EVALUATION OF BIVOLTINE SILKWORM (*Bombyx mori* L.) RACES UNDER DIFFERENT CLIMATE CONDITIONS

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ABSTRACT

Evaluation of productive silkworm breeds is the first important component in the development of sericulture. The present study was conducted to assess larvae and cocoon characteristics of 22 bivoltine silkworm races under standard and high tempearature and humidity conditions. Under the standard condition, the races with high reelibility > 80%, rendital < 7 kg, EI > 50 were TQ10 (59.51), IN6 (58.66), IN3 (57.14), IN2 (58.66), HQ4 (53.86), TQ9 (53.49), TQ5 (53.45), TQ3 (52.56), TQ7 (51.64) and TQ1 (50.08). In high temparature and humidity conditon, the silkworm races with high survival > 80% were VN2, TQ6, VN7, TQ1, TQ2 and TQ10. EI>50 were recorded in HQ4 (58.32), TQ7 (56.26), TQ10 (56.88), TQ9 (56.26), TQ6 (55.39), TQ3 (55.10), IN6 (54.79), TQ5 (54.78) and IN3 (54.29). Therefore, the identified races can serve as valuable resource materials for breeding silkworms programs tailored to challenging environmental conditions.

Keywords: *Silkworm race, bivoltine, evaluation index.*

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1. INTRODUCTION

Mulberry silkworm is one of the most important domesticated insects, which also play an important role in the economy. By nature, the silkworm is highly sensitive to enviromental conditions, which greatly influenced its growth and develepment. The optimal temperature for normal silkworms growth ranges from 20°C to 28°C, with 23°C to 28°C being ideal for maximum productivity. Temperature above 30°C adversely impact the health of the silkworm, while temperature below 20°C slow down physiological activities, especially in early instars making the worms weak and susceptible to various diseases [1]. Previous studies have shown that many quantitative traits, including survival and cocoon characteristics, decline significantly when the temperature exceeds 28°C during larval development [2, 3].

In fact, many silkworm varieties perform well in experimental conditions, but in practice, the productivity is not as expected due to the microclimate, rearing conditions and the adaptability of the variety to environmental conditions. Therefore, it is essential to evaluate and identify silkworm races under diverse environmental conditions. This is crucial not only for understanding the potential of existing silkworm genotypes but also for identifying ideal races with better adaptability to cope with changing climatic conditions.

There are many methods to evaluate silkworm races, including evaluation indexes, score indexes, heterosis and combilition ability. In which, evaluation indexes for evaluation are the most widely used in evaluation silkworm race [4 - 9].

In this paper, we evaluated 22 silkworm bivoltine races under standard condition to select those with superior cocoon quality races.

Additionally, we assesssed their performance under high-temperature and high-humidity conditions to identify races with high survival silkworm rates. These selected races will serve as materials for developing potential hybrids for various ecological conditions.

2. MATERIALS AND METHODS

2.1. Materials

The research was evaluated 22 two silkworm races which were reared at the Vietnam Sericulture Research Centre. The characteristics of the silkworms, cocoons, and their origins are detailed in table 1.

Table 1. Morphological charateristics of 22 bivoltine silkworm races

No.	Races	Lavae	Cocoon color	Cocoon shape	Origin
1	TQ1	Plain	White	Peanut	China
2	TQ3	Plain	White	Peanut	China
3	TQ5	Plain	White	Peanut	China
4	TQ7	Plain	White	Peanut	China
5	TQ9	Marked	White	Peanut	China
6	IN1	Marked	White	Peanut	India
7	IN3	Plain	White	Peanut	India
8	IN5	Marked	White	Peanut	India
9	VN7	Plain	White	Peanut	Vietnam
10	IN2	Plain	White	Oval	India
11	IN4	Plain	White	Oval	India
12	IN6	Plain	White	Oval	India
13	TQ2	Plain	White	Oval	China
14	TQ4	Plain	White	Oval	China
15	TQ6	Plain	White	Oval	China
16	TQ8	Plain	White	Oval	China
17	TQ10	Sex-limited	White	Oval	China
18	TQ12	Plain	White	Oval	China
19	HQ2	Plain	White	Oval	Korea
20	HQ4	Plain	White	Oval	Korea
21	HQ6	Plain	White	Oval	Korea
22	VN2	Plain	White	Oval	Vietnam

2.2. Method

2.2.1. Experimental design

The research consisted of two experiments involving 22 silkowm races correspoding to 22 treatments with 3 replications. The experiments were arranged in a Randomized Complete Block Design (RCBD). Each replication raised 300 4^{th}-instars larvae, during Spring (March – April) and autumn (September – October) in 2021 at Vietnam Sericulture Research Centre, Hanoi

- Experiment 1: Evaluation of 22 silkworm races under standard condition. The young age silkworm (1^{st} – 3^{rd} instars) was reared at 27 - 28°C with 80 - 85% relative humidity and the late age silkworm (4^{th} - 5^{th} instars) was maintained at 24 - 26°C with relative humidity of 70 - 80%.

- Experiment 2: Evaluation of 22 silkworm races under high temperature and humidity. The young age silkworm (1^{st} – 3^{rd} instars) was reared at 28 - 30°C with 85 - 90% relative humidity and the late age silkworm (4^{th} – 5^{th}instars) was maintained at 30 - 32°C with relative humidity of 80 - 85%.

2.2.2. Measurements

Cocoon harvesting was carried out on the fifth day of spinning to identify the yield and quality of cocoon related parameters including: Larvae duration, fercudity, hatching rate, survival rate, pupation rate, good cocoon percentage, weight of cocoon, shell weight, shell percentage, cocoon yield/300 larvae [10].

The silk quality related parameters including filament length, reelability, raw silk percentage and rendital.

Methods to investigate the data and information followed TCVN 13474-2:2022 Testing and appraisal procedures for animal breed – Part 2: Silkworm [11].

Evaluation index (EI) value for silkworm breed performance was calculated by using the following formula [12].

$$EI = (A - B)/C \times 10 + 50,$$

Where, A is mean of the particular trait; B is overall mean of particular trait; C is standard deviation; 50 is constant.

2.2.3. Data analysis

Analysis of variance (ANOVA) was performed using "Statistix 10". The significance of means values was analysed using Tukey's test (0.05).

3. RESULTS AND DISCUSSIONS

3.1. Evaluation of 22 silkworm races under standard condition

The larvae duration of 9 peanut - shaped cocoon races was aprroximately one day longer than 13 oval cocoon races (Table 2). The results showed that, most silkworm races had high hatching rate (more than 85%), except for TQ12 which had lower rate of 79.36%. The highest silkworm survival was record in TQ2 (90.73%), while the lowest was observed in IN1 (40.96%). Two silkworm races, IN6 (388 g) and TQ10 (392 g) exhibited significantly higher yield cocoon compared to TQ12 (161 g) and IN1 (172 g). Notably, although TQ12 also had lowest cocoon yield (161g), it achieved the highest cocoon shell rate was highest and the difference was statistically signficant.

Table 2. Mean performance of biological and economic traits of silkworm races under standard condition

No.	Races	Lavae duration (days)	Fecundity (No)	Hatching rate (%)	Survival (%)	Cocoon yield (g)	Whole cocoon weight (g)	Cocoon shell rate (%)
1	TQ1	24.00	519 ^{abc}	91.21 ^{ab}	85.63 ^{ab}	327 ^{ab}	1.303 ^{fgh}	19.88 ^{cde}
2	TQ3	24.00	583^{ab}	95.18 ^{ab}	75.72 ^{abcd}	345 ^{ab}	1.574 ^{abcdef}	20.52 ^{bcd}
3	TQ5	24.00	527 ^{abc}	90.21 ^{ab}	77.93 ^{abcd}	350 ^{ab}	1.552 ^{abcdefg}	21.03 ^{bcd}
4	TQ7	24.00	552 ^{abc}	94.70 ^{ab}	77.70 ^{abcd}	360 ^{ab}	1.590 ^{abcd}	18.16 ^{e}
5	TQ9	24.00	557^{abc}	86.42 ^{abc}	71.09 ^{abcd}	347 ^{ab}	1.502 ^{abcdefgh}	20.72 ^{bcd}
6	IN1	24.00	455 ^{bc}	85.41^{bc}	40.96 ^{e}	172 ^{c}	1.448 ^{abcdefgh}	21.21 ^{bcd}
7	IN3	24.00	567^{abc}	93.87 ^{ab}	75.01 ^{abcd}	352 ^{ab}	1.581 ^{abcde}	20.80 ^{bcd}
8	IN5	24.00	467 ^{abc}	93.46 ^{ab}	55.61 ^{cde}	242 ^{bc}	1.601 ^{abcd}	21.17 ^{bcd}
9	VN7	24.00	546 ^{abc}	94.39 ^{ab}	87.11 ^{ab}	347 ^{ab}	1.334 ^{defgh}	19.57 ^{de}
10	IN2	23.21	558^{abc}	93.84 ^{ab}	76.55 ^{abcd}	363^{ab}	1.622 ^{ab}	21.28 ^{bcd}
11	IN4	23.21	530 ^{abc}	87.16 ^{abc}	53.62 ^{de}	270 ^{abc}	1.613 ^{abc}	21.94 ^{b}

12	IN6	23.21	587[a]	92.76[ab]	81.63[abc]	388[a]	1.651[a]	21.44[bc]
13	TQ2	23.21	533[abc]	95.48[ab]	90.73[a]	345[ab]	1.292[gh]	20.55[bcd]
14	TQ4	23.21	526[abc]	95.88[ab]	89.13[a]	337[ab]	1.335[cdefgh]	20.62[bcd]
15	TQ6	23.21	449[c]	91.70[ab]	88.24[a]	322[ab]	1.311[efgh]	20.62[bcd]
16	TQ8	23.21	519[abc]	93.01[ab]	88.16[a]	358[ab]	1.408[abcdefgh]	19.56[de]
17	TQ10	23.21	532[abc]	96.62[a]	85.61[ab]	392[a]	1.581[abcde]	21.16[bcd]
18	TQ12	23.21	443[c]	79.36[c]	60.07[bcde]	161[c]	1.364[bcdefgh]	24.63[a]
19	HQ2	23.21	540[abc]	93.17[ab]	60.46[bcde]	268[abc]	1.610[abcd]	20.78[bcd]
20	HQ4	23.21	566[abc]	94.77[ab]	80.39[abc]	348[ab]	1.480[abcdefgh]	21.18[bcd]
21	HQ6	23.21	557[abc]	94.98[ab]	71.81[abcd]	313[ab]	1.511[abcdefgh]	21.56[bc]
22	VN2	23.00	536[abc]	91.97[ab]	86.04[ab]	318[ab]	1.279[h]	20.88[bcd]

Note: Values in the column followed by the same letter is not significantly different at the 0.05 probability level by Tukey's test.

The results of table 3 showed, the silkworm races have filament length (>800 m), high percentage of reelability (>80%) and low rendital (<7.0 kg) were recorded in IN3 (870, 90.24, 6.53) , TQ10 (843, 90.91, 6.99) and HQ4 (817, 81.83, 6.84). IN5 was found to be difficult to reel and thus, its silk quality traits could not be determined.

Table 3. Traits of silk quality silkworm race under standard condition

No.	Races	Filament length (m)	Percentage of reelability (%)	Raw silk percentage (%)	Rendital (kg)
1	TQ1	743	86.67	14.32	6.98
2	TQ3	696	88.89	14.71	6.80
3	TQ5	704	92.86	15.60	6.41
4	TQ7	645	83.33	13.97	7.16
5	TQ9	799	90.70	14.52	6.89
6	IN1	808	46.65	13.02	7.67
7	IN3	870	90.24	15.32	6.53
8	IN5	-	-	-	-
9	VN7	696	83.33	14.42	6.93
10	IN2	785	95.24	15.22	6.57
11	IN4	815	84.44	14.15	7.07
12	IN6	792	90.91	15.19	6.59
13	TQ2	582	81.58	13.43	7.09
14	TQ4	724	54.97	13.72	7.28
15	TQ6	662	83.33	13.97	7.16

16	TQ8	609	81.63	13.97	7.16
17	TQ10	843	90.91	14.31	6.99
18	TQ12	750	51.39	14.71	6.80
19	HQ2	873	52.38	16.16	6.19
20	HQ4	817	81.63	14.63	6.84
21	HQ6	662	67.80	12.69	7.88
22	VN2	711	81.63	15.17	6.59

The results of EI index evaluation of five cocoon quality indicators of silkworm races under standard condition showed that the race with higher EI values (above 50 EI value) were TQ10 (59.51), IN6 (58.66), IN3 (57.14), IN2 (58.66), HQ4 (53.86), TQ9 (53.49), TQ5 (53.45), TQ3 (52.56), TQ7 (51.64) and TQ1 (50.08).

Table 4. Evaluation Index Values of Selected Traits under standard conditions

No.	Races	Survival rate	Cocoon yield	Whole cocoon weight	Filament length	Reelability rate	Average	Rank
1	TQ1	57.82	50.69	41.55	50.12	55.07	50.08	10
2	TQ3	50.23	54.22	46.97	44.49	56.55	52.56	8
3	TQ5	51.92	55.04	51.36	45.44	59.20	53.45	7
4	TQ7	51.75	56.66	26.84	38.37	52.84	51.64	9
5	TQ9	46.68	54.49	48.69	56.83	57.76	53.49	6
6	IN1	23.59	25.99	52.93	57.91	28.37	36.68	21
7	IN3	49.68	55.31	49.43	65.34	57.45	57.14	3
8	IN5	34.82	37.39	52.55	-	-	26.34	22
9	VN7	58.96	54.49	38.86	44.49	52.84	49.87	11
10	IN2	50.87	57.21	53.46	55.15	60.79	57.02	4
11	IN4	33.29	42.00	59.14	58.75	53.58	49.61	12
12	IN6	54.76	61.28	54.89	55.99	57.90	58.66	2
13	TQ2	61.73	54.22	47.25	30.82	51.67	46.75	18
14	TQ4	60.50	52.86	47.82	47.84	33.92	46.77	17
15	TQ6	59.82	50.42	47.87	40.41	52.84	48.06	14
16	TQ8	59.76	56.30	38.79	34.06	51.71	49.24	13
17	TQ10	57.81	61.82	52.51	62.11	57.90	59.51	1
18	TQ12	38.24	24.18	82.10	50.96	31.53	37.17	20
19	HQ2	38.54	41.73	49.24	65.70	32.19	47.67	16
20	HQ4	53.80	54.76	52.62	58.99	51.71	53.86	5
21	HQ6	47.23	49.06	55.92	40.41	42.48	46.32	19
22	VN2	58.14	49.88	50.09	46.28	51.71	48.06	15

3.2. Evaluation of 22 silkworm races under high temperature and humidity condition

Silkworm rearing under high temperature and humidity condition resulted in faster growth and development of lavae. However survival rate, cocoon yield, cocoon weight and cocoon shell rate was found to be lower compared to rearing under standard condition (Table 5).

Table 5. Mean performance of biological and economic traits of silkworm races under high temperature and humidity condition

No.	Races	Larvae duration (days)	Fecundity (No)	Hatching rate (%)	Survival (%)	Cocoon yield (g)	Whole cocoon weight (g)	Cocoon shell rate (%)
1	TQ1	23.00	508 ^{abc}	87.63 ^{a}	81.80 ^{a}	277 ^{abc}	1.196	18.94 ^{efg}
2	TQ3	23.00	581 ^{ab}	94.46 ^{a}	70.80 ^{ab}	282 ^{ab}	1.371 ^{abcd}	19.26 ^{cdefg}
3	TQ5	23.00	538 ^{abc}	82.41 ^{a}	71.37 ^{ab}	267 ^{abc}	1.298 ^{cdef}	20.39 ^{bcdef}
4	TQ7	23.00	497 ^{abc}	92.61 ^{a}	74.10 ^{ab}	290 ^{ab}	1.328 ^{bcde}	18.00 ^{g}
5	TQ9	23.00	539 ^{ab}	84.34 ^{a}	64.78 ^{abc}	227 ^{abcd}	1.251 ^{defgh}	21.02 ^{bcde}
6	IN1	23.00	479 ^{abc}	83.82 ^{a}	35.00 ^{fg}	162 ^{de}	1.431 ^{ab}	20.41 ^{bcdef}
7	IN3	23.00	612 ^{a}	94.68 ^{a}	63.76 ^{abcd}	267 ^{abc}	1.472 ^{a}	19.13 ^{cdefg}
8	IN5	23.00	541 ^{ab}	91.99 ^{a}	39.44 ^{defg}	153 ^{def}	1.437 ^{ab}	21.20 ^{bcd}
9	VN7	23.00	556 ^{ab}	91.38 ^{a}	81.44 ^{a}	265 ^{abc}	1.127 ^{hi}	18.06 ^{g}
10	IN2	22.21	520 ^{abc}	92.61 ^{a}	32.09 ^{fg}	112 ^{ef}	1.240 ^{efgh}	18.20 ^{fg}
11	IN4	22.21	546 ^{abc}	96.79 ^{a}	29.89 ^{fg}	118 ^{ef}	1.390 ^{abc}	20.69 ^{bcde}
12	IN6	22.21	567 ^{ab}	95.09 ^{a}	69.78 ^{abc}	265 ^{abc}	1.330 ^{bcde}	21.45 ^{bc}
13	TQ2	22.21	566 ^{ab}	95.12 ^{a}	82.53 ^{a}	297 ^{ab}	1.201 ^{fgh}	19.24 ^{cdefg}
14	TQ4	22.21	531 ^{abc}	95.75 ^{a}	45.33 ^{cdefg}	153 ^{def}	1.213 ^{efgh}	19.07 ^{cdefg}
15	TQ6	22.21	443 ^{bc}	90.46 ^{a}	81.33 ^{a}	277 ^{abc}	1.200 ^{fgh}	19.35 ^{cdefg}
16	TQ8	22.21	523 ^{abc}	95.25 ^{a}	61.00 ^{abcde}	200 ^{bcde}	1.151 ^{ghi}	17.93 ^{g}
17	TQ10	22.21	524 ^{abc}	94.83 ^{a}	82.67 ^{a}	310 ^{a}	1.326 ^{bcde}	20.12 ^{cdefg}
18	TQ12	22.21	392 ^{c}	79.52 ^{a}	21.72 ^{g}	62 ^{f}	1.076 ^{i}	23.85 ^{a}
19	HQ2	22.21	542 ^{abc}	92.93 ^{a}	36.56 ^{efg}	142 ^{def}	1.306 ^{cdef}	22.54 ^{ab}
20	HQ4	22.21	577 ^{ab}	92.68 ^{a}	74.31 ^{ab}	323 ^{a}	1.400 ^{abc}	20.16 ^{cdefg}
21	HQ6	22.21	589 ^{ab}	92.40 ^{a}	52.11 ^{bcdef}	182 ^{cde}	1.250 ^{defg}	20.12 ^{cdefg}
22	VN2	22.00	575 ^{ab}	83.75 ^{a}	84.31 ^{a}	307 ^{a}	1.201 ^{efgh}	19.43 ^{cdefg}

Note: Values in the column followed by the same letter is not significantly different at the 0.05 probability level by Tukey's test.

VN2, TQ6, VN7, TQ1, TQ2, TQ10 silkworm races had silkworm survival above 80%, indicating that these silkworm races are more resilient to high temperature and humidity compare to other races. TQ12 has lowest survival, cocoon yield and cocoon shell rate with the difference being statistically signficant.

Table 6. Traits of silk quality of silkworm races under high temperature and humidity condition

No.	Races	Filament length (m)	Percentage of reelability (%)	Raw silk percentage (%)	Rendital (kg)
1	TQ1	511	52.04	13.06	7.66
2	TQ3	674	60.94	13.31	7.50
3	TQ5	595	79.59	14.20	7.04
4	TQ7	681	81.70	12.13	8.25
5	TQ9	790	79.59	14.33	6.98
6	IN1	-	-	-	-
7	IN3	714	46.43	12.01	8.33
8	IN5	-	-	-	-
9	VN7	496	61.67	10.80	9.26
10	IN2	-	-	-	-
11	IN4	641	56.52	10.95	9.14
12	IN6	781	52.05	15.05	6.64
13	TQ2	477	50.00	14.31	6.99
14	TQ4	644	46.43	13.14	7.61
15	TQ6	652	78.00	13.20	7.58
16	TQ8	686	48.72	11.83	8.47
17	TQ10	735	56.52	12.91	7.75
18	TQ12	727	32.61	13.45	7.44
19	HQ2	-	-	-	-
20	HQ4	772	56.52	12.13	8.24
21	HQ6	653	52.70	12.50	8.00
22	VN2	499	45.78	13.38	8.79

Under high temperature and humidity conditions, the silk quality index was lower compared to standard conditions. The percentage of reelability decreased, mostly below 80%, except TQ7 (81.70%). Varieties with low renditial (<7.6) included TQ5, TQ9, I6, TQ2, TQ6, TQ12.

Table 7. Evaluation Index Values of Selected Traits under high temperature and humidity conditions

No.	Races	Survival rate	Cocoon yield	Whole cocoon weight	Filament length	Percentage of reelability	Average	Rank
1	TQ1	59.48	57.52	45.08	57.52	45.08	48.79	10
2	TQ3	54.21	58.18	58.50	58.18	58.50	55.10	6
3	TQ5	54.49	56.19	52.95	56.19	52.95	54.78	8
4	TQ7	55.80	59.28	55.26	59.28	55.26	58.14	2
5	TQ9	51.33	50.90	49.31	50.90	49.31	56.26	4
6	IN1	37.07	42.30	63.13	42.30	63.13	28.50	20
7	IN3	50.84	56.19	66.32	56.19	66.32	54.29	9
8	IN5	39.20	41.19	63.60	41.19	63.60	28.80	19
9	VN7	59.31	55.97	39.74	55.97	39.74	48.48	13
10	IN2	35.67	35.68	48.48	35.68	48.48	23.97	22
11	IN4	34.62	36.56	60.00	36.56	60.00	45.86	16
12	IN6	53.72	55.97	55.39	55.97	55.39	54.79	7
13	TQ2	59.83	60.17	45.47	60.17	45.47	48.49	12
14	TQ4	42.02	41.19	46.40	41.19	46.40	44.14	17
15	TQ6	59.26	57.52	45.40	57.52	45.40	55.39	5
16	TQ8	49.52	47.37	41.58	47.37	41.58	47.09	15
17	TQ10	59.90	61.93	55.05	61.93	55.05	56.88	3
18	TQ12	30.71	29.06	35.86	29.06	35.86	37.00	18
19	HQ2	37.81	39.65	53.55	39.65	53.55	26.20	21
20	HQ4	55.89	63.69	60.80	63.69	60.80	58.32	1
21	HQ6	45.26	44.94	49.26	44.94	49.26	47.20	14
22	VN2	60.69	61.49	45.47	61.49	45.47	48.76	11

The average EI value above 50 was recorded in HQ4 (58.32), TQ7 (56.26), TQ10 (56.88), TQ9 (56.26), TQ6 (55.39), TQ3 (55.10), IN6 (54.79), TQ5 (54.78) and IN3 (54.29).

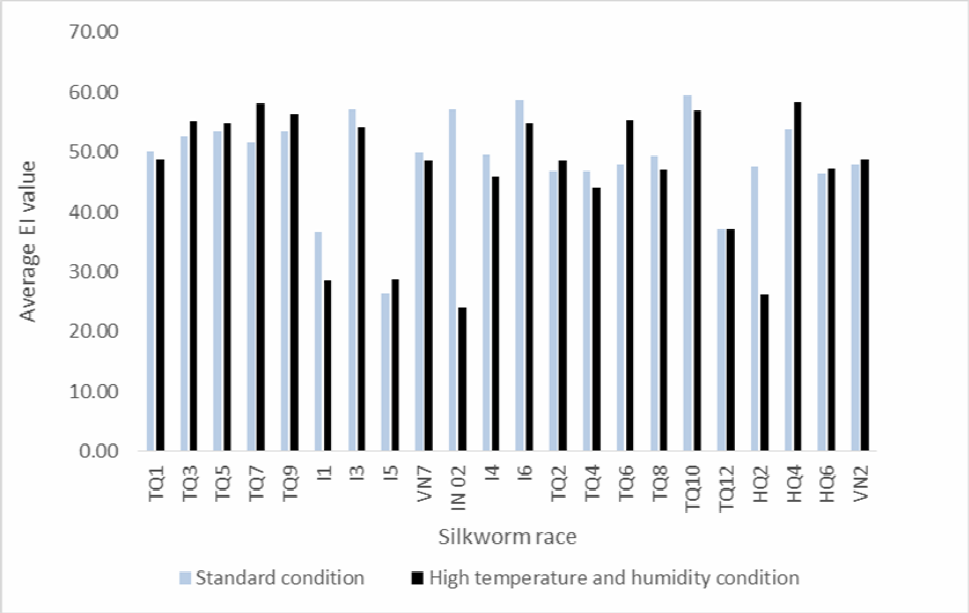

Figure 1. Average EI value of silkworm races under standard and high temperature and humidity condition

Under two different conditions, the silkworm races with EI value above 50 were TQ3, TQ5, TQ7, TQ9, I6, TQ10 and HQ4.

4. CONCLUSION

Under standard rearing condition, TQ10, IN6, IN3, IN2, HQ4, TQ9, TQ5, TQ3, TQ7 and TQ1 exhibited high reelibility, low rendital and great EI value, making them a potential source of as materials for creating high-quality cocoon silk breeds.

VN2, TQ6, VN7, TQ1, TQ2 and TQ10 silkworm breeds were survival rate greater 80%. Race with EI>50 included HQ4, TQ7, TQ10, TQ9, TQ6, TQ3, IN6, TQ5 and IN3. These silkworm races can be used as materials for developing new hybrid with high silkworm survival rates.

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