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ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

ISSN: 0976-3376

Asian Journal of Science and Technology
Vol. 11, Issue, 05, pp.10950-10958, May, 2020

RESEARCH ARTICLE

IDENTIFICATION OF SUITABLE TEMPERATURE AND HUMIDITY CONDITIONS FOR COMMERCIAL MULBERRY SILKWORM (*BOMBYX MORI* L.) HYBRIDS REARING THROUGH MULTIPLE TRAIT EVALUATION INDEX

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ARTICLE INFO

Article History:
Received 07th February, 2020
Received in revised form
19th March, 2020
Accepted 14th April, 2020
Published online 30th May, 2020

Key words:
Mulberry silkworm, *Bombyx mori*, identification, temperature, humidity, Evaluation Index (EI).

ABSTRACT

The Growth and development of insects, including the mulberry silkworm, *Bombyx mori* L. are directly affected invariably by external environmental factors, such as photoperiod, temperature and humidity. While sufficient published information on the impact of photoperiod on *B. mori* is available, critical information on temperature and humidity impacts on *Bombyx* silkworm is not available. The present communication describes such issues on identification of suitable temperature and humidity conditions for rearing commercial mulberry silkworm hybrids through multiple trait evaluation index method. Five temperature conditions (20, 25, 30, 35 and 40 °C) and five humidity conditions (RH; 50, 60, 70, 80 and 90%) were selected. Two popular silkworm hybrids (PM x CSR2, a multivoltine x bivoltine hybrid and CSR2 x CSR4, a bivoltine x bivoltine hybrid) were reared under the above temperature and humidity conditions, with LD 12 : 12 photoperiodic condition from egg hatching to cocoon harvest. Three rearing characteristics; hatching (%), ERR (effective rate of rearing) by number (number of cocoons harvested/10^4 larvae) and ERR by weight (cocoon yield in Kg./10^4 larvae) were considered to determine the suitability or otherwise of enrolled temperature and humidity conditions through multiple trait evaluation index. Based on the results on evaluation index (EI) two temperature (25 and 30 °C) and two humidity conditions (RH; 70 and 80%) registered higher values of EI > 50 and designated as suitable temperature and humidity conditions. Further, comparison of average EI values of three traits revealed that average EI is highest with 25 °C temperature and 80% RH conditions alone.

Citation: Narasimhulu, P., Lavanya Latha, K., Lakshminarayana Reddy, P., Sujatha, B. and Sankar Naik. 2020. "Identification of suitable temperature and humidity conditions for commercial mulberry silkworm (Bombyx mori L.) hybrids rearing through multiple trait evaluation index", *Asian Journal of Science and Technology*, 11, (05), 10950-10958.

INTRODUCTION

Many insects, including the commercial mulberry silkworm, *Bombyx mori* L. get cues from external sources or environment like photoperiod, temperature and humidity. Photoperiod has been referred to as the strongest environmental factor affecting the overt phenomena in growth and development, thus multiple traits, than temperature and humidity. Though genetic makeup determines the expression of rearing characteristics in *Bombyx* silkworm, the influence of environmental factors seems to affect all the rearing characters in a directional manner. Among these environmental factors, the impact of photoperiod was extensively studied (Sivarami Reddy, 1993; Lakshminarayana Reddy, 2001). Added, studies on the impact of various abiotic factors such as temperature and humidity on *Bombyx* silkworm were reviewed (Rahmatulla, 2012). The results on evaluation for judging their superiority or otherwise was mostly through ANOVA and t-test which takes care of one trait or character only, leaving ambiguity on involvement of other traits in decision making (Arunachalam and Bandyopadhyay, 1984).

Experiments in diverse research disciplines, in general and, sericulture, in particular deal inevitably with dependent characters and warrant decisions taken jointly on them. While methods of analysis would be available to arrive at conclusions on each of the characters individually, it remains a problem to collate them over the characters and arrive at a final decision. When made, such decisions become subjective, and would reflect the variation in the decision making processes adopted by individual investigators (Arunachalam and Bandyopadhyay, 1984). In commercial sericulture industry, the ultimate goal of evaluation of silkworm hybrid evaluation is the simultaneous genetic improvement in multiple traits (Mano *et al*., 1993). In this direction, a common evaluation index (Mano *et al*., 1993; Singh and SubbaRao, 1993) based on the variation index value, a method used in educational system in Japan to determine student's merit (Mano et al., 1993) has been emphasized (Vidyunmala et al., 1998). It is to be remembered that the multiple trait evaluation index (Mano *et al*., 1993; Vidyunmala *et al*., 1998; Ahmed *et al*., 2013) was adapted to judge the superiority of various silkworm hybrids in

a constant photoperiod, temperature and humidity conditions. Studies on judging suitability or otherwise of temperature and humidity conditions to silkworm rearing through multiple trait evaluation index are not available. In the present study, the method in reference is proposed to study the impacts of temperature and humidity on commercial silkworm multiple rearing characters to determine the suitability of temperature and humidity condition. Two popular commercial mulberry silkworm hybrids (PM x CSR2 and CSR2 x CSR4) and photoperiod (LD 12 : 12) were kept in common.

MATERIALS AND METHODS

Two mulberry silkworm (*B. mori*) hybrids; one from multivoltine x bivoltine hybrid, PM x CSR2 and the another from bivoltine x bivoltine hybrid, CSR2 x CSR4 that are popularly exploited for commercial silkworm rearing in the contemporary Indian sericulture are selected. The eggs of silkworm, commonly called as DFLs (disease free layings; each DFL is group of 400 to 500 silkworm eggs laid by a single silk moth on a single day on specific sheet of paper) of the two hybrids were procured from the Silkworm Seed Production Centre (SSPC), National Silkworm Seed Organization (NSSO), Central Silk Board (CSB), Madanapalli, India. The DFLs were transported, during evening cool hours to the Department of Sericulture, Sri Krishnadevaraya University, Anantapur; where the investigations were carried out. The DFLs, at the work spot were immediately spread into the pre disinfected plastic rearing trays (Nilkamal, India). The silkworm rearing method followed was that as advocated by Krishnaswami (1986). The chawki (young age; I & II instar silkworm larvae) rearing was not conducted to maintain uniformity in experimental conditions all through the experimentation. Hatched out larvae from the egg sheet, collected into pre-disinfected rearing trays were daily fed three times (06.00, 14.00 and 22.00 h) of the day on fresh mulberry (*Morus* sp., V1 variety) leaves except during larval-to-larval ecdysis (moulting). The larvae under moult were not disturbed. The rearing was conducted under natural solar day – LD 12 : 12 condition. The 24 h natural solar day was divided into 12 h dark part (scotophase) and 12 h light part (photophase). The photophase was initiated from 06.00 h and lasted at 18.00 h local time. Similarly, the scotophase was imposed from 18.00 h and continued up to 06.00 h local time. A 60 W bulb, as light source for illuminating the experimental animals during photophase of rearing period was arranged above the rearing tray, its height from the rearing tray was so monitored that the light intensity at the surface, where the experimental animals are exposed, did not exceed 50 lux (Sivarami Reddy, 1993).

Two categories of experimental conditions, temperature and humidity were adopted. In the first instance, experimentation was conducted with temperature. Five temperature regimes, 20, 25, 30, 35 and 40 °C were maintained separately in an environmental chamber (Kolarstat). Five replications, with 1 DFL per each temperature condition were maintained. The photoperiod (LD 12 : 12) and relative humidity (RH, 80%) conditions were common to this set of experimentation. In the second set of experimentation, humidity condition was studied. Five relative humidity (RH) regimes, 50, 60, 70, 80 and 90% were maintained separately in an environmental chamber (Kolarstat). Five replications, with 1 DFL per each RH condition were maintained. The photoperiod (LD 12 : 12) and temperature (25 °C) conditions were common in this experimentation. Only three parameters, hatching percentage (indicating the beginning of silkworm larval life), effective rate of rearing (ERR) by number and ERR by weight (end product of larval life) were considered. The hatching percentage was calculated based on total number of eggs in an egg sheet and total number of eggs that hatched successfully (hatching % = number of eggs hatched/total number of eggs x 100). Similarly, ERR was calculated by keeping 100 number of larvae (per each replication) for continuation after fourth larval-to-larval moult and continued till cocoon harvest. Silk cocoons were harvested on 6th day of spinning for PM x CSR2 and on 8th day of spinning for CSR2 x CSR4 (Kanika Trivedy, 2015). Cocoons thus harvested were processed, counted and weighed accurately. The number of cocoons were calculated for ERR by number (number of cocoons/10^4 larvae) = number of cocoons harvested/100 x 10000). Similarly, ERR by weight was calculated (weight of cocoons/10^4 larvae) = weight of cocoons harvested/100 x 10000). Analysis of data: The data were treated for average and standard deviation. Further, data were analyzed statistically (ANOVA). The crude data simultaneously were computed for Evaluation Index (EI) and for Average EI value according to Mano *et al*. (1983) as described by Singh and Subba Rao (1993). The EI value fixed to designate a temperature/humidity condition's suitability was > 50.

RESULTS

Identification of optimum temperature for multivoltine x bivoltine hybrid, PM x CSR2: It should be remembered that studies on identification of suitable temperature conditions for PM x CSR2 were conducted under LD 12 : 12 photoperiodic condition with 80% relative humidity. Data on the three selected rearing characteristics, hatching percentage, ERR by number and ERR by weight are presented in Table 1. From the table, it is seen all the three rearing parameters, hatching (%), ERR by number and by weight recorded high data points under temperature of 25 and 30 °C. Careful observation revealed that each rearing character responded differently under these two temperature conditions. Thus, hatching was highest (95.2 %) under 30 °C temperature condition ERR by number (9241) and by weight (16.8 Kg) under 25 °C temperature conditions. The parameters recorded less value under remaining temperature (20, 35 and 40 °C) conditions. In terms of commercial silkworm rearing conditions, these values of parameters and average levels as well are not economical (85% of hatching, 8254 number of cocoons and 14.7 Kg of cocoon per 10^4 larvae (Table 1).

Table 1. Recorded data on three rearing parameters in multivoltine x bivoltine (PM x CSR2) mulberry silkworm, *Bombyx mori* L. under five experimental temperature conditions. Data are mean of 5 replications. Common rearing conditions were LD 12 : 12 and 80% RH

Temperature (°C)	Hatching (%)	ERR (yield/10^4 larvae)	
		Number	Weight (kg.)
20	81.000	8137.000	14.096
25	92.800	9246.600	16.829
30	95.234	9092.000	16.636
35	83.345	7601.200	13.762
40	72.400	7195.400	12.080
Mean	84.956	8254.440	14.680
SD (±)	9.261	901.106	2.024

The crude data on the three rearing parameters (hatching percentage, ERR by number and ERR by weight) were treated

Table 2. Computed Evaluation Index (EI) values on three rearing parameters in multivoltine x bivoltine (PM x CSR2) mulberry silkworm, *Bombyx mori* L. under five experimental temperature conditions. Common rearing conditions were LD 12: 12 and 80% RH

Temperature (°C)	Hatching	ERR (yield/10^4 larvae)		EI Total value	EI average value	SD (±)
		Number	Weight (Kg.)			
20	45.729	48.697	47.110	141.536	47.179	1.485
25	58.470*	61.010**	60.614**	180.094	60.031**	1.367
30	61.098**	59.295*	59.661*	180.054	60.018**	0.953
35	48.260	42.751	45.464	136.475	45.492	2.755
40	36.442	38.247	37.151	111.841	37.280	0.909

* *Indicates EI > 50 and ** indicated highest EI*

for Evaluation Index (EI) and presented in Table 2. Incidentally, it is clear that EI for all the three rearing characters (hatching percentage, yield in number and weight for 10^4 larvae, ERR) more under temperature conditions of 25 and 30 °C. . However, EI for only hatching was the highest (61.1) under 30 °C temperature condition and the remaining two parameters, EI was highest for ERR by number and by weight (61 and 60.6) under 25 °C temperature condition. EI values for hatching percentage in PM x CSR2 under different temperature (20, 25, 30, 35 and 40 °C) conditions are graphically represented in Figure 1. From the figure, it is clear that EI of hatching is highest against 30 °C followed by that for 25 °C. The other temperature conditions, 20, 35 and 40 °C have registered EI < 50, indicating their non-significance for consideration them as suitable temperature conditions for commercial silkworm rearing.

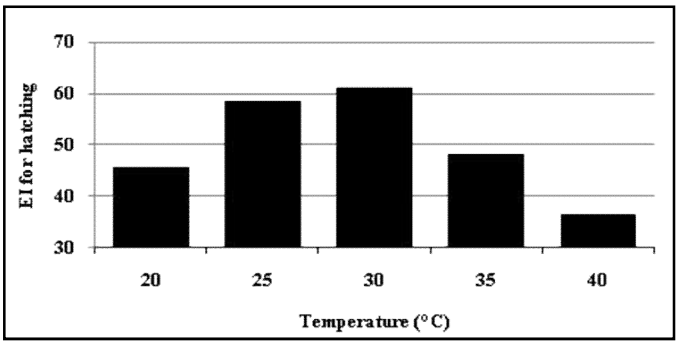

Figure 1. Graphical representation of computed Evaluation Index (EI) values for hatching percentage in multivoltine x bivoltine (PM x CSR2) mulberry silkworm, *Bombyx mori* L. under five experimental temperature conditions. Common rearing conditions were LD 12 : 12 and 80% RH

EI values for cocoon harvested per 10^4 numbers of larvae by number (ERR by number) are graphically represented in Figure 2.

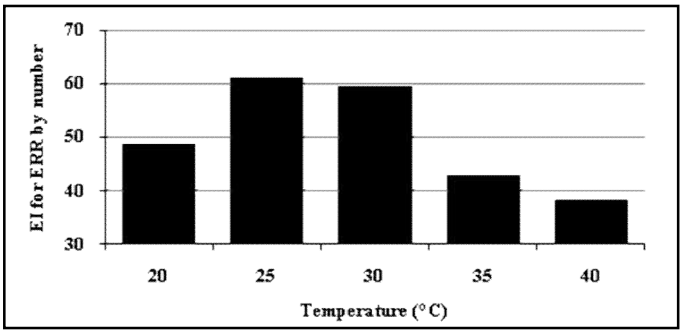

Figure 2. Graphical representation of computed Evaluation Index (EI) values for cocoon harvested per 10^4 numbers of larvae by number (ERR by number) in multivoltine x bivoltine (PM x CSR2) mulberry silkworm, *Bombyx mori* L. under five experimental temperature conditions. Common rearing conditions were LD 12 : 12 and 80% RH

Contrary to that of EI values for hatching percentage, EI for ERR by number registered highest (EI over 60) for 25 °C followed by that (EI less than 60) exposed to 30 °C, while the remaining temperature conditions 20, 35 and 40 °C registered EI values less than 50 (EI > 50, Figure 2). EI values for cocoon harvested per 10^4 numbers of larvae by weight (ERR by weight, Kg.) are graphically represented in Figure 3. In the case of EI for ERR by weight also registered highest (EI over 60) for 25 °C followed by that (EI less than 60) exposed to 30 °C, while the remaining temperature conditions 20, 35 and 40 °C registered EI values less than 50 (EI > 50, Figure 3).

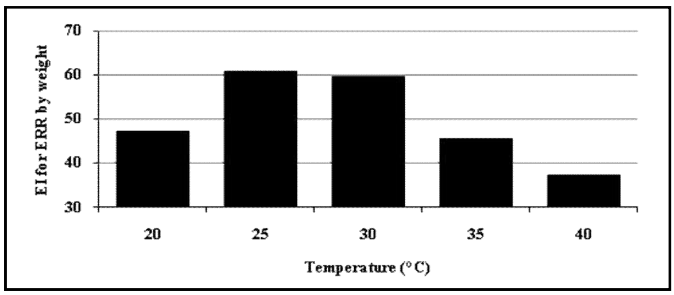

Figure 3. Graphical representation of computed Evaluation Index (EI) values for cocoon harvested per 10^4 numbers of larvae by weight (ERR by weight, Kg.) in multivoltine x bivoltine (PM x CSR2) mulberry silkworm, *Bombyx mori* L. under five experimental temperature conditions. Common rearing conditions were LD 12 : 12 and 80% RH

Average EI of the three rearing parameters, hatching percentage, ERR by number and ERR, by weight as given in Table 1, are presented in Figure 4. A comparison of average EI values revealed that average EI with 25 and 30 °C registered equal status (average EI at 25 °C, 60 = average EI at 30 °C, 60) and are > 50 indicating the suitability of these two temperatures (25 and 30 °C) for commercial silkworm rearing of PM x CSR2. The average EI values for the remaining experimental temperatures, 20, 35 and 40 °C conditions are not at all suitable for the average EI < 50, ranging from 37 to 47 (also see Table 2).

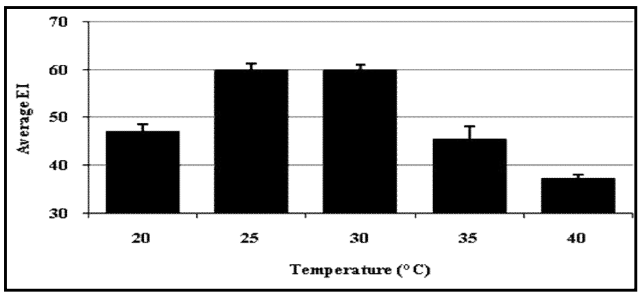

Figure 4. Graphical representation of average Evaluation Index (average EI for hatching percentage, ERR by number and ERR by weight) values in multivoltine x bivoltine (PM x CSR2) mulberry silkworm, *Bombyx mori* L. under five experimental temperature conditions. Common rearing conditions were LD 12: 12 and 80% RH

Identification of optimum temperature for bivoltine x bivoltine hybrid, CSR2 x CSR4: Data on the three selected rearing characteristics, hatching percentage, ERR by number and ERR by weight, reared under 5 experimental temperature (20, 25, 30, 35 and 40 °C) with constant RH of 80% and photoperiod of LD 12 : 12 for bivoltine x bivoltine hybrid, CSR2 x CSR4 are presented in Table 3. From the table, it is seen all the three rearing parameters, hatching (%), ERR by number and by weight recorded high data points differently under temperature conditions. Thus, for hatching percentage, higher values are recorded with two temperatures (25 and 30 °C) while for ERR by number and weight, higher values are seen with temperature of 25 °C alone. The parameters recorded less value under remaining temperature (20, 35 and 40 °C) conditions. In terms of commercial silkworm rearing conditions, these values of parameters and average levels as well are not economical (69% of hatching, 6457 number of cocoons and 12.2 Kg of cocoon per 10^4 larvae (Table 3).

EI values for cocoon harvested per 10^4 numbers of larvae by number (ERR by number) are graphically represented in Figure 6. Contrary to that of EI for hatching, EI for ERR by number registered highest (EI over 60) for 30 °C followed by that (EI less than 60) exposed to 25 °C. The remaining temperature conditions 20, 35 and 40 °C registered EI values less than 50 (EI > 50, Figure 6). EI values for cocoon harvested per 10^4 numbers of larvae by weight (ERR by weight, Kg.) are graphically represented in Figure 7. In the case of EI for ERR by weight, the values registered highest (EI over 60) for 25 °C followed by that (EI less than 60) exposed to 30 °C. The other temperature conditions 20, 35 and 40 °C registered EI values less than 50 (EI > 50, Figure 7). Average EI of the three rearing parameters, hatching percentage, ERR by number and ERR by weight as given in Table 4, are presented in Figure 8. A comparison of average EI values revealed that average EI with 25 and 30 °C registered above 50 (average EI > 50, average EI at 25 °C = 64 and average EI at 30 °C = 55) and are > 50 indicating the suitability of these two temperatures (25 and 30 °C) for commercial silkworm rearing of CSR2 x CSR4. The average EI values for the remaining experimental temperatures, 20, 35 and 40 °C conditions are not at all suitable for the average EI < 50, ranging from 39 to 48 (also see Table 4).

Table 3. Recorded data on three rearing parameters in bivoltine x bivoltine (CSR2 x CSR4) mulberry silkworm, *Bombyx mori* L. under five experimental temperature conditions. Data are mean of 5 replications. Common rearing conditions were LD 12 : 12 and 80% RH

Temperature (°C)	Hatching (%)	ERR (yield/10^4 larvae)	
		Number	Weight (kg.)
20	76.600	7047.400	13.023
25	93.800	9243.800	17.850
30	96.600	7695.000	14.840
35	79.400	7359.600	14.100
40	69.400	6457.800	12.167
Mean	83.160	7560.720	14.396
SD (±)	11.623	1045.367	2.184

Table 4. Computed Evaluation Index (EI) values on three rearing parameters in bivoltine x bivoltine (CSR2 x CSR4) mulberry silkworm, *Bombyx mori* L. under five experimental temperature conditions. Common rearing conditions were LD 12 : 12 and 80% RH

Temperature (°C)	Hatching	ERR (yield/10^4 larvae)		EI Total value	EI average value	SD (±)
		Number	Weight (Kg.)			
20	44.356	45.090	43.714	133.159	44.386	0.6885
25	59.154*	66.100**	65.820**	191.075	63.692**	3.9319
30	61.564**	51.285*	52.033*	164.881	54.960*	5.7308
35	46.765	48.076	48.642	143.483	47.828	0.9629
40	38.161	39.449	39.791	117.402	39.134	0.8596

** Indicates EI > 50 and ** indicated highest EI*

The crude data on the three rearing parameters (hatching percentage, ERR by number and ERR by weight) for bivoltine x bivoltine hybrid, CSR2 x CSR4 of *Bombyx* silkworm were treated for Evaluation Index (EI) and presented in Table 4. From the table, it is clear that EI for all the three rearing characters (hatching percentage, yield in number and weight for 10^4 larvae, ERR) are > 50 for 25 and 30 °C temperature conditions. In the case of CSR2 x CSR4 also, EI for only hatching was the highest (62) under 30 °C temperature condition and for the remaining two parameters, EI was highest for ERR by number and by weight (66 and 65) under 25 °C temperature condition. EI was < 50 for the other three temperature conditions (20, 35 and 40 °C).

EI values for hatching percentage in CSR2 x CSR4 studied under five temperature (20, 25, 30, 35 and 40 °C) conditions are graphically represented in Figure 5. From the figure, it is clear that EI for hatching is highest against 30 °C followed by that for 25 °C. The other temperature conditions, 20, 35 and 40 °C registered EI < 50, indicating their non-significance for consideration as suitable temperature conditions for commercial silkworm rearing.

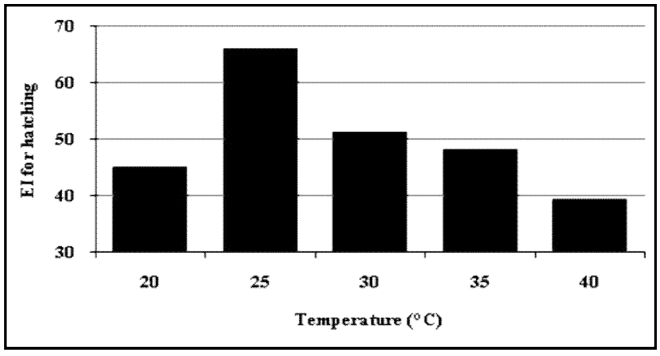

Figure 5. Graphical representation of computed Evaluation Index (EI) values for hatching percentage in bivoltine x bivoltine (CSR2 x CSR4) mulberry silkworm, *Bombyx mori* L. under five experimental temperature conditions. Common rearing conditions were LD 12 : 12 and 80% RH

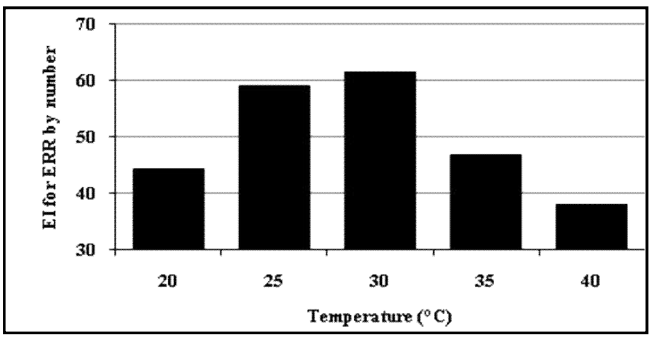

Figure 6. Graphical representation of computed Evaluation Index (EI) values for cocoon harvested per 10^4 numbers of larvae by number (ERR by number) in bivoltine x bivoltine (CSR2 x CSR4) mulberry silkworm, *Bombyx mori* L. under five experimental temperature conditions. Common rearing conditions were LD 12 : 12 and 80% RH

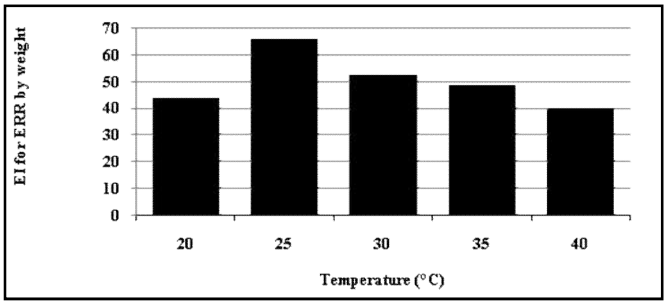

Figure 7. Graphical representation of computed Evaluation Index (EI) values for cocoon harvested per 10^4 numbers of larvae by weight (ERR by weight, Kg.) in bivoltine x bivoltine (CSR2 x CSR4) mulberry silkworm, *Bombyx mori* L. under five experimental temperature conditions. Common rearing conditions were LD 12 : 12 and 80% RH

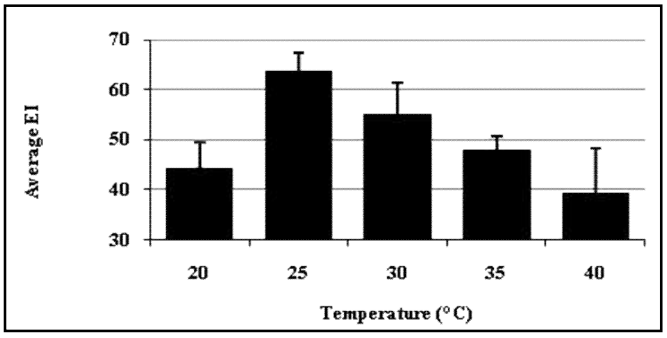

Figure 8. Graphical representation of average Evaluation Index (average EI of hatching percentage, ERR by number and ERR by weight) values in bivoltine x bivoltine (CSR2 x CSR4) mulberry silkworm, *Bombyx mori* L. under five experimental temperature conditions. Common rearing conditions were LD 12 : 12 and 80% RH

Identification of optimum relative humidity for multivoltine x bivoltine hybrid, PM x CSR2: Data on the three selected rearing characteristics, hatching percentage, ERR by number and ERR by weight, reared under 5 experimental humidity (50, 60, 70, 80 and 90% RH) with constant temperature of 25 °C and photoperiod of LD 12 : 12 for multivoltine x bivoltine hybrid, PM x CSR2 are presented in Table 5. It is pointed out that all the three rearing parameters, hatching (%), ERR by number and by weight recorded high data points differently under RH conditions. However, all the measurements (hatching percentage, ERR by number and ERR by weight) recorded highest values with only one humidity condition (80% RH). The parameters recorded less value under remaining humidity (RH; 50, 60, 70 and 90%) conditions. In terms of commercial silkworm rearing conditions, these values of parameters and average levels as well are not economical (mean hatching of 89%, 8842 number of cocoons and 16 Kg of cocoon per 10^4 larvae respectively (Table 5).

Table 5. Recorded data on three rearing parameters in multivoltine x bivoltine (PM x CSR2) mulberry silkworm, *Bombyx mori* L. under five experimental relative humidity conditions. Data are mean of 5 replications. Common rearing conditions were LD 12 : 12 and 80% RH

Relative Humidity (%)	Hatching (%)	ERR (yield/10^4 larvae)	
		Number	Weight (kg.)
50	81.000	8137.000	14.096
60	82.200	8933.200	16.174
70	95.200	9105.800	16.763
80	97.000	9150.600	17.151
90	91.600	8884.600	15.751
Mean	89.400	8842.240	15.987
SD (±)	7.393	409.872	1.186

The crude data on the three rearing parameters (hatching percentage, ERR by number and ERR by weight) for multivoltine x bivoltine hybrid, PM x CSR2 of *Bombyx* silkworm under different RH conditions were treated for Evaluation Index (EI) and presented in Table 6. From the table, it is clear that EI for all the three rearing characters (hatching percentage, yield in number and weight for 10^4 larvae, ERR) are greater than 50 (EI > 50) for 80 and 90% RH conditions. EI was highest for ERR by number (58) and ERR by weight (60) under 80% RH condition alone. Interestingly, EI for hatching was greater than 50 (EI > 50) for RH conditions of 70 and 90% RH conditions. The other two parameters, ERR by number and ERR by weight reacted separately. Thus EI was greater than 50 (EI >) with 60, 70 and 90% RH as well for ERR by number. EI > for ERR by weight under RH of 60 and 70%. For the remaining RH conditions, EI was less (EI < 50). When the data on individual EI were averaged, only two RH conditions, 70 and 80% recorded EI > 50. However, average EI was highest with RH condition of 80% (59) followed RH of 70% (57) alone (Table 6).

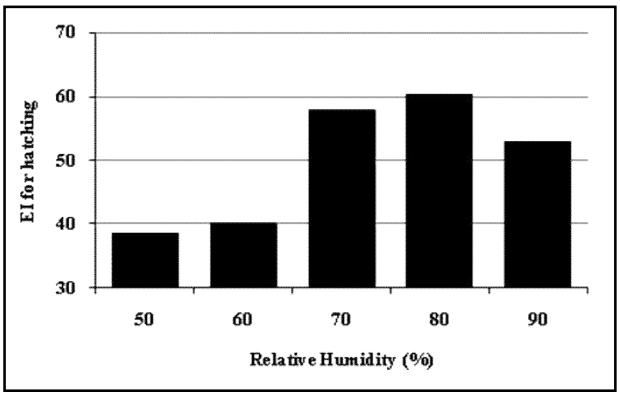

Figure 9. Graphical representation of computed Evaluation Index (EI) values for hatching percentage in multivoltine x bivoltine (PM x CSR2) mulberry silkworm, *Bombyx mori* L. under five experimental RH conditions. Common rearing conditions were LD 12 : 12 and 80% RH

EI values for hatching percentage in PM x CSR2 studied under five RH (RH; 50, 60, 70, 80 and 90%) conditions are graphically represented in Figure 9.

Table 6. Computed Evaluation Index (EI) values on three rearing parameters in multivoltine x bivoltine (PM x CSR2) mulberry silkworm, *Bombyx mori* L. under five experimental RH conditions. Common rearing conditions were LD 12 : 12 and 80% RH

Relative Humidity (%)	Hatching	ERR (yield/10^4 larvae)		EI Total value	EI average value	SD (±)
		Number	Weight (Kg.)			
50	38.638	32.794	34.050	105.481	35.160	3.07661
60	40.261	52.219*	51.580*	144.060	48.020	6.726857
70	57.845*	56.430*	56.542*	170.817	56.939*	0.786525
80	60.280**	57.523**	59.815**	177.618	59.206**	1.47573
90	52.976*	51.033*	48.013	152.023	50.674*	2.500594

* *Indicates EI > 50 and ** indicated highest EI*

From the figure, it is clear that EI for hatching is highest against 80% RH condition followed by that for 70% RH (EI = 58) and RH of 90% (EI = 53). The other RH conditions, 50, 60% registered Evaluation Index (EI < 50), indicating their non-significance for consideration as suitable RH conditions for commercial silkworm rearing. Similarly, EI computed for ERR by number for multivoltine x bivoltine silkworm hybrid, PM x CSR2 under five RH conditions (RH; 50, 60, 70, 80 and 90%) are given in Figure 10. In the case of ERR by number in PM x CSR2, all the RH conditions, except RH of 50% resulted in EI over 50. With RH of 50%, however, EI was below 50 (EI < 50). Among the other RH conditions, EI was highest with RH of 80% (EI = 50) followed by RH of 70% (EI = 56), 60% (EI = 52) and RH of 90 (EI = 51).

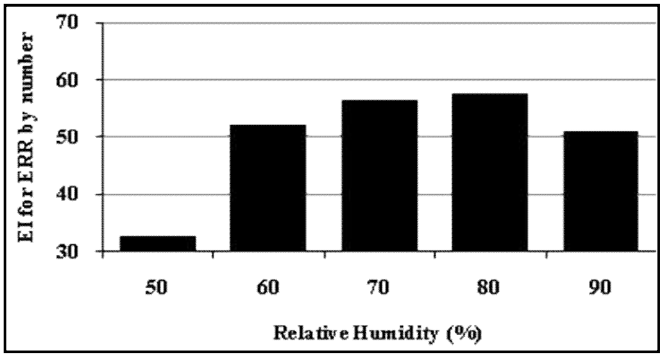

Figure 10. Graphical representation of computed Evaluation Index (EI) values for ERR by number in multivoltine x bivoltine (PM x CSR2) mulberry silkworm, *Bombyx mori* L. under five experimental RH conditions. Common rearing conditions were LD 12 : 12 and 80% RH

Computed ERR by weight for multivoltine x bivoltine silkworm hybrid, PM x CSR2 under five RH conditions (RH; 50, 60, 70, 80 and 90%) are given in Figure 11. EI for ERR by weight in PM x CSR2 was more than 50 for RH conditions of 60, 70 and 80%. EI was highest (58) for RH of 80% followed by 57 (for RH of 70%) and 52 (for RH of 60%). However, EI was below 50 for the other 2 RH conditions (RH; 50 and 90%) recording EI of 49 for RH of 90% and EI of 34 for RH of 50%.

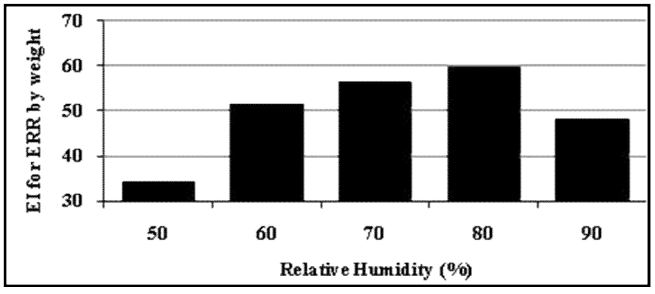

Figure 11. Graphical representation of computed Evaluation Index (EI) values for ERR by weight in multivoltine x bivoltine (PM x CSR2) mulberry silkworm, *Bombyx mori* L. under five experimental RH conditions. Common rearing conditions were LD 12 : 12 and 80% RH

Average EI of the three rearing parameters, hatching percentage, ERR by number and ERR by weight for PM x CSR2, subjected to five RH conditions are in Figure 12. A comparison of average EI values revealed, interestingly, that EI exceeded 50 for two RH conditions, 70 and 80% extensively (EI = 59 for RH of 80% and 57 for RH of 70%). Further, EI was marginally also over 50 (EI = 51) foe RH of 90%. The other two RH conditions, 50 and 60% recorded EI < 50, thus indicating that RH of 50 and 60% are not preferred for silkworm rearing.

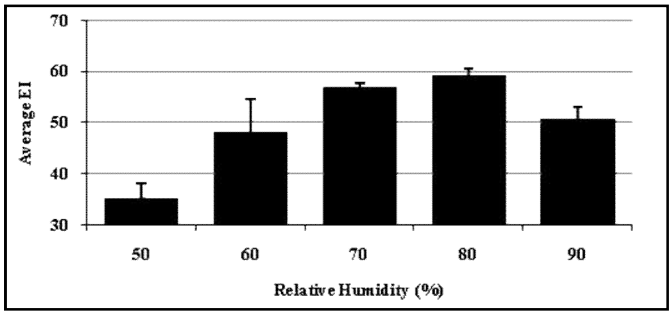

Figure 12. Graphical representation of computed average Evaluation Index (average EI) values for three rearing parameters, hatching, ERR by number and by weight in multivoltine x bivoltine (PM x CSR2) mulberry silkworm, *Bombyx mori* L. under five experimental RH conditions. Common rearing conditions were LD 12 : 12 and 80% RH

Identification of optimum relative humidity for bivoltine x bivoltine hybrid, CSR2 x CSR4: Data on the three selected rearing characteristics, hatching percentage, ERR by number and ERR by weight, reared under 5 experimental humidity (50, 60, 70, 80 and 90% RH) conditions, with constant temperature of 25 °C and photoperiod of LD 12 : 12 for bivoltine x bivoltine hybrid, CSR2 x CSR4 are presented in Table 7. It is seen that all the three rearing parameters, hatching (%), ERR by number and by weight recorded high data points differently under RH conditions. However, all the measurements (hatching percentage, ERR by number and ERR by weight) recorded highest values with only one humidity condition, 80% RH. The parameters recorded less value under remaining humidity (RH; 50, 60, 70 and 90%) conditions. In terms of commercial silkworm rearing conditions, these values of parameters and average levels as well are not economical (mean hatching of 81%, 8278 number of cocoons and 17 Kg of cocoon per 10^4 larvae respectively (Table 7). The crude data on the three rearing parameters (hatching percentage, ERR by number and ERR by weight) for bivoltine x bivoltine hybrid, CSR2 x CSR4 of *Bombyx* silkworm under different RH conditions were computed for Evaluation Index (EI) and presented in Table 8. From the table, it is clear that EI for all the three rearing characters (hatching percentage, yield in number and weight for 10^4 larvae, ERR) are greater than 50 (EI > 50) for 80 and 90% RH conditions.

Table 7. Recorded data on three rearing parameters in bivoltine x bivoltine (CSR2 x CSR4) mulberry silkworm, *Bombyx mori* L. under five experimental relative humidity conditions. Data are mean of 5 replications. Common rearing conditions were LD 12 : 12 and 80% RH

Relative Humidity (%)	Hatching (%)	ERR (yield/10^4 larvae)	
		Number	Weight (kg.)
50	59.200	6877.400	13.005
60	80.000	8016.000	16.474
70	88.200	8718.200	17.987
80	92.400	9461.000	20.912
90	88.200	8321.800	15.607
Mean	81.600	8278.880	16.797
SD (±)	13.305	952.038	2.926

Table 8. Computed Evaluation Index (EI) values on three rearing parameters in bivoltine x bivoltine (CSR2 x CSR4) mulberry silkworm, *Bombyx mori* L. under five experimental RH conditions. Common rearing conditions were LD 12 : 12 and 80% RH

Relative Humidity (%)	Hatching	ERR (yield/10^4 larvae)		EI Total value	EI average value	SD (±)
		Number	Weight (Kg.)			
50	33.164	35.279	37.042	105.486	35.162	1.942
60	48.797	47.239	48.895	144.931	48.310	0.929
70	54.961*	54.615*	54.066*	163.641	54.547*	0.451
80	58.117**	62.417**	64.064**	184.599	61.533**	3.071
90	54.961*	50.451*	45.933	151.344	50.448*	4.514

* *Indicates EI > 50 and ** indicated highest EI*

Highest EI was observed for hatching with RH of 80%. For the other parameters, EI was highest in 80% RH. Except for ERR by weight, all the parameters recorded EI > 50. The remaining two humidity conditions, RH of 50 and 60%, EI was < 50. For average also, the EI was greater than 50 for RH conditions of 70, 80 and 90%, however, RH of 80% recorded the highest EI (Table 8). EI values for hatching percentage in CSR2 x CSR4 studied under five RH (RH; 50, 60, 70, 80 and 90%) conditions are graphically represented in Figure 13. From the figure, it is clear that EI for hatching is highest against 80% RH condition followed by that for 70% RH (EI = 55) and RH of 90% (EI = 50). The other RH conditions, 50, 60% registered Evaluation Index (EI < 50), indicating their non-significance for consideration as suitable RH conditions for commercial silkworm rearing.

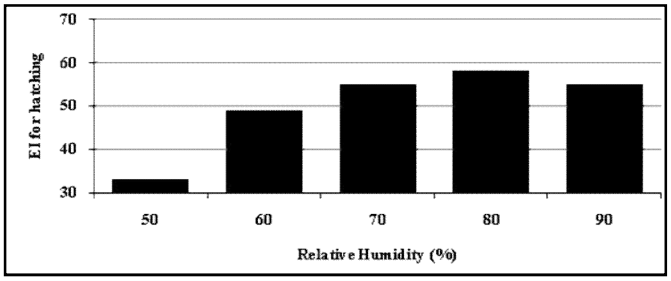

Figure 13. Graphical representation of computed Evaluation Index (EI) values for hatching percentage in bivoltine x bivoltine (CSR2 x CSR4) mulberry silkworm, *Bombyx mori* L. under five experimental RH conditions. Common rearing conditions were LD 12 : 12 and 80% RH

Similarly, EI computed for ERR by number for bivoltine x bivoltine silkworm hybrid, CSR2 x CSR4 under five RH conditions (RH; 50, 60, 70, 80 and 90%) are given in Figure 14. In the case of ERR by number in CSR2 x CSR4, all the RH conditions, except RH of 50 and 60% resulted in EI over 50. With RH of 50% and 60, however, EI was below 50 (EI < 50). Among the other RH conditions, EI was highest with RH of 80% (EI = 62) followed by RH of 70% (EI = 55) and RH of 90 (EI = 50).

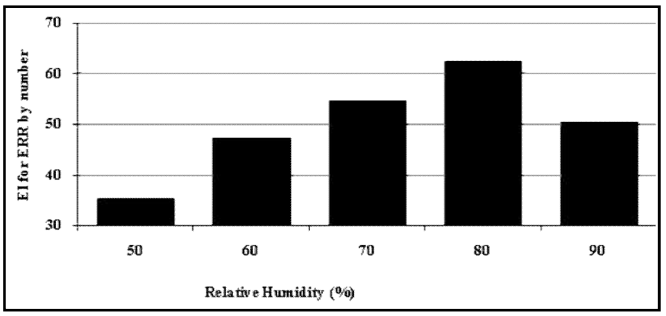

Figure 14. Graphical representation of computed Evaluation Index (EI) values for ERR by number in bivoltine x bivoltine (CSR2 x CSR4) mulberry silkworm, *Bombyx mori* L. under five experimental RH conditions. Common rearing conditions were LD 12 : 12 and 80% RH

Computed ERR by weight for bivoltine x bivoltine silkworm hybrid, CSR2 x CSR4 under five RH conditions (RH; 50, 60, 70, 80 and 90%) are given in Figure 15. EI for ERR by weight in CSR2 x CSR4 was more than 50 for RH conditions of 70 and 80% only. EI was highest (64) for RH of 80% followed by 54 (for RH of 70%). However, EI was below 50 for the other 3 RH conditions (RH; 50, 60 and 90%) recording EI of 46 for RH of 90%, 37 for RH of 50% and EI of 49 for RH of 60%.

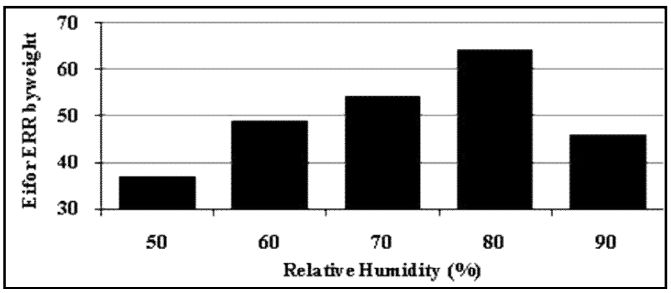

Figure 15. Graphical representation of computed Evaluation Index (EI) values for ERR by weight in bivoltine x bivoltine (CSR2 x CSR4) mulberry silkworm, *Bombyx mori* L. under five experimental RH conditions. Common rearing conditions were LD 12 : 12 and 80% RH

Mean EI of the three rearing parameters, hatching percentage, ERR by number and ERR by weight for CSR2 x CSR4, subjected to five RH conditions are in Figure 16. When average EI values are compared, it is revealed, interestingly, that EI exceeded 50 for three RH conditions, 70, 80 and 90% exclusively (EI = 62 for RH of 80%, 54 for RH of 70% and 50 for RH of 90%). The other two RH conditions, 50 and 60% recorded EI < 50, thus indicating that RH of 50 and 60 are not preferred for silkworm rearing.

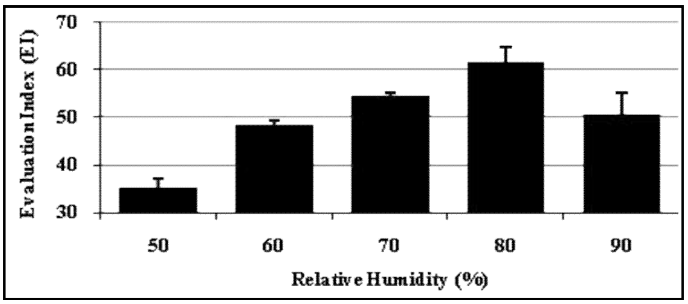

Figure 16. Graphical representation of computed average Evaluation Index (average EI) values for three rearing parameters, hatching, ERR by number and by weight in bivoltine x bivoltine (CSR2 x CSR4) mulberry silkworm, *Bombyx mori* L. under five experimental RH conditions. Common rearing conditions were LD 12 : 12 and 80% RH

DISCUSSIONS

In the present study only three common rearing parameters; egg hatching percentage, ERR by number and ERR by weight, with two popular silkworm hybrids; PM x CSR2 and CSR2 x CSR4, were considered. However, these characteristics of two silkworm hybrids were tested with five temperature and five relative humidity regimes in order to judge or weigh the suitability or otherwise. In order to come to a considerably primitive way of comparison, the researcher would first watch the highest, lowest, average and range of weights or values recorded for each temperature and humidity condition. Thus, if the recorded readings in hatching, ERR by number and ERR by weight are compared for multivoltine x bivoltine hybrid (PM x CSR2, Table 1), one can easily say that hatching percentage is high with temperature of 30 °C and the minimum hatching percentage as 72 at 40 °C. But, ERR by number and ERR by weight were highest at 25 °C temperature. This situation was common for humidity and temperature conditions too for both the silkworm hybrids. One should not forget that such comparison is based on, mere more or less than, by mathematical means and even the value is more by 1, particular value is said to be higher only and this type of comparison is not acceptable for. Similarly, when these rearing parameters are compared for humidity conditions, it should be accepted that all the three parameters, egg hatching percentage, ERR by number and ERR by weight registered the highest values with RH of 80% (Table 5 for PM x CSR2 and Table 7 for CSR2 x CSR4).

In the statistical literature the mechanisms of testing process, ANOVA and t-test of differences, and decision based on a large number of characters ensure the superiority of the proposed method over the traditional ones. In the latter only the numerical superiority over the floor value of a character is considered. Such superiority may not be upheld by statistical test leading to erroneous decisions. Though apparently no weight is associated with each character, it is evident the method followed in the present study takes into adequate, account the relative importance of the characters. On the other hand, discriminant function technique suffers essentially from arbitrary assignment of weights to characters. The problem of character weighting has been dealt with in great detail by Sneath and Sokal (1973) who defended equal weighting on several independent grounds. Moreover, exact rules for estimating weights cannot be formulated. When many characters are employed, the statistical analysis of similarity is only slightly affected by weighting (unless this weighing is extreme). Such uncertainty is almost eliminated in the present EI method. When a number of characters are considered, it is general that there could be a sequential relationship between them. For example, poor and uneconomical silkworm eggs hatching directly affects ERR both by number and by weight in commercial sericulture and that, further affects in turn the value of the end product of silkworm rearing, the cocoon for the farmer. Therefore, decisions based on several important characters spanning the entire growth phase will be fair and precise due to an automatic weighting in the expression of various silkworm rearing characteristics measured sequentially over the growth period. Thus, comparing the highest and lowest values of a particular character is replaced by a sophisticated method of computing the recorded data like the mechanisms of testing process, ANOVA and t-test of differences. However, such method of comparing characters in different temperature and humidity conditions is also not fully satisfactory, because, ANOVA and t-test mainly concentrate on a single character over a given temperature/humidity conditions. In such case, multiple trait Evaluation Indexing (EI) has been proposed by Mano *et al*, (1993) as described by Singh and Subba Rao (1993) was adopted in the present study to study various characters under different temperatures and humidity conditions, fixing 50 as suitability floor value to designate suitability of a temperature/humidity condition (EI > 50). Finally, all the EI values are averaged to designate the combined end product of temperature/humidity conditions.

Thus, when EI values of three rearing parameters (hatching, ERR by number and ERR by weight) are considered for temperature conditions, only one rearing parameter, hatching percentage showed EI > 50 for two temperature conditions (25 and 30 °C). However, EI was highest with 30 °C, indicating a special consideration for discussion. On the other hand, EI for ERR by weight and weight were highest with 25 °C, though it was more than 50 for 30 °C also. It should be recalled that for silkworm rearing, different levels of temperatures were recommended (Krishnaswami, 1986; Krishnaswami *et al*., 1973; Datta, 1992; Rahmatulla, 2012; Kanika Trivedy, 2015) during different phases of entire silkworm rearing period like incubation of silkworm eggs for hatching, chawki (young) age silkworm rearing and late age silkworm rearing. Thus, for incubation and late age silkworm rearing, a temperature of 25 °C was suggested while for young (chawki) age rearing 28 °C was recommended (Krishnaswami, 1986; Krishnaswami *et al*., 1973; Datta, 1992; Rahmatulla, 2012; Kanika Trivedy, 2015). When highest EI of hatching at 30 °C is considered, it is accepted that this temperature is very close to recommended temperature (28 °C) and naturally EI would be expected to be higher than other imposed temperature conditions. Interestingly, EI values for the other two parameters, ERR by number and ERR by weight were high with temperature of 25 °C alone. On the other hand EI values for all the three rearing

parameters were over 50 under humidity conditions (RH) of 70 and 80%. In all the silkworm rearing technologies ((Krishnaswami, 1986; Krishnaswami *et al*., 1973; Datta, 1992; Rahmatulla, 2012; Kanika Trivedy, 2015), optimum relative humidity recommended was 80%. Therefore, highest EI for all the rearing characters studied with RH of 80% is justified irrevocably, though EI > 50 for RH of 70% also. The fact that temperature of 25 °C and RH of 80 are more suited for *Bombyx* silkworm rearing is further confirmed when the average EI values are examined. Temperature being stronger than relative humidity is more emphasized by many researchers. Thus, Brussel (1970) opined that temperature plays primary and direct role while humidity plays a secondary and indirect role on insects. The fact is more true for purely domesticate commercial silkworm, *B. mori* too. The reports of Lakshminarayana Reddy *et al*, (2003) also confirmed the above. Narasimhulu *et al*, (2020) viewed that temperature affects in a charring mode while humidity in desiccative way. Therefore, temperature of 25 °C and humidity of 80% are more suited for commercial silkworm rearing, as the average EI were (EI > 50) highest over the other temperature and humidity conditions. Other temperature conditions (20, 35 and 40 °C) and humidity conditions (RH; 50, 60, 70 and 90%) are not suitable for silkworm commercial rearing.

REFERENCES

Ahmad, M. N.; Chishti, M. Z. and Khan, M. A. 2013. Studies on the identification of summer specific silkworm *Bombyx mori* L. hybrids under temperate climatic conditions of Jammu and Kashmir, India, *JIARM*, 1(3): 1-14.

Arunachalam, V. and Bandyopadhyay, A. 1984. A method to make decision jointly on a number of dependent charachers. *Indian J. Genetics*., 44: 419-424.

Brussel, E. 1970. *An introduction to insect physiology*, Academic Press, London and New York, pp 276.

Datta, R. K. 1992. *Guidelines for bivoltine rearing*, Central Silk Board, Bangalore, India.

Kanika Trivedy. 2015. Intensive bivoltine sericulture technology package, Central Sericultural Research & Training Institute, Central Silk Board, Govt. of India: Ministry of Textiles, Berhampore – 742 101, India.

Krishnaswami, S. 1986. *New technology of silkworm rearing*, Bulletin No. 2, Central Silk Board, Bangalore, India.

Krishnaswami, S.; Narasimhanna, M. N.; Suryanarayana, S. K. and Kumararaja, S. 1973. *Manual on sericulture, Vol. 2 – Silkworm rearing*, (FAO of United Nations: Rome), pp. 1-131.

Lakshminarayana Reddy, P. 2001. Implications of high temperature and low humidity on the silkworm (*Bombyx mori* L.) physiology and its economics of rearing, Ph. D., thesis, Sri Krishnadevaraya University, Anantapur, India.

Lakshminarayana Reddy, P.; Sankar Naik, S.; Subba Rao, M. and Sivarami Reddy, N. 2003. Implications of high temperature and low humidity on cocoon economic traits in the silkworm, *Bombyx mori* L., *J. Adv. Zool*., 24(1&2): 34-40.

Mano, Y.; Nirmal Kumar, S.; Basavaraja, H. K.; Mal Reddy, N. and Datta, R. K. 1993. A new method to select promising breeds and combinations, *Indian Silk*, 33(10): 53.

Narasimhulu, P.; Lakshminarayana Reddy, P.; Sujatha, B.; Lavanya Latha, K,; Vinayak Reddy, B. and Sankar Naik S. 2020. On the implications of temperature and humidity on egg hatching in the commercial silkworm, *Bombyx mori* L., *International Journal of Life Sciences Research*, 8(1): 26-40.

Rahmathulla, V. K. 2012. Management of climatic factors for successful silkworm (*Bombyx mori* L.) crop and higher silk production: A review, *Psyche*, 1-12.

Singh, T. and Subba Rao, G. 1993. A multiple trait evaluation index to screen useful silkworm (*Bombyx mori*) hybrid genotypes. *G. it. Ent*, 6: 379-382.

Sivarami Reddy, N. 1993. Implications of photoperiod on the silkworm, *bombyx mori* L. (PM x NB4D2), Ph. D., Thesis, Sri Venkateswara University, Tirupati, India.

Sneath, P. H. A. and Sokal, R. R. 1973. *Numerical Taxonomy.* W. H. Freeman and Co. San Francisco, pp. 96-113.

Vidyunmala, S.; Narasimha Murthy, B. and Sivarami Reddy, N. (1998) Evaluation of new silkworm (*Bombyx mori* L.) hybrids (multivoltine x bivoltine) through multiple trait evaluation index, *J. ent. Res*., 22(1): 49-53.

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