IDENTIFICATION OF MULTIVOLTINE BREEDS AND MULTIVOLTINE × BIVOLTINE HYBRIDS OF THE SILKWORM, *BOMBYX MORI* L. THROUGH SUBORDINATE FUNCTION INDEX METHOD

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ABSTRACT: A study was conducted for the identification of multivoltine breeds and multivoltine × bivoltine hybrids of the mulberry silkworm, *Bombyx mori* L. utilizing subordinate function indices method of Gower (1971). Out of four multivoltine breeds, DNP_1 ranked first exhibiting maximum cumulative subordinate function indices value of 9.36 for eleven characters followed by DNP_3 which exhibited higher cumulative subordinate function indices value of 9.07. Among seventeen multivoltine × bivoltine hybrids, $DNP_1 \times CSR_2$ ranked first exhibiting maximum cumulative subordinate function indices values of 8.03 followed by $DNP_1 \times CSR_{17}$ exhibiting cumulative subordinate function indices values of 7.68. Besides, seven multivoltine × bivoltine hybrids *viz*., $DNP_3 \times CSR_{17}$, $DNP_2 \times CSR_{17}$, $DNP_3 \times CSR_2$, $DNP_2 \times NB_4D_2$, $DNP_2 \times CSR_2$, $DNP_1 \times NB_4D_2$ and $DNP_2 \times CSR_4$ were also found promising which exhibited cumulative subordinate function indices values of 6.73, 6.63, 6.58, 6.53, 6.31, 6.24 and 6.11, respectively. Application of subordinate function indices method for the identification of silkworm breeds and hybrids has been discussed.

KEY WORDS: *Bombyx mori,* performance, multivoltine × bivoltine hybrids, silkworm breeds, subordinate function indices.

Several statistical methods like analysis of combining ability (Kempthorne, 1957), subordinate function index method (Gower, 1971), Duncan's multiple range test (Gomez & Gomez, 1984), evaluation index method (Mano et al., 1993) have been employed for the identification of promising silkworm breeds and hybrids. Silkworm breeds and hybrids are judged on the basis of cumulative effect of several economic characters (Narayanaswamy et al., 2002). In the mulberry silkworm, *Bombyx mori* L., subordinate function index method of Gower (1971) has been employed for the identification of promising silkworm hybrids (Ramesh Babu et al., 2002; Rao et al., 2001, 2004, 2006; Lakshmi & Chandrashekharaiah, 2007; Nirupama et al., 2008). Recently, studies have been carried out on short-listing of silkworm breeds and hybrids (Ravindra Singh & Nirupama, 2012; Ravindra Singh & Gangopadhyay, 2013). In the present study, an attempt was made to identify promising polyvoltine breeds developed utilizing parthenogenesis coupled with conventional breeding techniques and multivoltine × bivoltine hybrids through subordinate function index method.

MATERIALS AND METHODS

In the present study, four multivoltine breeds *viz*., DNP_1, DNP_2, DNP_3 and DNP_4 and Pure Mysore (PM) and seventeen multivoltine × bivoltine hybrids were prepared utilizing four bivoltine breeds *viz*., CSR_2, CSR_4, CSR_{17} and NB_4D_2. Three replications were reared in each hybrid and 250 larvae were retained after IIIrd moult. The performance of multivoltine breeds is presented in Table 1. Data were recorded for eleven characters *viz,* fecundity, hatching percentage, pupation percentage, cocoon yield/10,000 larvae by weight, cocoon weight, cocoon shell weight, cocoon shell percentage, filament length, reelability, raw silk percentage and neatness. Data were analyzed through subordinate function index method (Gower, 1971). Subordinate function index method is used to shortlist breeds / hybrids showing a character with a small range of variation contribute as much as another character with a large variation range. In ranging the smallest value for the character is subtracted from each value and the results are divided by range. The subordinate function is calculated by utilizing the following formula –

Xu = (Xi - Xmin) / (Xmax - Xmin)
Where,
Xu = Sub ordinate function,
Xi = Measurement of trait of tested breed,
Xmin =Minimum value of the trait among all the tested breeds,
Xmax =Maximum value of the trait among all the tested breeds.

RESULTS

Data presented in Table 1 showed variation for various characters among the different multivoltine breeds. Two breeds DNP_1 and DNP_3 recorded higher values for six and three out of eleven characters respectively. Subordinate function index values in multivoltine breeds for eleven characters are given in Table 2. DNP_1 and DNP_3 showed their superiority by exhibiting cumulative subordinate function index value of 9.36 and 9.07 respectively. Mean rearing performance of seventeen multivoltine × bivoltine hybrids is given in Table 3. Two hybrids namely, DNP_1 × CSR_2 and DNP_3 × CSR_{17} exhibited maximum performance for four and three characters respectively. As per the subordinate function index method, DNP_1 ranked first exhibiting maximum cumulative subordinate function indices value of 9.36 for eleven characters followed by DNP_3 which exhibited higher cumulative subordinate function indices value of 9.07. Among seventeen multivoltine × bivoltine hybrids, DNP_1 × CSR_2 ranked first exhibiting maximum cumulative subordinate function indices values of 8.03 followed by DNP_1 × CSR_{17} exhibiting cumulative subordinate function indices values of 7.68. In addition, seven multivoltine × bivoltine hybrids *viz.*, DNP_3 × CSR_{17}, DNP_2 × CSR_{17}, DNP_3 × CSR_2, DNP_2 × NB_4D_2, DNP_2 × CSR_2, DNP_1 × NB_4D_2 and DNP_2 × CSR_4 were also found promising which exhibited cumulative subordinate function indices values of 6.73, 6.63, 6.58, 6.53, 6.31, 6.24 and 6.11, respectively.

DISCUSSION

Analysis of data indicated superiority of the hybrid DNP_1 × CSR_2 exhibiting maximum performance for four economic characters followed by DNP_3 × CSR_{17} exhibiting maximum performance for three characters. No single hybrid excelled in all the eleven characters under study. Therefore, it is necessary to adopt reliable statistical method to identify promising breeds / hybrids which give weight-age to all the economic characters. In this direction, efforts have been made to identify promising silkworm hybrids utilizing subordinate function index method (Ramesh Babu et al., 2002; Rao et al., 2001, 2004, 2006; Lakshmi & Chandrashekharaiah, 2007; Nirupama et al., 2008).

It was interesting to note that eight out of seventeen multivoltine × bivoltine hybrids recorded significant increase for five characters namely, pupation percentage (>95%), cocoon weight(>1.900 g), cocoon shell weight (>0.370 g), filament length (>850 m) and neatness (90 - 91 p). In the present study, the indices obtained from subordinate function index method were worked out both for multivoltine silkworm breeds and multivoltine × bivoltine hybrids. The results demonstrated the superiority of two breeds DNP_1 and DNP_3 among four breeds and two hybrids DNP_1 × CSR_2 and DNP_1 × CSR_{17} which excelled among seventeen hybrids. The hybrids exhibited high subordinate cumulative index values (8.03 and 7.68). In view of the results obtained, DNP_1 and DNP_3 can be further utilized in future breeding programmes for the development of outstanding multivoltine breeds and two promising multivoltine × bivoltine hybrids DNP_1 × CSR_2 and DNP_1 × CSR_{17} may be recommended for commercial exploitation.

LITERATURE CITED

Gomez, K. A. & Gomez, A. A. 1984. Statistical Procedure for Agricultural Research (2nd Edn.). John Willey and Sons, New York.

Gower, J. C. 1971. A general co-efficient of similarity and some of its properties. Biometrics, 27: 857-871.

Kempthorne, O. 1957. An introduction to genetics Statistics, John Willey and Sons, Inc. New York, Inc. London, Chapman and Hall Ltd. Pp. 208-341.

Lakshmi, H. & Chandrashekharaiah 2007. Identification of breeding resource material for the development of thermo-tolerant breeds of silkworm, *Bombyx mori* L. J. Exp. Zool. India, 10: 55-63.

Mano, Y., Nirmal Kumar, S., Basavaraja, H. K., Mal Reddy, N. & Datta, R. K. 1993. A new method to select promising silkworm breeds/ combination. Indian Silk, 31: 53.

Narayanaswamy, T. K., Govindan, R. & Ananthanarayana, S. R. 2002. Selection of multivoltine × bivoltine cross breeds of the silkworm, *Bombyx mori* L. through evaluation indices. Indian J. Seric., 41: 176-178.

Nirupama, R., Ravindra Singh & Gangopadhyay, D. 2008. Identification of promising multivoltine × bivoltine hybrids of the silkworm, *Bombyx mori* L. Entomon, 33 (2): 147-150.

Ramesh Babu, M., Chandrashekharaiah, Lakshmi, H. & Prasad, J. 2002. Multiple traits evaluation of bivoltine hybrids of the silkwotm, *Bombyx mori* L. Internat. J. Indust. Entomol., 5: 37-44.

Rao, C. G. P., Chandrashekharaiah, Ramesh, C, Ibrahim, B. K., Seshagiri, S. V. & Nagaraju, H. 2004. Evaluation of polyvoltine hybrids based on silk productivity in silkworm, *Bombyx mori* L. Int. J. Indust. Entomol., 8 (2): 181-187.

Rao, C. G. P., Seshagiri, S. V., Ramesh, C. Basha, K., Ibrahim, H, Nagaraju, H. & Chandrashekharaiah 2006. Evaluation of genetic potential of the polyvoltine silkworm (*Bombyx mori* L.) germplasm and identification of breeding programme. J. Zhejiang Univ. Sci., 7: 215-220.

Rao, P. S., Ravindra Singh, Kalpana, G. V., Naik, V. N., Basavaraja, H. K., Rama Swamy, G. N. & Datta, R. K. 2001. Evaluation and Identification of Promising Bivoltine Hybrids of Silkworm, *Bombyx mori* L., for Tropics. Int. J. Indust. Entomol., 3 (1): 31-35.

Ravindra Singh & Gangopadhyay, D. 2013. Identification of bivoltine breeds and hybrids of the mulberry silkworm, *Bombyx mori* L. Mun. Ent. Zool., 8 (1): 203-207.

Ravindra Singh & Nirupama , R. 2012. Short listing of breeds and hybrids of the silkworm, *Bombyx mori* L. Mun. Ent. Zool., 7 (2): 978-982.

Table 1. Performance of multivoltine breeding lines of the silkworm, *Bombyx mori* L..

Breeds	Fecundity (no)	Hatching (%)	Pupation rate (%)	Cocoon yield/10,000 larvae (kg)	Cocoon wt. (g)	Cocoon shell wt. (g)	Cocoon shell (%)	Filament length (m)	Reelability (%)	Raw silk (%)	Neatness (p)
DNP_1	450	91.73	92.56	12.516	1.349	0.225	16.71	573	79.3	12.38	89
DNP_2	470	87.83	81.78	10.742	1.328	0.214	16.11	546	74.6	12.29	86
DNP_3	484	91.45	91.94	12.504	1.368	0.219	16.01	556	83.2	12.21	89
DNP_4	451	91.85	83.27	9.322	1.249	0.199	15.93	516	74.5	11.89	89
Max	**484**	**91.85**	**92.56**	**12.516**	**1.368**	**0.225**	**16.71**	**573**	**83.2**	**12.38**	**89**
Min	**450**	**87.83**	**81.78**	**9.322**	**1.249**	**0.199**	**15.93**	**516**	**74.5**	**11.89**	**86**
Mean	**464**	**90.72**	**87.39**	**11.271**	**1.324**	**0.214**	**16.19**	**548**	**77.9**	**12.19**	**88**
SD	**16.34**	**1.93**	**5.65**	**1.54**	**0.05**	**0.01**	**0.35**	**23.92**	**4.18**	**0.21**	**1.50**

Table 2. Subordinate index value of multivoltine breeding lines of the silkworm, *Bombyx mori* L..

Breeds	Fecundity	Hatching	Pupation rate	Yield/10,000 larvae	Cocoon wt.	Cocoon shell wt.	Cocoon shell (%)	Filament length	Reelability	Raw silk (%)	Neatness	Cumulative subordinate index value
DNP_1	0.00	0.97	1.00	1.00	0.84	1.00	1.00	1.00	0.55	1.00	1.00	9.36
DNP_2	0.59	0.00	0.00	0.44	0.66	0.58	0.23	0.53	0.01	0.82	0.00	3.86
DNP_3	1.00	0.90	0.94	1.00	1.00	0.77	0.10	0.70	1.00	0.65	1.00	9.07
DNP_4	0.03	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	2.17

Table 3. Performance of multivoltine × bivoltine hybrids of the silkworm, *Bombyx mori* L..

Multivoltine × bivoltine Hybrids	Fecundity (no)	Hatching (%)	Pupation rate (%)	Yield/10,000 larvae (kg)	Cocoon wt. (g)	Cocoon shell wt. (g)	Cocoon shell (%)	Filament length (m)	Reelability (%)	Raw silk (%)	Neatness (p)
$DNP_1 \times CSR_2$	457	94.63	95.50	18.193	1.950	0.402	20.62	878	83.0	15.99	91
$DNP_1 \times CSR_4$	485	92.15	94.60	17.420	1.883	0.371	19.70	854	72.7	14.59	89
$DNP_1 \times CSR_{27}$	455	93.91	96.20	19.360	1.936	0.396	20.45	927	83.8	15.12	90
$DNP_1 \times NB_4D_2$	478	94.51	97.80	17.560	1.831	0.362	19.77	854	81.0	14.54	91
$DNP_2 \times CSR_2$	566	95.25	86.20	16.300	2.059	0.384	18.63	914	82.1	14.42	91
$DNP_2 \times CSR_4$	509	93.76	94.40	17.372	1.900	0.369	19.42	885	84.2	14.45	90
$DNP_2 \times CSR_{27}$	551	94.25	93.50	18.570	1.965	0.376	19.14	998	83.1	13.73	89
$DNP_2 \times NB_4D_2$	492	94.33	89.80	17.529	1.985	0.391	19.70	933	82.8	15.48	89
$DNP_3 \times CSR_2$	434	94.20	95.20	18.817	1.994	0.389	19.49	916	83.0	14.09	90
$DNP_3 \times CSR_4$	461	93.73	96.80	18.360	1.946	0.372	19.12	823	80.9	13.83	90
$DNP_3 \times CSR_{27}$	548	91.72	97.20	19.920	2.135	0.385	18.02	862	85.5	13.75	90
$DNP_3 \times NB_4D_2$	474	92.98	93.60	18.220	1.935	0.369	19.07	798	82.7	14.17	89
$DNP_4 \times CSR_2$	474	97.42	87.60	16.440	1.798	0.366	20.37	896	81.1	14.77	89
$DNP_4 \times CSR_4$	389	97.03	92.80	16.960	1.808	0.368	20.37	868	81.7	15.10	89
$DNP_4 \times CSR_{27}$	425	96.24	96.80	16.580	1.800	0.343	19.04	854	75.5	13.77	88
$DNP_4 \times NB_4D_2$	424	93.90	98.20	15.640	1.719	0.318	18.50	802	80.5	13.89	88
$PM \times CSR_2$	528	92.89	91.07	16.437	1.872	0.399	18.11	807	81.0	13.42	88
Max	**566**	**97.42**	**98.20**	**19.920**	**2.135**	**0.402**	**20.62**	**998**	**85.5**	**15.99**	**91**
Min	**389**	**91.72**	**86.20**	**15.640**	**1.719**	**0.318**	**18.02**	**798**	**72.7**	**13.42**	**88**
Mean	**479**	**94.29**	**93.96**	**17.628**	**1.913**	**0.374**	**19.38**	**875**	**81.4**	**14.42**	**89**
SD	**49.07**	**1.54**	**3.51**	**1.17**	**0.10**	**0.02**	**0.02**	**53.08**	**3.11**	**0.70**	**1.01**

Table 4. Subordinate index value of multivoltine × bivoltine hybrids of the silkworm, *Bombyx mori* L..

Multivoltine × bivoltine hybrids	Fecundity	Hatching	Pupation rate	Yield/10,000 larvae	Cocoon wt.	Cocoon shell wt.	Cocoon shell	Filament length	Reelability	Raw silk	Neatness	Cumulative subordinate index value
$DNP_1 \times CSR_2$	0.38	0.51	0.78	0.60	0.56	1.00	1.00	0.40	0.80	1.00	1.00	8.03
$DNP_1 \times CSR_4$	0.54	0.08	0.70	0.42	0.39	0.63	0.65	0.28	0.00	0.46	0.33	4.47
$DNP_1 \times CSR_{27}$	0.37	0.38	0.83	0.87	0.52	0.93	0.93	0.65	0.87	0.66	0.67	7.68
$DNP_1 \times NB_4D_2$	0.50	0.49	0.97	0.45	0.27	0.52	0.67	0.28	0.65	0.44	1.00	6.24
$DNP_2 \times CSR_2$	1.00	0.62	0.00	0.15	0.82	0.79	0.23	0.58	0.73	0.39	1.00	6.31
$DNP_2 \times CSR_4$	0.68	0.36	0.68	0.40	0.44	0.61	0.54	0.44	0.90	0.40	0.67	6.11
$DNP_2 \times CSR_{27}$	0.92	0.44	0.61	0.68	0.59	0.69	0.43	1.00	0.81	0.12	0.33	6.63
$DNP_2 \times NB_4D_2$	0.58	0.46	0.30	0.44	0.64	0.87	0.65	0.68	0.79	0.80	0.33	6.53
$DNP_3 \times CSR_2$	0.25	0.44	0.75	0.74	0.66	0.85	0.57	0.59	0.80	0.26	0.67	6.58
$DNP_3 \times CSR_4$	0.41	0.35	0.88	0.64	0.55	0.64	0.42	0.13	0.64	0.16	0.67	5.48
$DNP_3 \times CSR_{27}$	0.90	0.00	0.92	1.00	1.00	0.80	0.00	0.32	1.00	0.13	0.67	6.73
$DNP_3 \times NB_4D_2$	0.48	0.22	0.62	0.60	0.52	0.61	0.40	0.00	0.78	0.29	0.33	4.86
$DNP_4 \times CSR_2$	0.48	1.00	0.12	0.19	0.19	0.57	0.90	0.49	0.66	0.53	0.33	5.45
$DNP_4 \times CSR_4$	0.00	0.93	0.55	0.31	0.21	0.60	0.90	0.35	0.70	0.65	0.33	5.54
$DNP_4 \times CSR_{27}$	0.20	0.79	0.88	0.22	0.19	0.30	0.39	0.28	0.22	0.14	0.00	3.62
$DNP_4 \times NB_4D_2$	0.20	0.38	1.00	0.00	0.00	0.00	0.18	0.02	0.61	0.18	0.00	2.58
$PM \times CSR_2$	0.79	0.21	0.41	0.19	0.37	0.96	0.03	0.05	0.65	0.00	0.00	3.64