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Impact of microsporidian infection on economic characteristics of various bivoltine breeds of silkworm *Bombyx mori*

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Abstract
Crop loss is a regular feature associated with the Indian sericulture caused by various factors with major reasons being the outbreak of different diseases, parasitic attacks and fluctuations in the environmental conditions. The productivity of silkworm, *Bombyx mori* is adversely affected by various pathogens that cause considerable yield loss to silkworm rearers.

Among the various diseases, pebrine caused by protozoa, the microsporidian *Nosema bombycis* is one of the most important pathogen causing majority of damage to the sericulture industry. The present study was conducted to study the effect of microsporidian (*Nosema bombycis*) on the commercial and economic parameters in six races of silkworm, *Bombyx mori* viz; SK1, SK6, SK28, SH6, NB4D2 & CSR2. The results of the study elucidated that the commercial and economic parameters of the silkworm races under study were adversely affected due to the pebrine disease. Among the six races under study SH6 race showed least effect due to the microsporidian infection and the race SK28 suffered the maximum loss in terms of all parameters under study.

Keywords: *Bombyx mori*, microsporidian, cocoon, disease, larvae, mortality

Introduction
Silkworm, *Bombyx mori*- a Lepidopteran insect with the marvellous ability to produce silk fiber, which is considered as the most elegant textile, owing to its unparalleled grandeur, natural sheen, inherent affinity, high absorbance, light weight, soft touch and high durability. Worldwide, the silk is known as 'Queen of Textiles'. Silk and silk products are traditionally associated with luxury and are usually very costly. Natural silk is produced in a few countries, china and India being the two major silk producers in the world among 58 silk producing countries. The output from sericulture industry however is largely dependent on the successful harvest of cocoon crops. The silkworm *Bombyx mori* has become quite susceptible to various disease due to domestication over centuries and the diseases in the silkworm are the major constraints in the sericulture industry which adversely affects the economics of this culture by causing 35-40% crop loss (Sahay *et al*., 2000) [16] A number of micro-organisms, directly or indirectly, influence the silk production - muscardine (fungal disease), flacherie(bacterial disease) grasserie (viral disease) and pebrine (protozoan or Microsporidian disease). Among these, Microsporidiosis, caused by the microsporidia *Nosema bombycis* (Nageli) is considered as one of the most serious pathogen as is transmitted both vertically and horizontally (Bhat *et al.*, 2009) [3]. In fact, this disease has the propensity to decide the success or failure of any sericulture enterprise (Steinhaus, 1949).

Microsporidia are obligately intracellular protozoon parasites, infectious and difficult to eradicate after its occurrance in a particular silkworm batch. The transmission of the Pebrine disease can be either primary through mother moth or secondary through food contamination depending on the exposure of the host to the pathogen. The emergence of this disease can be observed with the appearance of black spots on the integument. With the result, the hypodermal cells extend in their size and turn black due to the formation of melanin (Ganga, 2003). The extension of the developmental phase (Larval duration), small size and low larval weight is associated with this disease (Rath *et al*., 2003) [13]. The present study was carried out to emphasize the symptological and pathological changes in *Bombyx mori* due to the pebrine disease as well as evaluate the impact of microsporidian infection on the commercial economic characteristics of silkworm under temperate climatic conditions of Kashmir.

Material and Methods

The disease free layings of six bivoltine races viz. SK_1, SK_6, SK_{28}, CSR_2, SH_6 and NB_4D_2 selected for the study were procured from the germplasm of College of Temperate Sericulture, Mirgund, SKUAST-K. The silkworms were reared under optimum conditions and as per standard package of practice (Dandin, 2003) [4] in the spring season for two consecutive years. The worms after the third moult were inoculated by feeding them on the mulberry leaves smeared with *Nosema* spores.

Isolation of Nosema spores

The inoculum was prepared by isolating the *Nosema spores* from the diseased silkworms by homogenizing them in autoclaved pestle and mortar using distilled water. The homogenate was filtered through double-layered muslin cloth to remove the tissue debris. The filtrate was then centrifuged at 3000 rpm for 15 minutes to sediment the spores, which was further subjected to Percoll centrifugation (Sato and Watanabe, 1980) [17]. The suspension was again centrifuged at 5000 rpm for 5 minutes and the supernatant was discarded. The sediment was suspended in 1 ml of distilled water and washed thrice in distilled water with the help of centrifugation. The final sediment was suspended in physiological saline (0.85% NaCl) and stored for further experimentation and inoculation.

Inoculation by nosema spores: The spore count was enumerated to prepare a working solution with inoculum dosage of $1x10^6$ spores per ml using Neubuar's haemocytometer. The larvae were fed with the spore smeared leaves for 24 hours to ensure complete ingestion of the inoculated leaves. Hereafter, silkworms were fed with the normal leave still the worms settled for seriposition. A control batch of each race was also maintained separately wherein these were fed with mulberry leaves smeared with distilled water.

Observations recorded

Following parameters were recorded during the pre and post cocoon stages

1. 5th age larval Duration (h): It was measured as the number of hours consumed from the first day of the fifth instar upto mounting of the ripe worms.

2. Weight of the matured larvae (g larvae^{-10}): Ten mature larvae were selected randomly and recorded with the help of electronic weighing balance. The mean of ten readings was taken as the representative of the entire treatment.

3. Larval mortality: The larval mortality represents the percentage of dead larvae from the total number of larvae's after third moult.

$$\text{Larval Mortality} = \frac{\text{Total no.of dead larvae}}{\text{Total no. of larvae retained after third moult}} \times 100$$

4. Single Cocoon Weight (g): Ten male and ten female cocoons were randomly selected from each treatment, weighed and analyzed for the average single cocoon weight.

5. Single Shell Weight (g): In each replication, ten cocoons were cut, pupae and cast skin was separated and the cocoon shell weight was recorded.

6. Shell Ratio (%): It was calculated by the ratio of single shell weight to the single cocoon weight in percentage.

$$\text{Shell Ratio, \%} = \frac{\text{Single Shell weight}}{\text{Single cocoon weight}} \text{ x } 100$$

7. Cocoon yield/10,000 larva: It was measured in the form of number and weight basis.

$$\text{Cocoon Yield} = \frac{\text{No.of cocoons harvested from each replicate}}{\text{No.of worms retained after 3rd moult}} \times$$

10,000 -------- (Number basis)

$$\text{Cocoon Yield} = \frac{\text{Weight of cocoons harvested from each replicate}}{\text{No.of worms retained after 3rd moult}} \times$$

10,000 ----- (Weight basis)

8. Pupation rate, %: The pupation rate determines the percentage of live pupae survived after the harvesting stage and was measured using the below mentioned formula

$$\text{Pupation rate} = \frac{\text{No. of live pupae obtained}}{\text{Total no.of cocoons harvested}} x\ 100$$

9. Moth emergence, %: Moth emergence for each replication of each treatment was observed and calculated by the following formula:

$$\text{Moth emergence} = \frac{\text{No.of live moths emerged}}{\text{Total no.of cocoons per replication}} x\ 100$$

10. Filament length, m: Ten randomly selected cocoons were stifled and reeled to obtain the average filament length.

11. Fecundity: 10 layings of each treatment were selected randomly and no. of eggs were counted to determine no. of eggs laid per moth.

12. Hatching percentage: The hatching of eggs was used as criteria to assess the hatching percentage from the total number of eggs in the laying process.

$$\text{Hatching percentage} = \frac{\text{No. of eggs hatched}}{\text{Total no.of eggs in the laying}} x\ 100$$

13. Statistical Analysis: The results were analyzed in SPSS software through CD value to check the individual effect and interactive effect of independent parameters on the response parameters at 5% level of significance.

Result and Discussion

The results obtained are presented in table 1 and 2. These are explained and discussed below:

Effect of microsporodian infection on 5th age larval duration: The larval duration in all the inoculated races was more than that of the control batches with maximum duration 218.82 hours observed in T5 (SK_{28}), whose control batch observed a larval duration of 184 hrs hours. The minimum larval duration was observed in the inoculated batch of T7 (SH6)-192 hrs while as its control batch recorded a larval duration of 177 hrs. These observations were statistically significant at 5% level of significance and is in line with the study of Madhusudan *et al*., 2011 [10], where the pebrine

infected larvae showed increased larval duration in comparison to the healthy ones in *Antheraea mylitta* infected with *Nosema* species who conculed that the developmental time in the infected larvae usually gets delayed due to depletion of nutritional reserves as well as their reduced ability to assimilate food efficiently.

Variation in mature larval weight due to microsporodian infection: The results of the experiment showed that the inoculation of different races of Silkworm *Bombyx mori* with same spore load of inoculum of *Nosema bombycis* caused varied response in terms of larval weight in all the six races of silkworm under study. The weight of ten mature larvae was lower in the inoculated batches in comparison to control batches. The highest larval weight of 38.63 g among the inoculated races was observed in T7 (SH6) followed by T9 (NB4D2) whose larval weight was 38.18 g. The weight of 10 mature larvae in the control batches of these races was-T8 (SH6 Control)-41.58 g and T10 (NB4D2 control)-42.04 g. The lowest larval weight was observed in T5 (SK28)- 31.81g followed by T11 (CSR2) –34.36 g whose control batches recorded larval weights T6 (SK28 control)- 45.49 g and T12 (CSR2 control)- 42.14 g. The weight of ten mature larvae recorded by other treatment combinations is T1 (SK1)-34. g, T2 (SK1 Control)-46.08 g, T3 (SK6)- 33.93 g and T4 (SK6 Control)-45.01 g respectively. This reduction in the larval weight may be attributed to the fact that there may be decrease in the food consumption, digestion, relative consumption rate, efficiency of conversion of ingested food in fifth instar of silkworms' larvae due to the infection of *Nosema species* as reported by (Rath *et al*., 2003) [13].

Effect on larval mortality due to microsporodian infection: The larval mortality was apparent in all the races inoculated with microsporidian infection with higher mortality in the inoculate batches as compared to the control batches. Statistical analysis revealed that morality percentage in T5(SK28)-46.34% was statistically the highest among all other treatment combinations followed by T1(SK1) which recorded a larval mortality of 39.45%. The larval mortality observed in the control batches of these races was T6(SK28)-Control-3.86% and T2(SK1 Control)-4.28%.The lowest larval mortality was observed in T7(SH6)-31.11% followed by T9(NB4D2)-34.27% whereas the larval mortality observed in the control batches of these races was T8(SH6 Control) control-3.21% andT10(NB4D2 Control)-2.87%. Fig. 1. This falls in conformity with the findings of Sen *et al*. 1969 [18] who observed that the mortality of *A. mylitta* larvae accelerates from 3rd moult onwards and reaches its zenith in the fifth instar, mainly due to the high intensity of virulent parasitic microsporidian, *Nosema mylittensis as* the invading pathogens exploit the nutritional resources of the silkworm.

Decrease in the pupation rate due to microsporodian infection: The results of the study revealed that the inoculation of different races of silkworm *Bombyx mori* with the spores of *Nosema bombycis* affected the pupation rate in all the inoculated races, however, the percentage varied in all the races. Statistical analysis revealed that pupation rate in T5(SK28)-53.61% was statistically the lowest among all other treatment combinations followed by T11(CSR2) which recorded a pupation rate of 55.17%. The pupation rate observed in the control batches of these races was T6(SK28 Control)-93.40% and T12(CSR2 Control)-93.74%. The highest pupation rate was observed in T7(SH6)-59.84% followed by T9(NB4D2)-59.30% whereas the pupation rate observed in the control batches of these races was T8 (SH6 control)-94.37% and T10(NB4D2 Control)-95.88%.The pupation rate to a large extent depends on the accumulation of nutritious substances in the larva before pupation. These protozoans develop in the fat bodies of the host silkworm and result in the depletion of nutritive reserves, thereby causing less rate of pupation (Arm strong and Bass, 1986; Verber and Jassic, 1961) [1, 21].

Reduction in fecundity due to microsporodian infection: A significant decrease of fecundity in the inoculated batches as compared to control as well as among the races under study was observed from the results of the present study. Among all the inoculated races, lowest fecundity was observed in T5 (SK28)-349 eggs followed by T11 (CSR2)-360 eggs which differed significantly from their controls having 520 eggs and 518 eggs respectively as their fecundity. The highest fecundity among the inoculated races was observed in T7 (SH6)-391 eggs followed by T11 (NB4D2)-383 eggs whose control batches recorded fecundity of 515 eggs and 519 eggs respectively. These observations are affirmed by findings of Rath *et al* 2013 [14] who also observed a decline in ovary weight, fecundity and fertility in *Antheraea mylitta* infected with *Nosema* spp. These observations were also affirmed by the findings of Madana Mohanan *et al*., 2005 [9] who conculed that reduced fecundity and egg hatching in microsporidian-infected silkworm may not only be due to high temperature (>29 ºC) but also due to severe damage of the fat body and gonads of the infected larvae. Also damage to the reproductive tissues and the dissolution of muscular tissues following infection by the microsporidians are possible reasons for the reduced fecundity in insects (Yup-lian 1995) [23].

Decrease in the moth emergence percentage

The results of the present study show that Moth Emergence Percentage was significantly different in all the races under study, also the races differed statistically from their control batches. The highest moth emergence %age among the inoculated batches was observed in T7(SH6)-59.18% cocoons, followed by T9(NB4D2)-57.59% whereas moth emergence %age observed in the control batches of these races was T8(SH6 control)-95.38% and T10(NB4D2 control)-94.58%. The lowest moth emergence %age was recorded by T5(SK28)-52.91% and T11 (CSR2)-54.595% which differed statically from their respective controls whose cocoon yield by weight was T6(SK28)-94.55% and T12(CSR2)- 95.20%. This is in accordance with the findings of Thomson, 1958 [20]; Veber and Jasic, 1961; Smirnoff and Chu, 1968 [19] who reported that microsporidia depletes the nutritive reserves used for reproduction and thereby reduced fecundity, hatchability as well as moth emergence. These findings were also in line with the observations of Madana Mohana 2005 [9], who reported that reduced moth emergence is due to the fact that microsporidia depletes the nutritive reserves used for metamorphosis and hence results in reduced or decreased moth emergence. As the Microsporidian infection proceeds, the pathogen invades the fat body which reduces the overall protein turnover of the host and ultimately affects the normal growth and development of the larvae/ insect.

Furthermore, from the results of Table-2, its quite evident that the microsporodian infection substantially reduces the cocoon

as well as the reeling parameters of silkworm, *Bombyx mori* characters. The effect of the microsporidian infection on various commercial characters of silkworm, *Bombyx mori* have been summarised below:

Cocoon weight: Cocoon weight indicates the approximate quantity of raw silk that could be reeled
from the cocoons (Mahadevappa *et al.,* 2000) [8]. The cocoon price is usually determined based on the weight of the cocoon. The cocoon weight deteriorated substantially due to the microsporidian infection. A significant decrease in the single cocoon weight in the inoculated batches as compared to control as well as among the races under study was observed from the results of the study. Among all the inoculated races, lowest single cocoon weight was observed in T5 (SK28)-1.37 g followed by T11 (CSR2)-1.44 g which differed significantly from their controls having 1.87 g and 1.76 g respectively as their single cocoon weights. The highest single cocoon weight among the inoculated races was observed in T7 (SH6) -1.48 g followed by T9 (NB4D2)-1.47 g whose control batches recorded single cocoon weight of 1.73 g and 1.76 g respectively. This is in confirmation with the findings of Rath and Sinha (2005) [12] studied the parasitization of fifth instar larvae of *Antheraea mylitta* by Uzifly have reported the decrease in cocoon weight and shell weight in the infected larvae. Kumar *et al*., 2010 [7] and Reddy *et al*., 2012 also concluded that the potential fitness and maturity attainment in silkworm larvae is only possible when the larva obtain adequate amount of nutrients in a required balance and the deficiency these nutrients due to any biotic stress leads to longer larval duration, lesser ERR and cocoon yield.

Shell weight

This economic trait represents the total quantity of silk in a cocoon. This parameter also differed significantly among all the treatment combinations. Among the inoculated batches, the highest shell ratio was observed in two treatments T7 (SH6)-0.23 g and T9 (NB4D2)-0.23 g which were statistically at par with each other and were significantly different from their respective controls whose shell weight was 0.43g and 0.32g respectively. The lowest shell ratio was recorded in T5 (SK28)-0.19 g followed by T11 (CSR2)-0.21 g. this in accordance with the findings of Rath *et al*., (2003) [13] who reported a decrease in shell weight in *A. mylitta* larvae infected with *Nosema sp.* Also, Rath and Sinha (2005) [12] working on parasitization of fifth instar larvae of *A. mylitta* by Uzi fly have reported the decrease (27-63.5%) in cocoon weight and shell weight in the infected larvae.

Shell ratio: It denotes the total amount of silk available in a single cocoon and is expressed in percentage. The parameter shell ratio is dependent on two parameters- single cocoon weight and shell weight. This parameter also differed significantly among all the treatment combinations. The highest shell ratio among the inoculated batches was exhibited by T7 (SH6)- 15.48% followed by T9 (NB4D2)-15.59% whose control batches recorded shell ratios as T8 (SH6-Control)-18.72% and T10 (NB4D2 Control)-18.46%. The lowest shell ratio was recorded in T5 (SK28)-14.22% followed by T11 (CSR2)-14.58% which differed significantly from their control batches which showed shell ratio as T6 (SK28 Control)-18.44% and T10 (NB4D2 Control)- 18.46% respectively. This in confirmation with the results of Lakshmi Velide *et al.* (2013) [5] who reported that the healthy growth and development of the silkworm is directly related to economical cocoon traits. She also noticed poor cocoon characters from pebrine infected tropical tasar silkworm *Antheraea mylitta*.

Effective rate of rearing (Cocoon yield by number &weight): The results from Table 2 indicate that the effective rate of rearing parameters- **(**Cocoon yield by number &weight) deteriorated drastically due to the microsporidian infection and differed statistically from their un-inoculated or control batches having better rearing parameters. The highest cocoon yield by number was observed in T7(SH6)-6059 cocoons, whose control observed 9367cocoons as cocoon yield by number. The least cocoon yield by number was observed in T5(SK28)- 4208 cocoons, whereas its control T6(SK28-control) observed 9384 cocoons as cocoon yield by number.

The highest cocoon yield by weight was observed in T7(SH)-8.98 Kg, whileas the least cocoon yield by weight was observed in T5(SK28)-5.73Kg. The cocoon yield by weight observed in the control batches of these two races was T8(SH6 Control)- 16.25 Kg and T6(SK28-control)-17.17 Kg, respectively. This is in conformation with the findings of Velide *et al.* (2013) [5] who observed that effective rate of rearing is directly proportional to the the healthy growth and development of the silkworm. She also reported poor economic and commercial cocoon characters from pebrine infected tropical tasar silkworm *Antheraea mylitta*.

Average filament length: The results from Table 2 indicate that the reeling parameters-average filament length deteriorated drastically due to the microsporidian infection and differed statistically from their un-inoculated or control batches having better reeling parameters. In case of average filament length the maximum percent reduction over control of 35.02% was observed in SK28 having AFL of 674.74 m, followed by CSR2-33.15% reduction over control and having AFL of 520.09 m was recorded. The least percent reduction over control in case of AFL was observed in SH6-28.60% which was statistically at par with NB4D2-30.09% reduction over control. This is in accordance with findings Bhat *et al* 2009 [3] who reported that silk from the infected cocoons is usually of inferior quality. Also, The findings of Renuka and Shamita 2013 [15] revealed that there is a substantial decrease in the post cocoon parameters of pebrine infected *Antheraea mylitta.* Also, Jhansi Lakshmi (2003) [6] observed a reduction of economical parameters due to *Beauveria bassiana* infection and attributed that it may be due to the decline in the synthesis of silk proteins and the direct or indirect effect of *Beauveria bassiana* on the growth and development of silkgland of the silkworm *Bombyx mori.* More number of breakages and higher denier were also noticed in experimental cocoons with reference to healthy ones. It may be assumed that the physiological and *b*iochemical stress induced by a fungal pathogen caused to exude uneven amounts of silk fluid in lumps.

Raw silk percentage

This parameter also differed significantly among all the treatment combinations. Among the inoculated batches, the highest Raw silk percentage was observed in two treatments T7 (SH6)-28.86% and T9 (NB4D2)-28.36g which were statistically at par with each other and were significantly different from their respective controls whose shell weight

was 30.07% (T8-SH6 Control)and 30.89% (T10 NB4D2 control)respectively. The lowest Raw silk percentage was recorded in T5 (SK28)-25.68% followed by T11 (CSR2)-27.11%. This in confirmation with the studies of Ganga 2003, who while working on microsporidia is in Daba TV *ecorace, A. mylitta* drury have reported a significant reduction in the reeling parameters of Nosema infected cocoons comparative to healthy control pebrine- free cocoons.

Table 1: Effect of pebrine on development and survival of mulberry silkworm, *Bombyx mori*

Race	Larval Duration (in hrs)	Weight of ten mature larvae (g)	Larval Mortality (%)*	Pupation rate (%)*	Fecundity (No. of eggs)	Moth emergence (%)
T1 (SK1 Inoculated)	211.55	34.55	39.45(6.41)	57.87(7.21)	370	55.20(7.03)
T2 (SK1 Un-Inoculated)	183.5	46.08	4.28(1.97)	92.43(9.22)	517	92.54(9.25)
T3 (SK6 Inoculated)	206.66	36.44	42.56(6.34)	58.60(7.33)	378	56.26(7.13)
T4 (SK6 Un-Inoculated)	183	45.01	3.35 (1.33)	92.55(9.25)	523	93.45(9.35)
T5 (SK28 Inoculated)	218.83	31.81	46.34(6.63)	53.61(7.02)	349	52.91(7.93)
T6 (SK28 Un-Inoculated)	184	45.49	3.86(1.77)	93.40(9.34)	520	94.55(9.48)
T7 (SH6 Inoculated)	191.99	38.62	31.11(5.97)	59.84(7.49)	391	59.18(7.33)
T8 (SH6 Un-Inoculated)	177	41.51	3.21(1.28)	94.37(9.42)	515	95.38(9.60)
T9 (NB4D2 Inoculated)	193.33	37.18	34.75(6.03)	59.30(7.38)	383	57.59(7.25)
T10 (NB4D2 Un-Inoculated)	175.5	42.04	2.87(1.07)	95.88(9.76)	519	94.58(9.48)
T11 (CSR2 Inoculated)	201.83	34.36	37.83(6.11)	55.17(7.06)	360	54.59(7.98)
T12 (CSR2 Un-Inoculated)	174.66	42.14	4.11(1.82)	93.74(9.39)	518	95.20(9.54)
CD ($p \leq 0.05$)	3.16	2.47	1.417	0.819	10.78	0.342

*The values in brackets are the mean square root transformed values.

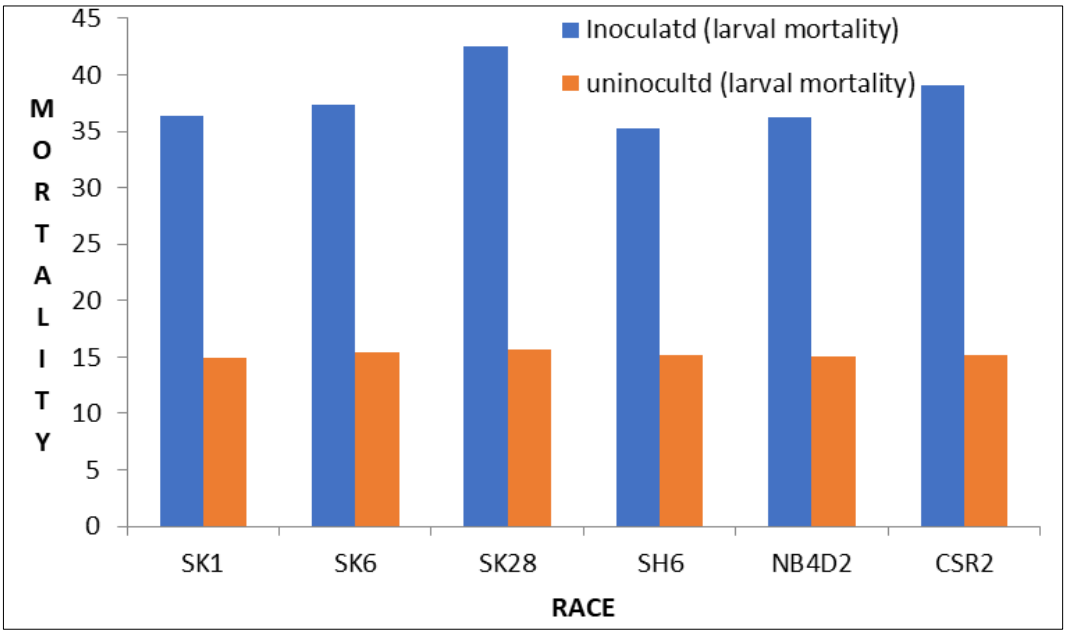

Fig 1: Larval mortality of inoculated and inoculated samples of different races of *BombyxMori*

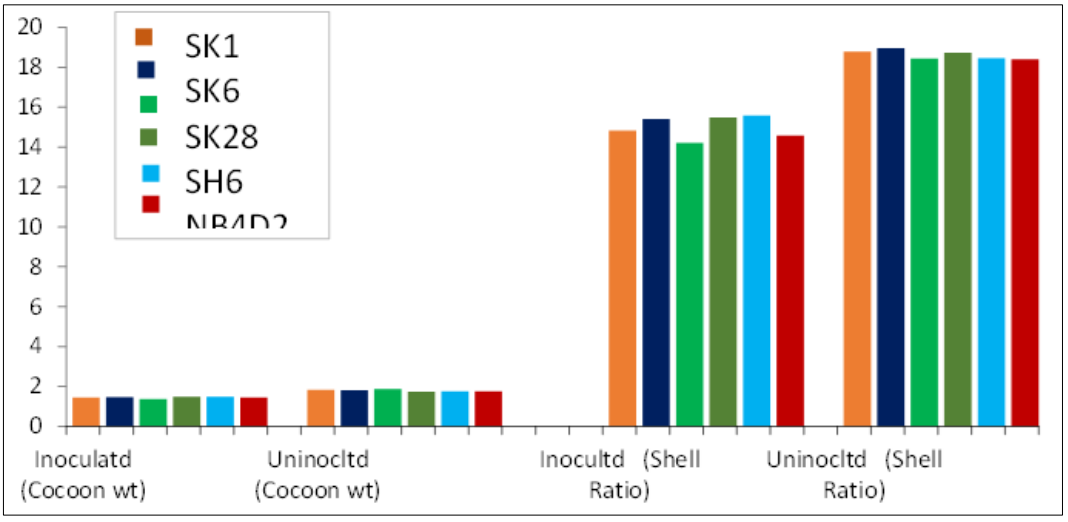

Fig 2: Commercial parameters of cocoon production for different races

Table 2: Impact of nosema on the commercial cocoon characters of mulberry silkworm, *Bombyx mori*:

Race	Cocoon Weight (g)	Shell Weight (g)	Shell Ratio (%)	ERR		Average filament length (m)		Raw silk percentage
				By No.	By Wt.	AFL	% Reduction over control	
T1 (SK1 Inoculated)	1.45	0.21	14.83(3.81)	5104.5	7.40	695.14	32.44	(%) 27.66(5.26)
T2 (SK1 Un-Inoculated)	1.83	0.34	18.79(4.30)	9347	17.15	1028.94		31.85(5.60)
T3 (SK6 Inoculated)	1.46	0.22	15.40(3.93)	5037	7.35	728.83	31.46	28.17(5.30)
T4 (SK6 Un-Inoculated)	1.82	0.34)	18.95(4.32)	9351.5	17.02	1063.39		31.98(5.67)
T5 (SK28 Inoculated)	1.37	0.19	14.22 (3.77)	4208	5.76	674.74	35.02	25.68(5.09)
T6 (SK28 Un-Inoculated)	1.87	0.34	18.44(4.27)	9384	17.17	1038.51		31.44(5.59)
T7 (SH6 Inoculated)	1.48	0.23	15.48(3.87)	6059	8.98	532.58	28.60	28.86(5.36)
T8 (SH6 Un-Inoculated)	1.73	0.32	18.72(4.33)	9367	16.25	745.96		30.70(5.53)
T9 (NB4D2 Inoculated)	1.47	0.23	15.59 (3.94)	5878.5	8.68	512.64	30.09	28.36(5.25)
T10 (NB4D2 Un-Inoculated)	1.76	0.32	18.46(4.25)	9450	16.63	733.34		30.89(5.55)
T11 (CSR2 Inoculated)	1.44	0.21	14.58(4.27)	4865	7.00	520.09	33.15	27.11(5.23)
T12 (CSR2 Un-Inoculated)	1.76	0.32	18.41(4.31)	9385	16.56	778.06	32.44	31.01(5.57)
CD ($p \leq 0.05$)	0.0590	0.016	0.46	285.91	1.377	18.62		2.08

*The values in brackets show the mean square root transformed values.

Conclusion

The reduction of rural poverty continues to be a paramount goal of the developing countries like India as the majority of the poor population still resides in the country-side. The World Bank, for example, estimates that more than 70% of the world's poor live in rural areas. So far, various strategies have been pursued to address this concern and among the major ones is rural employment creation. The agriculture sector, however, has been contending with a number of factors that have limited its potential for generating new jobs in rural areas. Those factors may include the small land holding size, insufficient capital and investment incentives, the inadequate farm infrastructure, limited market and stagnant prices of agricultural products. It is, therefore necessary to focus on a broader spectrum of the rural economy. The establishment of rural based industries like sericulture, in particular, can be very effective in creating new job opportunities and providing supplemental income. Being a rural agro-based labour intensive industry sericulture sector can also play vibrant role in checking migration from rural to urban areas and is possible only when there would be less diseases and thereby better and quality produce. Pebrine is considered to be one of the most serious diseases of sericulture industry and has the propensity to decide the success or failure of any sericulture enterprise because of the reason that it gets transmitted across the generations. In the present study, the microsporidian infection in six races of *Bombyx mori* induced changes that influenced the growth and development of silkworm larvae which subsequently affected the cocoon quality as well as the post cocoon parameters. All the parameters were significantly lower in inoculated batches as compared to the un-inoculated/control batches.

The results of our study indicated that though the microsporidian infection (biotic stress) affected both the growth and developmental parameters as well as the commercial & economic characters of all the races under study of *Bombyx mori*, SH6 and NB4D2 races (genotypes) proved promising elite genotypes, as these races were able to withstand the given biotic stress (microsporidian infection) comparative to other races under study. The races viz; SH6have shown better region specific performance for *Nosem a bombycis* (microsporidian) infection by depicting better growth and developmental parameters viz; 5th age larval duration (192 hours), weight of ten larvae (38.62g), larval mortality (38.62%), pupation rate (59.84%), fecundity(391 eggs), moth emergence % (59.18%) as well as better commercial cocoon characters i.e. single cocoon weight (1.48g), shell weight (0.23g), shell ratio (15.48%), ERR (8.96kg; by weight), ERR (6059; by no.), average filament length (532m; 28.86% reduction over control), raw silk percentage (28.86%)] (table 2). Whereas the genotype Sk_{28} showed the least regional specific performance for the given biotic stress (*Nosema bombycis*) for the above mentioned growth & development parameters (table1) viz; 5th age larval duration (218 hours), weight of ten larvae (31.81g), larval mortality (46.34%), pupation rate (53.61%), fecundity(349 eggs), moth emergence % (52.91%) and commercial parameters viz; single cocoon weight(1.37g), shell weight (0.19g), shell ratio (14.22%), ERR (5.76kg; by weight), ERR (4208; by no.), average filament length (674m; 35.02% reduction over control), raw silk percentage (25.86%) (table2). Selecting a better, robust and tolerant genotype at the farmers level can prove a better strategy to prevent the incidence of microsporidian infection in *Bombyx mori* so that the marginal farmers who take sericulture as a subsidiary farming can generate a good income out of it especially in areas like Jammu and Kashmir where the sericulture activities are declining day by day.

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