergence of multivoltine silkworm(Bombyx mori L.) genotypes based on economic characters. Entomon, 28, 193-198.

Kumaresan, P., Sinha, R.K., Mohan, B. and Thangavelu, K. (2004) Conservation of multivoltine Silkworm (Bombyx mori L.) germplasm in India- An Overview. Int. J. Indust. Entomol. 9, 1-13.

Kumaresan, P., Sinha, R.K. and Thangavelu, K.(2005) Phenotypic stability and G _ E inter action in cocoon weight of multivoltine silkworm(Bombyx mori L.) genotypes. Indian J. Seric. 44, 136-138.

Murakami, A. (1994) Growth phenomena in Bombyxmori L. with a special reference to genetic factorsresponsible for growth accelerationand moultinism. Indian J. Seric. 33, 12-14.

Mukherjee, P., Mukherjee, S. and Kumaresan, P.(1999) An analysis of genetic divergence in Indian multivoltine silkworm (Bombyx mori L.) germplasm. Sericologia, 39, 337-347.

Narasimharaju, R., Govindan, R., Ashoka, J., Rayar,S.G. (1990) Genetic variability for quantitative traits in silkworm B. mori. Entomon, 15, 197-201.

Ramamohana Rao, P. and Nakada, T. (1998) Clustering of polyvoltine strains of the silkworm B. mori by image processing method: Significanceof cocoon size and weight variables. Indian J.Seric. 37, 33-39.