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Analysis of Quantitative Characters in Selected Multivoltine Races and Biovoltine Races/Breed of Silkworm *Bombyx Mori* (Linn.) And Their Hybrids in Different Seasons of the Year.

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ABSTRACT: *Realizing the importance of tropical environment for the production of quality silk, this study was undertaken to understand the impact of different seasons on mulberry crop and cocoon production. The quantitative characters studied in six multivoltine breeds, pre, npnd, C.nichi, PM and Daizo and four bivoltine breeds, C_{108}, KA, NB_4D_2 are bivoltine races and CSR_2 is an evolved bivoltine breed along with the eight hybrids, PM x C_{108}, PM x KA, PM x NB_4D_2, PM x CSR_2, C_{108} x PM, KA x PM, NB_4D_2 x PM and CSR_2 x PM, expressed differential expression in all the three seasons viz., pre-monsoon, monsoon and post-monsoon of the year for the traits studied, proved environment along with genetic makeup plays an important role in the manifestation of commercial characters.*

KEYWORDS: ***Silkworm, Bombyx mori, multivoltine, bivoltine, race, breeds, hybrids, commercial characters, triats, seasons.***

INTRODUCTION: It is noteworthy that *Bombyx mori*, a silk moth of great economic value is extensively being used for the production of commercial silk in many countries since, this fiber is in association with human culture for the past 4000 years. Sericulture is one of the important commercial crops in our country and hence India occupies second prominent position in the global silk production next to China (Datta, 1994). Realizing the importance of tropical environment for the production of quality silk, several studies were undertaken to understand the impact of different seasons on mulberry crop and cocoon production (Narayanan *et al.*, 1964; Kasivishwanathan *et al.*, 1970). It is important to note that the

introduction of promising bivoltine races during 1970-2000 has resulted in the increase of silk production by many folds (Datta, 2000). The rearing of bivoltines has clearly indicated that they failed to display uniform crop performance in the unfavorable environmental conditions of our country compared to multivoltine and multivoltine x bivoltine hybrids (Kalpana, 1992). As a result multivoltine races and their hybrids are always preferred by the rearers than bivoltine and bivoltine hybrids. The genotype of silkworm races which are selected for experiment related hybridization or for any basic experiment needs to be systemically reared and evaluated in known environmental conditions to understand the expression of economic traits (Tazima, 2001). Such an analysis of variable performance of both multivoltine and bivoltine races/breeds in different environments of our country have been demonstrated by many silkworm breeders (Sidhu *et al.*, 1968; Narasimhanna, 1976; Kalpana *et al.*, 1998; Nirmal Kumar *et al.*, 1999 and 2002; Datta *et al.*, 2001; Basavaraja *et al.*, 2005; Rohith L. Shankar *et al.*, 2008). The studies have clearly demonstrated the influence of environmental factors on the expression of economic traits irrespective of the silkworm races and breeds (Umashankara and Subramanya, 2002). Although the above studies are conducted utilising selected quantitative traits only in a known environmental condition yet, a comparative analysis of the selected multivoltine races along with the bivoltine races/ breed are very limited (Sengupta, 1969; Umashankara and Subramanya, 2001). Keeping these in view seasonal performances of silkworm races utilizing two temperate multivoltine races, two tropical multivoltine races and four bivoltine races/breed and eight hybrids has been carried out. The above races/breed, were reared in three different seasons of the year in order to understand how a particular environment may be most favorable than the others for expression of twelve economic traits and the data obtained is presented and discussed.

MATERIALS AND METHODS: The four multivoltine races and four bivoltine races/breed and eight hybrids were selected for the present investigation. The multivoltine races are *pre* (precocity), *npnd* (non pigmented non diapause), C.nichi and Pure Mysore (hence denoted as PM) (Plate.1). Among bivoltines C_{108}, Kalimpong-A, (hence forth denoted as KA) NB_4D_2 are bivoltine races and CSR_2

is an evolved bivoltine breed (Plate. 2). The eight hybrids utilized in the experiment are PM x C_{108}, PM x KA, PM x NB_4D_2, PM x CSR_2, C_{108} x PM, KA x PM, NB_4D_2 x PM and CSR_2 x PM. The description of characteristic features of the six multivoltine races and four bivoltine races/breed are presented in Table-1.

I. Breeding materials: All these two voltine groups are drawn from the germplasm bank of the Department of Studies in Sericulture Science, Manasagasngothri, Mysuru. Eight hybrid combinations mentioned above were prepared following the standard procedure of Gamo (1976) and Yokoyama (1979) reared in three replicates conducting cellular rearings, feeding quality M_5 mulberry leaves. The rearing was conducted in three different periods of the year namely pre-monsoon, monsoon, and post-monsoon season. Thirteen important economic traits are evaluated during rearing namely fecundity, hatching percentage, larval weight, larval duration, yield by number, yield by weight, cocoon weight, shell weight, shell percentage, pupation rate, length of the filament, denier and renditta.

II. Grainage and Rearing Methodology: The races/breeds/hybrids were thoroughly evaluated during egg stage, larval stage, pupa/cocoon stage and moth stage for their overall health and performances by following standard rearing techniques of Krishnaswamy and Narasimhana (1974). The selected healthy male and female moths are allowed to mate for definite period and separated. Female moths were allowed for oviposition on the egg sheet to produce disease free layings (DFL's). The eggs prepared kept for incubation after acid treatment to break diapauses/hibernation. The hybrid combinations was prepared based on the performances of parental race selected for the study. Hence the most hardy and resistance local variety PM, which is well acclimatized for local environmental conditions, is crossed to all BV's to prepare eight hybrid combinations. PM females are used for four regular crosses and PM males were used in four reciprocal crosses. The hatched larvae of *Bombyx mori* from the eggs are selected and kept in rearing tray for further development. Cellular rearing in each replicates of three each was conducted by fixing the base number of 300 larvae after 3 moult. Thus cocoons produced at the end of larval duration were selected based on visual observation on the basis of their colour,

size and shape rejecting flossy, flimsy and deformed cocoons. The individual cocoon characters were recorded. The pupas inside the cocoons were also examined for their health and racial characters by removing them by cut opening the few selected cocoons.

III. Statistical methods: The analysis of variance (ANOVA) was estimated following the methodology described by Snedecor and Cochran (1967). The data obtained on the seasonal performance of the multivoltine, bivoltine and hybrids was analyzed by employing the statistics SPSS 20.0 packages.

RESULTS AND DISCUSSION: The mean values of each of the thirteen economic traits of four multivoltine races, four bivoltine races/breed selected both from temperate and tropical belt selected based on important economic traits observed and evaluated during four stages of the life cycle *viz*., egg, larva, pupa and adult, along with eight hybrids. 'F' values obtained by ANOVA, the difference in regard to the expression of quantitative traits among pure races and hybrids for all the thirteen economic traits namely fecundity, hatching percentage, larval weight, larval duration, yield by number, yield by weight, cocoon weight, shell weight, shell ratio, filament length, pupation rate, denier and renditta during three periods are presented in Tables 2, Table 3, Table 4 for pre-monsoon, monsoon and post-monsoon respectively and their average mean is represented in the table-5.

A close scrutiny of the data in regard to the pre-monsoon season (Table-2), all the multivoltine (MV) races shown uniformity in all the traits studied is attributed to the their genetic constitutions manifested to suit the tropical conditions over the generations. The traits hatching %, cocoon yield by No. and pupation rate were recorded higher values in MV than Bivoltine (BV) and Hybrids. Larval duration is one of the most influential characters of sericulture industry in terms of economy is more in PM (540 hrs) among MV and on par with other races/hybrids. Race pre (18 days), npnd (20 days) and C.nichi (20 days) was true to their racial characters. Among BV there was an uniform expression for all the traits in C_{108}, KA and NB_4D_2, but CSR_2 breed exhibited superiority for all the traits than other races, except for hatching % (94.67) and pupation rate (82.47). The economic traits like Cocoon weight, shell weight and shell ratio was more in BV's. Renditta

(7.32) was very high in CSR_2 over all the MV races (14.85 to 17.28), remaining three BV races (8.54 to 8.85) and eight hybrids (ranging from 9.19 to 12.37). The 'F' value is significant for all the traits of pre-monsoon season except for shell weight.

The most favorable season in tropical condition is monsoon, where climatic conditions are suitable for all agricultural activities including sericulture revealed better yield in all MV, BV and Hybrids. The data in Table-3, reveled all the four MV's were good in hatching % (>95%) and pupation rate (>95%). Cocoon yield by No/10,000 was more than 96%. As usual the renditta was very poor. The four BV's exhibited good performances for all the traits except the cocoon yield by No. (8865.67 to 9064.67) and pupation rate (85.67 to 90.00). The denier is more than two (>2) in all BV's and the renditta is superior (6.67 in CSR_2 to 8.23 in KA). The CSR_2 breed is found to be superior for all the traits. On the other hand the hybrids studied were found to exhibit moderate values for all the traits, except cross PM x CSR2, which was found to be superior over both MV and BV races. But the trait fecundity (414.67) and renditta (99.19) is inferior to BV but more than MV's. The reciprocal cross CSR_2 x PM was also found to be good for most of the traits studied compared to other hybrid and MV races. The highest value for cocoon yield by No. (9673.00) is recorded in KA x PM during pre-monsoon seasons and the renditta of 7.32 in CSR_2. The lowest value for renditta is in PM x C_{108} (12.37) and PM x KA (12.19) but still better compared to MV the hybrids of both regular crosses and reciprocal crosses were found to be exhibit moderate values for the traits studies with few exceptions like (PM x CSR_2) and (CSR_2 x PM) where they performed better for most of the traits including renditta except for fecundity (456.00 in PM x CSR_2) and filament length (845.33 and 848.00 in PM x CSR_2 and CSR_2 x PM respectively). The 'F' value was found to be significant for all the traits.

The Table-4, shows the data on the post- monsoon season, in which all the MV races were exhibited longer larval duration (451.18hrs in *pre* to 622.06hrs in PM) than pre-monsoon (Table-2) and monsoon (Table-3). The other characters were registered better values than pre-monsoon and slightly less than monsoon season. Hatching %, cocoon yield by No., and pupation rate were high. The highest fecundity was recorded in the BV breed

CSR_2 (597). Once again the cocoon characters of BV races registered high value as like monsoon season than both MV and Hybrids. The interesting factor in hybrids was PM x CSR_2 and CSR_2 x PM were shown higher values for all the traits studied including renditta except fecundity of 9166.00 (PM x KA) to 9778(NB_4D_2 x PM). The effective rate of rearing (ERR%) or pupation rate was very good over BV races/breed ranging from 85.15 (PM x C_{108}) to 94.73 (PM x CSR_2), shell % was high in both KA x PM and NB_4D_2 x PM (20.66 and 20.37 respectively). The 'F' values were found to ne significant for all the traits studied in post monsoon season.

Considering the performance of four multivoltines and bivoltine in three seasons it is important that there is variable effect of three periods on fecundity (Hassanein and Sharawy 1962a). It is observed that monsoon and post-monsoon season produced considerable impact on the differential performances (Umashankara and Subramanya, 2001). A similar trend was observed from the mean results (Table-5) for the trait hatchability in all the seasons. The present results in regard to the differences in the larval duration among different multivoltine races will be ascribed to the "*lme*" genes (late maturity gene) as revealed by Tazima (1988). On the other hand Murakami (1988) utilizing a multivoltine *Cambodge* race demonstrated that reduction in the larval duration in any race may be due to the role played by the genes present on the 'X' chromosome ('Z' chromosome). Similar to multivoltine races, the four bivoltine races have also recorded reduction and prolongation of larval duration in their hybrids (Rohith and Subbramanya 2010a, 2010b, 2010c and 2010d), such differential performance in various races in three different seasons of the year for this trait has been reported in different bivoltine races. The Japanese breeders (Gamo and Shimazaki, 1967; Gamo, 1976) reported that in the winter seasons of temperate climatic conditions there is always a prolongation in the larval period in BV's, as evident in the result (Table-5). Data pertaining to the weight of V^{th} instar exhibited highest weight in all the seasons whereas the *pre* race recorded the lowest larval weight. Similarly, among the four bivoltine races/breed the CSR_2 recorded highest larval weight which is superior to all the three bivoltines. Significant variation observed among the races both in multivoltine, bivoltine races/breed and hybrids could be ascribed

to the environmental conditions for the expression of this under study (Ohi *et al.*, 1970; Petkov *et al*., 1984). Further, in tropical breeds of India recorded higher larval weight in the bivoltine races during monsoon period (Narasimhanna,1976; Mallik *et al*., 2006). The trait yield by number in all the hybrids recorded high value than multivoltine and bivoltine pure races proved the hybrids superiority for the same in the monsoon season, it is similar to the observations of Krishnaswami and Tikoo (1971). Further, Subramanya (1985), demonstrated that different regional ecoraces of PM revealed highest ERR during monsoon season compared to other multivoltine races. The yield of cocoon by weight per 10,000 larvae brushed revealed highly significant ($P<0.05$) differences among multivoltine races and hybrids, where as all the bivoltine races exhibited a general trend of insignificant results ($P>0.05$) (Tables-2, -3 and -4). It is noteworthy that the bivoltine breed CSR_2 exhibited superiority for this trait in all the three seasons compared to C_{108}, NB_4D_2 and KA (Basavaraja *et al*., 1995). The data pertaining to the trait cocoon weight, shell weight and shell percentage are generally considered as cocoon traits (Rayar, 2009; Sidhu *et al*.,1969b), recorded differential performance in different multivoltine races that corroborated it to the genetic plasticity of the multivoltine races to the changing environmental conditions and that's been manifested in the hybrids when they are crossed to bivoltine races (Table -5). Contrary to the above Gamo *et al*., (1976), demonstrated that increase in the pupal weight and decrease in the shell weight during winter seasons. The superior performance of the CSR_2 breed for cocoon traits in three different seasons is recorded, that is similar to the findings of Basavaraja *et al.*, (1995), Kamble (1998) and Krishnaprasad (2003). The values obtained for the filament length corroborates with the detail investigations of Murakami and Ohtsuki (1989) who have indicated the lowest filament length for *pre* and *npnd* (Rohith and Subbramanya, 2010a, 2010b, 2010c and 2010d) compared to the Cambodge race. Supporting the above findings in regard to the filament length in Pure Mysore race Narasimhanna (1976), Subramanya (1985) demonstrated that PM as multivoltine is also known for the higher production of cocoons (ERR) with lower filament length. The yield of cocoon by weight per 10,000 larvae brushed revealed highly significant ($P<0.05$)

differences among multivoltine races and hybrids, where as all the bivoltine races exhibited a general trend of insignificant results (P>0.05) (Tables-2, -3 and -4). Ullal and Narasimhanna (1978) have demonstrated the superiority of the NB_4D_2 series compared to KA in P_4 and P_3 forms of Karnataka. But, a close scrutiny on the performance of CSR_2 breed shows that, it has excelled all the other three races there by ranking first for this trait and tallies with the findings of Basavaraja *et al*., (1995), Datta (1999) and Nirmal Kumar *et al*., (1999). It is evident that Pure Mysore along with *pre* and *npnd* recorded highest pupation rate in all the three seasons of the year, Supporting the findings of Sidhu *et al*., 1968; Narasimhanna, 1976; Subramanya, 1985 and Chandrashekaraiah, 1992. Further, the superior performance of NB_4D_2 and KA races in three seasons was shown by Narasimhanna (1976). In view of the differential performance of each of the races/breed it can be said that they are genetically distinct. The hybrids were found to exhibit uniform values respectively in all the three seasons reared. Denier is one of the important post cocoon traits was fine in MV'S and moderate in BV's and hybrids (Hassanein and Sharawy 1962b). Renditta is one of the important traits which denote production of number of kilograms of cocoons required to produce one kg of raw silk. It is considered as an important parameter to judge the superiority of a race/breed. In order to observe high production of raw silk generally lower renditta is preferred (Yokoyama, 1979). Superiority of the CSR_2 breed in different agro-climatic conditions of Karnataka and other States for this trait has been well demonstrated by Basavaraja *et al*. (1995) and Datta (1999). In regard to the performance of eight hybrids, the results (Tables-2, -3, -4 and -5) have indicated the superior performance of both multi x bi and bi x multi hybrids in the monsoon season followed by post-monsoon and pre-monsoon seasons. The superior performance of multi x bi hybrids was reported by Narasimhanna (1976) indicated the importance of multi x bi hybrids in tropical environments of India compared to bi x multi hybrids. On the basis of performance of four regular hybrids PM x C_{108}, PM x KA, PM x NB_4D_2 and PM x CSR_2 and four reciprocal hybrids C_{108} x PM, KA x PM, NB $_4D_2$ x PM and CSR_2 x PM, it is found that the expression of the thirteen traits understudy in three seasons vary significantly from one another and excelled the performance

of regular hybrids for the quantitative traits like larval weight, larval duration, fecundity, cocoon weight, shell weight, shell percentage, and filament length. However, the regular hybrids exhibited superior performance for pupation rate and yield by number.

CONCLUSION: A comparative picture on the effects of three periods on the expression of the characters understudy has revealed that the pre-monsoon season has no discernible effects on the expression of the traits studied. However, the monsoon season has influenced the expression of economic traits in the favorable direction. The post- monsoon season has intermediary effect on the expression of economic traits. A comparison of the four multivoltines for thirteen traits in the *pre*, *npnd*, Pure Mysore and C.nichi exhibited higher pupation rate and yield by number in all the three periods indicating the superior performance of these races. On the basis of the performance of bivoltine races C_{108}, KA, NB_4D_2 and CSR_2 breed it is noteworthy that CSR_2 breed excelled all the other bivoltines understudy for productivity traits such as cocoon weight, shell weight, shell percentage, filament length and larval weight. However, for the traits of yield by number and pupation rate C_{108} revealed superior performance than those of the other three races. On the basis of mean performance of the characters understudy during three seasons, it is the monsoon season which has influenced significant better performance of traits than those of the other two seasons. The author contends that the characters under study have responded differently among pure races/breed and their hybrids to different environmental conditions resulting in differential expression of the traits in three periods. Even though there is non uniform expression of the traits in three periods, it is evident that post-monsoon season has significant effect on the larval period which is evident by prolongation in the growth and development of the larvae in both voltine groups. On the other hand, in the monsoon period the traits yield by number, yield by weight, cocoon weight, shell weight, and filament length, are found to be significantly influenced in relation to productivity in the both voltine groups.

Thus, the present study brings to light how various quantitative traits express differently in variable environment exhibiting their genetic differences. Such a study is important in understanding the

ageing and correlation of economic traits as well as the suitability of the hybrids races for different seasons, to recommend them to a particular season to exploit their economic potentiality to the highest by commercial production.

REFERENCES

[1] Basavaraja, H.K., Ashwath, S.K., Suresh Kumar, N., Mal Reddy, N., Kalpana, G.V. (2005). *Silkworm Breeding and Genetics*. CSB, Bangalore, pp. 409-439.

[2] Basavaraja, H.K., Nirmal Kumar, S., Suresh Kumar, N., Mal Reddy, N., Kshama Giridhar, Ahsan, M.M. and Datta, R.K. (1995) New productive bivoltine hybrids. *Indian Silk*, 34: 5-9.

[3] Chandrashekaraiah (1992). Studies on the genetics of quantitative traits in a few multivoltine and bivoltine races of silkworm, *Bombyx mori* L. *Ph.D. Thesis*, University of Mysore, Mysore.

[4] Datta, R.K. (1994). Production and demand of silk in India. *Proc. Intl. Conf. Seric.*, Oxford and IBH Pub. Co. Pvt. Ltd., New Delhi.

[5] Datta, R.K. (2000). Silkworm Breeding in India – Present status and new challenges - Lead Paper. *Natl. Conf. Strat. Seric. Res. Dev*., 16-18 November 2000, CSRTI, Mysore.

[6] Datta, R.K. (1999). Advances in silkworm breeding and genetics in India. *Proc. Of Natl. Sem. Trop. Seri*., Univ. of Agricultural Sciences, Bangalore. 4: 11-23

[7] Datta, R.K., Suresh Kumar, N. and Basavaraja, H.K., Kishor Kumar, C.M. and Mal Reddy, N. (2001**).** CSR_{18} x CSR_{19} a robust bivoltine hybrid for all seasonal rearing. *Indian Silk*, April: pp.5-7.

[8] Gamo, T. (1976). Recent concepts and trends in silkworm breeding. *Farming*, 10(6): 11-12.

[9] Gamo, T. and Shimazaki, A. (1967). Racial differences of proteinase activity of digestive juice of the silkworm. *Acta Sericol*., 64: 26-31.

[10] Hassanien, M.H. and Sharawy, M.F. E. (1962a). Studies on the effect of feeding the silkworm with different mulberry variation on the technology of the seric fiber. Revue Du Ver a Sole, *J. of silkworm*. 14: T III.

[11] Hassanien and Sharawwy, M.F.E. (1962b). The effect of feeding the silkworm, *Bombyx mori* with different varieties on the fecundity of moths. *J. Silkworm*, **14**: 163-170.

[12] Kalpana, G.V. (1992). Breeding of superior races of Silkworm, *Bombyx mori*

L. for tropical climates. *Ph.D. Thesis*, Univ. of Mysore, Mysore.

[13] Kalpana, G.V., Raju, P.J., Subramanya, G. and Sreerama Reddy, G. (1998)' Synthesis of promising multivoltne races of silkworm *Bombyx mori* with productivity merits. *Proc. Natl. Workshop Silkworm Breeding* (Editor–in-Chief G. Sreerama Reddy). Oxford and IBH Pub. Pvt. Co. Ltd., New Delhi.

[14] Kamble, C.K. (1998). Evaluation of heterosis in the newly evolved bivoltine hybrids of silkworm, *Bombyx mori* L. *Madras Agric.* J., 85(5&6): pp. 297-299.

[15] Kasiviswanathan, K. Iyengar, M.N.S. and Krishnaswami, S. (1970). Effect of feeding leaves grown under different systems of mulberry cultivation on the silkworm cocoon crops. *Indian J. Seric*., 9(1): 53-58.

[16] Krishnaprasad, N.K., Sannappa, B. and Varalakshmi, R. (2003). Comparative performance of newly evolved bivoltine breeds of *Bombyx mori* L. *Bull. Ind. Acad. Seri.*, 7(1): 65-69.

[17] Krishnaswami,S. and Narasimhanna,M,N. (1974). Large scale trials on bivoltine hybrids in mysore state. *Ind.J.Genet. and pl.Breed*.34:229-236.

[18] Murakami, A and Ohtsuki, Y. (1989). Genetic studies on tropical races of silkworm (*Bombyx mori*) with special reference to cross breeding strategy between tropical and temperate races. *JARQ*, 23(1): 37-45.

[19] Murakami, A. (1988). Ecogenetical studies on tropical mulberry *Bombyx mori. Proc. Intl. Cong. Tropic. Seric. Prac*., Bangalore, India, 1

[20] Narasimhanna, M.N. (1976). Contribution to the genetics of silkworm. *Ph. D. Thesis*, Univ. of Mysore, Mysore.

[21] Narayanan, E.S., Prahalada Rao, L.S. and Nagaraja Rao, H.A. (1964). Studies on correlation between the duration of mating and number of viable eggs laid by the silk moth, *Bombyx mori* L. I - Effect of duration of copulation on the resulting number of viable eggs. *Indian J. Seric*., 3(2): 1-9.

[22] Nirmal Kumar, S., Kishore Kumar, C.M. and Datta, R.K. (2002). Maintenance strategies in silkworm (*Bombyx mori* L.) for improvement of cocoon production. *Natl. Conf. Start. Seric. Res. Dev*., 16-18 November 2002, CSRTI, Mysore.

[23] Nirmal Kumar, S., Mal Reddy, N., Basavaraja, H.K., Ramesh Babu, M., Suresh Kumar, N., Ashan, M.M. and

Datta, R.K. (1999**).** Identification of bivoltine double hybrids for commercial exploitations. *Indian J. Seric*., 38(2): 135–139.

[24] Ohi, H., Miyahara, J. and Yamashita, A. (1970). Analysis of various practically important characteristics in the silkworm in early breeding generation of hybrids. Variation among strains, correlation between parents and offspring as well as relation between each character. *Bull., Seric. Exp. Sta*., MAFF., 93: 39-49.

[25] Rayar, S.G. (2009). Studies on combining ability and heterosis in some bivoltine breeds of silkworm, *Bombyx mori* L. *Ph.D. Thesis* Univ. of Bangalore.

[26] Rohith L. Shankar, Doddaswamy, Murthy, N. and Subramanya, G. (2007). Evaluation and identification of promising new bivoltine silkworm hybrids using combined trait selection index. Indian Journal of Sericulture 46 (2), 117-125.

[27] Rohith L Shankar and Subramany.G. (2010a). Development of a new bivoltine breed of silkworm *Bombyx mori* MU51 with short larval duration. The Bioscan 5(1);25-29.

[28] Rohith L Shankar and Subramany.G. (2010b). A newly developed bivoltine breed of silkworm *Bombyx mori* MU52 with short larval duration and their suitability for tropical sericulture. Bulletin of Indian academy of Sericulture.14(2):35-45.

[29] Rohith L Shankar and Subramany.G. (2010c). Evolution of a new bivoltine breed of silkworm *Bombyx mori* MU53 with shorter larval duration for tropical sericulture. Geobios. 37(3-7):223-227.

[30] Rohith L Shankar and Subramany.G. (2010d). Evolution of a new bivoltrine breed of silkworm *Bombyx mori* MU54 with short larval duration for tropical sericultyre.My Science. 4(1-2):73-81.

[31] Sengupta, K. (1969). An analysis of genotype environment interaction in some races of silkworm, *Bombyx mori* L. *Indian J. Seric*., **8**(1): 4-6.

[32] Siddhu, N.S., Venugopala Pillai, S., Kamala singh, and Sreenivasan, R. (1968). The performance of an evolved multivoltine silkworm breed. *Indian J. Seric*., **7**(1): 6-12.

[33] Sidhu, N.S., Tikoo, B.L., Kamala Singh and Venugopal Pillai, S. (1969). New hybrids of silkworm for commercial crops for multivoltine regions. *Silkworm Inf. Bull.*,1(2): 18-25.

[34] Snedecor, W.G. and Cochran, C.W. (1967). Statistical methods. *Oxford and IBH Pub., India*, 1967.

[35] Subramanya, G. (1985). Eco-genetic approach for determination of high yielding breeds of silkworm, *Bombyx mori* L. *Ph. D. Thesis*, Univ. of Mysore, Mysore.

[36] Tazima, Y. (1988). A view on the improvement of Mysore breeds. *Proceedings of the international congress on tropical sericulture practices*. Part IV Silkworm breeding and seed production. Bangalore, India, 1-5.

[37] Tazima, Y. (2001). Improvement of biological functions in the silkworm (Translated from Japanese). Oxford and IBH publication Co. Pvt. Ltd., New Delhi.

[38] Ullal, S.R. and Narasimhanna, M.N. (1978). *Handbook of Practical Sericulture.* CSB, Bangalore, p.130.

[39] Umashankara, M.L. and Subrmanya, G. (2002). Correlation between larval weight and cocoon characters in five breeds of silkworm, *Bombyx mori* L. *Geobios*, 29: 154-157.

[40] Umashankara.M.L and Subramanya,G. (2001). Evaluation of the rearing performance of new exotic and indigenous races of silkworm *Bombyx mori* L. Geobios, 129-132

[41] Yokoyama, T. (1979). Silkworm selection and hybridization. In: Genetics in Relation to Insect Management. *Worked papers, Rockefeller Foundation,* 71-83.