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Full Length Research Paper

Study of thirty-one economically important traits in twenty silkworm *Bombyx mori* varieties

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The aim of this experiment was to study thirty-one economically important traits in twenty silkworm *Bombyx mori* breeds varieties. These varieties included 31, 1005, 113 (2029), 153 (Xihang-1), 5118 × 10133-3-3, F6 × 101, 1433-15, 1126 (111), 113-K, 1003-4, M2-6-18 (109), M2-6-22 (107), 151 (103 × M-1-1), Xihang 2/3, M-1-1 × 103, 7409, 107-K, 103, T5-M and 101433-1-4. Rearing of young silkworm instars was performed by feeding with chopped leaves and by using paraffin paper as a coverage while to the last instars, entire leaves and branches were administered. Rice straw was used as cocoon frames for spinning in each replication separately. Seven days after the starting of cocoon spinning, obtained cocoons were gathered and sorted on the basis of form, thickness, clarity, etc., into four classes including good, middle, double and low cocoons. The ratio of each cocoon class was calculated for each replication separately. The data obtained for different parameters were subjected to analysis of variance (ANOVA) to determine if the differences found among treatments were significant. Following ANOVA, Tukey's studentized range test in a complete randomized design was used at $p < 0.05$. **Obtained results showed that among studied varieties, the highest level of percentage of hatchability was observed in 107-K (97.77%), while 1003-4 variety (63.07%) remained at lower level than other varieties. Meanwhile, among studied varieties, the highest level of good cocoon number belonged to Xihang-1 (328.33), and 109 variety (159.67) remained at the lowest level with respect to other varieties (p < 0.05). Also, the highest level of good cocoon weight belonged to 1003-4 (341.83 g) and 7409 variety (194.09 g) remained at the lowest level in comparison to other varieties (p < 0.05). Finally, it is shown that the highest level of cocoon shell percentage belonged to 111 (1126) (23.11%) and 113-k variety (18.10%) remained at the lowest level as compared to other varieties (p < 0.05).**

Key words: Silkworm, performance, germplasm, cocoon, fecundity, disease.

INTRODUCTION

Silkworm have a large role in rural life in many countries being an insect of economic importance. Silkworm produces silk as high quality fiber and silk fabrics are highly attractive. There are different lines and strains for silk production.

Production of cocoon and raw silk are affected by several factors, such as genetic potential of commercial varieties, quality of silkworm eggs, pests and diseases incidence, quality of mulberry leaves, weather, breeding and management plans and silk reeling methods (Bizhannia and Seidavi, 2008).

Researchers should investigate and compare productive potential of various varieties and select the high productive lines in order to perform hybridization. Rahman and Rahman (1990) studied genetic potential of 36 varieties during four rearing seasons, and found that these varieties have high heritability and different genotypes have high genetic diversity that can be used for breeding programs. The importance and role of additive gene effects on phenotype selection in these traits were also emphasized.

There are many researches about genetics, feeding and performance in silkworm and other insects (Chaudhuri, 2003; Hajarika et al., 2003; Reddy, 2010; Yadav and Mahobiam, 2010). Rayar et al. (1989) studied the structure of genetic variation of 18 economical traits in 29 silkworm varieties and found larval weight, larval duration, cocoon shell weight and length of fiber to have high heritability.

some silkworm varieties of Iran gene bank is unknown, thus to study 31 economically important traits in twenty silkworm *Bombyx mori* varieties was the aim of this experiment.

MATERIALS AND METHODS

Twenty studied silkworm varieties were used in the present study. These varieties included 31, 1005, 113 (2029), 153 (Xihang-1), 5118 × 10133-3-3, F6 × 101, 1433-15, 1126 (111), 113-K, 1003-4, M2-6-18 (109), M2-6-22 (107), 151 (103 × M-1-1), Xihang 2/3, M-1-1 × 103, 7409, 107-K, 103, T5-M and 101433-1-4. This study was conducted in Islamic Azad University, Rasht Branch, Iran during 2010. This experiment was performed to study the productive and economical traits of these twenty silkworm varieties. Silkworm egg of twenty varieties was provided by Iran Silkworm Research Center (ISRC). Rearing was standard conducted following rearing technology. It was applied in a favorable conditions for larva rearing, such as 25 to 28°C and 75 to 85% relative humidity. After egg hatching, every group was bred separately under standard situations (ESCAP, 1993). Rearing in young silkworm instars was performed by chopped leaves and by using paraffin paper as a coverage, while to the last instars entire leaves and branches were administered. Rice straw was used as cocoon frames for spinning in each replication separately. Seven days after starting of cocoon spinning, obtained cocoons were gathered and sorted on the basis of form, thickness, clarity, etc., into four classes, including good, middle, double and low cocoons. The ratio of each cocoon class was calculated for each replication separately. Furthermore, it was investigated on the health or disease of the total obtained pupae, after which the ratio of each class cocoon disease was calculated for each replication separately. Cocoon weight for good and double cocoons was recorded. All records were conducted on the 8th day of cocoon spinning. Recorded traits were compared between six studied native groups.

Recorded traits for this study were number of produced eggs, number of healthy eggs, number of the unfertilized and dead eggs, number of the dead newly-born larvae, percentage of hatchability, good cocoon number, weight, percentage, mortality, middle cocoon number, percentage, mortality, low cocoon number, percentage, mortality, double cocoon number, weight, percentage, mortality, total mortality, female cocoon weight, shell weight, shell percentage, male cocoon weight, shell weight, shell percentage, average of cocoon weight, sum of cocoon weight for male and female, average of shell cocoon weight, sum of shell cocoon weight and cocoon shell percentage. The number of considered individuals in order to determine any of the aforementioned parameters were 25 male and female individuals.

These parameters were measured using standard protocols (ESCAP, 1993). Furthermore, data above 70% or below 30% undergone inverse sine transformation ($Z = \text{Arcsin } P_{ij}^{½}$) and data between 0 and 1, undergone square transformation ($P^{½}$). The data were subjected to analysis of variance (ANOVA) to determine if the differences found between treatments and the differences within the same treatments were significant. In addition to the analysis of variance, Tukey's studentized range (HSD) test in a complete randomized design was used at $p < 0.05$.

RESULTS AND DISCUSSION

Number of produced eggs

Obtained results are summarized in Tables 1-5. The obtained results showed that the number of produced eggs in the twenty studied varieties was between 307 and 575. The highest amount of produced eggs belonged to 1005 (575), while 1003-4 variety (307) recorded a lower level than other varieties. Meanwhile, statistical differences among studied varieties for this trait were significant ($p < 0.05$).

Number of healthy eggs

The obtained results showed that the number of the healthy eggs in the twenty studied varieties was between 388 and 516. The highest amount of healthy eggs belonged to 113 [2029] (516), and 1005 variety (388) performed at a lower level than other varieties. Meanwhile, statistical differences among studied varieties for this trait were significant ($p < 0.05$) (Table 1).

Number of unfertilized and dead eggs

The obtained results showed that the number of the unfertilized and dead eggs in the twenty studied varieties was between 3 and 74. The highest number of unfertilized and dead eggs belonged to 151 (74) and the lowest to the Xihang-1 variety (3). Meanwhile, statistical differences among studied varieties for this trait were not significant ($p > 0.05$).

Number of dead newly-born larvae

The obtained results showed that the number of the dead hatched eggs in the twenty studied varieties was between 3.67 and 31.67. Among the studied varieties, the highest level of the number of dead hatched eggs belonged to M-1-1 × 103 (31.67), and 15-1433 variety (3.67) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Percentage of hatchability

The obtained results showed that the amount of percentage of hatchability in the twenty studied varieties was between 63.07 and 97.77%. Among the studied varieties, the highest level of percentage of hatchability belonged to 107 (97.77%), and 4-1003 variety (63.07%) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Good cocoon number

The obtained results showed that the amount of good

Table 1. Mean comparison (± SEM) of productive parameters in twenty studied silkworm varieties.

Variety	Parameter					
	Number of produced eggs	Number of the healthy eggs	Number of the unfertilized and dead eggs	Number of the dead hatched eggs	Percentage of hatchability (%)	Good cocoon Number
31	428.67 ± 45.32[ab]	412.67 ± 43.90[abc]	3.67 ± 1.76[c]	12.33 ± 2.03[c]	97.10 ± 0.17[a]	291.67 ± 31.22[ab]
1005	574.67 ± 28.54[a]	494.67 ± 42.78[ab]	12.00 ± 8.02[c]	68.00 ± 38.03[ab]	88.23 ± 6.55[a]	164.67 ± 18.27[c]
113 (2029)	553.33 ± 39.19[a]	515.33 ± 36.86[a]	5.00 ± 1.00[c]	33.00 ± 8.14[bc]	95.67 ± 1.56[a]	221.67 ± 13.57[abc]
153 (Xihang-1)	480.33 ± 43.94[ab]	455.67 ± 53.80[abc]	3.00 ± 2.08[c]	21.33 ± 10.04[c]	95.07 ± 2.75[a]	328.33 ± 102.81[a]
5118×10133-3-3	481.33 ± 71.95[ab]	436.00 ± 71.04[abc]	13.33 ± 4.91[c]	32.00 ± 3.61[bc]	93.00 ± 0.50[a]	225.00 ± 12.49[abc]
F6×101	532.77 ± 32.38[a]	479.09 ± 47.66[abc]	6.52 ± 0.87[c]	47.16 ± 14.43[abc]	90.70 ± 3.36[a]	291.47 ± 49.95[ab]
1433-15	470.33 ± 89.70[ab]	436.67 ± 94.27[abc]	3.67 ± 2.03[c]	30.00 ± 3.00[c]	92.83 ± 1.68[a]	224.00 ± 14.11[abc]
1126 (111)	468.00 ± 37.32[ab]	414.33 ± 42.27 [abc]	13.67 ± 5.17[c]	40.00 ± 3.61[abc]	90.97 ± 1.41[a]	166.33 ± 20.48[c]
113-K	514.67 ± 26.35[ab]	460.33 ± 30.37[abc]	18.00 ± 6.08[c]	45.33 ± 14.17[abc]	91.00 ± 3.02[a]	205.33 ± 36.15[ab]
1003-4	307.00 ± 158.80[b]	283.67 ± 146.3[c]	7.00 ± 3.79[c]	16.33 ± 8.76[c]	63.07 ± 31.53[b]	266.67 ± 38.99[abc]
M2-6-18 (109)	384.67 ± 14.62[ab]	366.00 ± 13.61[abc]	6.67 ± 0.33[c]	12.00 ± 1.53[c]	96.80 ± 0.35[a]	159.67 ± 25.83[c]
M2-6-22 (107)	428.00 ± 16.04[ab]	412.33 ± 14.77[abc]	19.00 ± 11.14[c]	10.33 ± 2.85[bc]	97.77 ± 0.68[a]	177.33 ± 9.39[ab]
151 (103×M-1-1)	458.43 ± 1.33[ab]	309.64 ± 0.90[bc]	74.39 ± 0.22[a]	74.39 ± 0.22[a]	81.03 ± 0.23[ab]	173.92 ± 0.50[ab]
Xihang 2/3	448.67 ± 61.58[ab]	401.67 ± 63.17[abc]	16.33 ± 9.06[c]	30.67 ± 10.17[c]	93.23 ± 1.78[a]	250.00 ± 23.97[abc]
M-1-1×103	460.00 ± 12.90[ab]	381.00 ± 0.58[abc]	31.67 ± 5.46[b]	44.67 ± 10.17[abc]	89.00 ± 1.59[a]	253.00 ± 18.01[abc]
7409	468.67 ± 26.64[ab]	441.67 ± 20.17[abc]	7.00 ± 2.65[c]	20.67 ± 5.93[c]	95.90 ± 1.40[c]	201.00 ± 49.80[ab]
107-K	447.33 ± 65.05[ab]	420.33 ± 65.86[abc]	6.33 ± 1.33[c]	20.67 ± 1.20[c]	95.07 ± 0.80[a]	177.00 ± 2.65[ab]
103	446.67 ± 44.18[ab]	418.00 ± 42.55[abc]	6.33 ± 2.85[c]	22.33 ± 6.17[c]	94.93 ± 1.36[a]	230.67 ± 11.14[abc]
T5-M	459.67 ± 62.61[ab]	432.00 ± 64.58[abc]	9.67 ± 0.88[c]	18.33 ± 3.53[c]	95.57 ± 1.49[a]	216.00 ± 38.43[abc]
101433-1-4	382.33 ± 66.79[ab]	331.00 ± 63.10[abc]	6.33 ± 1.86[c]	21.00 ± 10.60[c]	92.57 ± 4.80[a]	204.68 ± 13.30[bc]

*Means in each row followed by the same letters are not significantly different at $p < 0.05$.

cocoon number in the twenty studied varieties was between 159.67 and 328.33. Among the studied varieties, the highest level of good cocoon number belonged to Xihang-1 (328.33), and 109 variety (159.67) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Good cocoon weight

The obtained results showed that the amount of good cocoon weight in the twenty studied varieties was between 194.09 and 341.83 g. Among the studied varieties, the highest level of good cocoon weight belonged to 4-1003 (341.83 g), and [7409] variety (194.09 g) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Middle cocoon number

The obtained results showed that the amount of middle cocoon number in the twenty studied

Table 2. Mean comparison (± SEM) of productive parameters in twenty studied silkworm varieties.

Variety	Parameter					
	Good cocoon weight (g)	Good cocoon percentage (%)	Good cocoon mortality (%)	Middle cocoon Number	Middle cocoon percentage (%)	Middle cocoon mortality (%)
31	339.52 ± 23.43^{a}	86.30 ± 0.57^{de}	12.73 ± 3.21^{cde}	36.33 ± 7.17^{cd}	10.50 ± 1.08^{de}	1.00 ± 0.30^{a}
1005	237.69 ± 4.13^{bcd}	78.17 ± 0.85^{abc}	9.23 ± 1.53^{de}	39.00 ± 2.52^{cd}	18.77 ± 1.24^{bcde}	7.47 ± 1.23^{a}
113 (2029)	241.36 ± 15.97^{bcd}	85.93 ± 4.37^{a}	27.93 ± 5.56^{a}	30.67 ± 9.74^{d}	11.93 ± 3.83^{cde}	4.07 ± 0.95^{a}
153 (Xihang-1)	283.75 ± 24.83^{ab}	78.00 ± 5.52^{abc}	6.63 ± 1.69^{e}	71.00 ± 4.04^{abc}	19.60 ± 4.67^{bcde}	2.83 ± 1.44^{a}
5118×10133-3-3	277.14 ± 16.71^{abc}	78.77 ± 6.90^{a}	20.80 ± 5.37^{abcd}	59.00 ± 26.63^{bcd}	19.13 ± 6.8^{bcde}	2.83 ± 0.54^{a}
F6×101	337.77 ± 41.09^{a}	84.88 ± 2.15^{e}	15.15 ± 1.62^{bcde}	32.11 ± 1.74^{cd}	9.88 ± 0.95^{e}	2.86 ± 0.43^{a}
1433-15	229.88 ± 4.36^{bcd}	79.93 ± 0.92^{abc}	23.00 ± 4.32^{abc}	45.67 ± 5.84^{cd}	16.20 ± 1.54^{cde}	5.93 ± 1.33^{a}
1126 (111)	218.77 ± 20.06^{bcd}	76.87 ± 2.35^{abc}	24.60 ± 6.35^{abc}	40.33 ± 7.17^{cd}	18.30 ± 1.12^{bcde}	8.67 ± 3.97^{a}
113-K	228.61 ± 38.37^{bcd}	68.23 ± 1.19^{a}	13.90 ± 1.40^{abcde}	84.67 ± 12.14^{ab}	28.43 ± 0.58^{ab}	2.40 ± 0.98^{a}
1003-4	341.15 ± 34.56^{a}	84.47 ± 3.32^{ab}	8.33 ± 1.52^{de}	39.67 ± 20.58^{cd}	10.63 ± 5.33^{de}	1.77 ± 1.11^{a}
M2-6-18 (109)	198.99 ± 30.04^{cd}	65.03 ± 4.91^{a}	12.07 ± 0.43^{cde}	71.00 ± 11.14^{abc}	29.47 ± 4.54^{ab}	5.90 ± 2.16^{a}
M2-6-22 (107)	223.67 ± 4.01^{bcd}	77.23 ± 4.71^{bcde}	14.60 ± 0.2^{bcde}	47.00 ± 12.10^{bcd}	19.67 ± 3.84^{bcde}	3.40 ± 0.46^{a}
151 (103×M-1-1)	242.92 ± 0.70^{bcd}	73.39 ± 0.21^{bcd}	18.50 ± 0.05^{abcde}	54.29 ± 0.16^{bcd}	22.92 ± 0.07^{bc}	2.51 ± 0.01^{a}
Xihang 2/3	276.94 ± 22.85^{abc}	79.73 ± 1.47^{abc}	27.93 ± 4.05^{a}	61.00 ± 10.54^{bcd}	19.17 ± 1.37^{bcde}	5.80 ± 0.17^{a}
M-1-1×103	288.78 ± 11.52^{ab}	84.07 ± 1.71^{ab}	6.43 ± 3.83^{e}	37.67 ± 8.4^{cd}	12.50 ± 2.5^{cde}	1.73 ± 0.78^{ab}
7409	194.41 ± 21.16^{d}	74.07 ± 6.61^{a}	26.23 ± 7.71^{ab}	53.33 ± 6.36^{bcd}	21.63 ± 5.12^{bcd}	7.13 ± 2.13^{a}
107-K	227.09 ± 10.69^{bcd}	62.77 ± 5.05^{a}	5.67 ± 2.88^{e}	99.67 ± 24.10^{a}	34.00 ± 5.35^{a}	3.17 ± 0.47^{a}
103	272.49 ± 19.32^{abcd}	75.03 ± 1.10^{bcde}	13.40 ± 3.53^{bcde}	65.33 ± 8.37^{abcd}	21.20 ± 2.33^{bcde}	3.90 ± 1.82^{a}
T5-M	229.49 ± 35.97^{bcd}	82.80 ± 3.63^{ab}	15.67 ± 6.32^{abcde}	34.33 ± 1.33^{cd}	14.07 ± 2.72^{cde}	4.07 ± 1.87^{a}
101433-1-4	287.03 ± 24.14^{ab}	83.63 ± 0.51^{ab}	5.87 ± 0.84^{e}	34.62 ± 2.60^{cd}	14.10 ± 0.21^{cde}	2.11 ± 0.92^{a}

*Means in each row followed by the same letters are not significantly different at $p < 0.05$.

varieties was between 30.67 and 99.67. Among the studied varieties, the highest level of middle cocoon number belonged to K-107 (99.67), and [2029] 113 variety (30.67) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Middle cocoon mortality

The obtained results showed that the amount of middle cocoon mortality in the twenty studied varieties was between 1.00 and 8.67. Among the studied varieties, the highest level of middle cocoon mortality belonged to [111] 1126 (8.67 mg/dl), and [31] variety (1.00 mg/dl) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were not significant ($p > 0.05$).

Middle cocoon percentage

The obtained results showed that the amount of

Table 3. Mean comparison (±SEM) of productive parameters in twenty studied silkworm varieties.

Variety	Parameter					
	Low cocoon number	**Low cocoon percentage (%)**	**Low cocoon mortality (%)**	**Double cocoon number**	**Double cocoon weight (g)**	**Double cocoon percentage (%)**
31	6.00 ± 1.73^{bc}	1.80 ± 0.50^{bc}	1.77 ± 0.48^{abc}	4.33 ± 0.33^{bcde}	10.28 ± 0.88^{abcd}	1.33 ± 0.28^{bcd}
1005	5.00 ± 1.53^{bc}	2.37 ± 0.67^{bc}	2.33 ± 0.68^{abc}	1.67 ± 1.20^{cde}	4.54 ± 2.95^{cd}	0.73 ± 0.47^{cd}
113 (2029)	2.67 ± 0.33^{bc}	1.03 ± 0.12^{c}	1.00 ± 0.10^{abc}	2.67 ± 1.20^{bcde}	6.19 ± 2.56^{cd}	1.03 ± 0.45^{bcd}
153 (Xihang-1)	6.67 ± 3.48^{bc}	1.87 ± 1.28^{bc}	1.87 ± 1.28^{abc}	2.00 ± 1.15^{cde}	4.87 ± 2.85^{cd}	0.50 ± 0.36^{cd}
5118×10133-3-3	5.67 ± 1.33^{bc}	1.97 ± 0.49^{bc}	1.83 ± 0.38^{ab}	0.33 ± 0.33^{e}	0.83 ± 0.83^{d}	0.13 ± 0.13^{cd}
F6×101	16.05 ± 1.73^{a}	5.27 ± 1.30^{a}	3.76 ± 2.17^{abc}	1.00 ± 0.58d^{e}	1.87 ± 1.08^{d}	0.25 ± 0.14^{cd}
1433-15	6.33 ± 0.88^{bc}	2.30 ± 0.44^{bc}	2.27 ± 0.46^{a}	4.33 ± 1.20^{bcde}	8.61 ± 2.02b^{cd}	1.53 ± 0.42^{bcd}
1126 (111)	10.00 ± 4.04^{ab}	4.17 ± 1.27^{ab}	4.13 ± 1.24^{abc}	1.67 ± 1.67^{cde}	4.28 ± 4.28^{cd}	0.62 ± 0.62^{cd}
113-K	8.33 ± 2.85^{bc}	2.90 ± 0.95^{abc}	1.87 ± 0.30^{abc}	1.33 ± 0.88^{de}	3.56 ± 2.65^{d}	0.37 ± 0.23^{cd}
1003-4	4.67 ± 4.67^{bc}	1.13 ± 1.13^{c}	1.10 ± 1.10^{abc}	2.33 ± 1.86^{cde}	6.83 ± 5.71^{cd}	0.67 ± 0.57^{cd}
M2-6-18 (109)	7.33 ± 0.88^{bc}	3.00 ± 0.35^{abc}	3.00 ± 0.35^{abc}	6.00 ± 0.58^{abc}	15.14 ± 1.84^{abc}	2.43 ± 0.03^{abc}
M2-6-22 (107)	6.00 ± 3.21^{bc}	2.43 ± 1.26^{bc}	2.40 ± 1.23^{abc}	1.33 ± 0.88^{de}	3.73 ± 2.42^{cd}	0.67 ± 0.48^{cd}
151 (103×M-1-1)	3.02 ± 0.01^{bc}	1.31 ± 0.00^{bc}	1.21 ± 0.00^{abc}	7.04 ± 0.02^{ab}	20.06 ± 0.06^{a}	3.02 ± 0.01^{ab}
Xihang 2/3	2.67 ± 1.33^{bc}	0.87 ± 0.45^{c}	0.87 ± 0.45^{abc}	0.67 ± 0.67^{e}	1.92 ± 1.92^{d}	0.20 ± 0.20^{cd}
M-1-1×103	9.00 ± 3.79^{bc}	2.97 ± 1.16^{abc}	3.00 ± 1.14^{abc}	1.33 ± 0.67^{de}	2.99 ± 1.50^{d}	0.40 ± 0.20^{cd}
7409	1.67 ± 0.33^{c}	0.63 ± 0.15^{c}	0.60 ± 0.15^{abc}	9.00 ± 2.89^{a}	18.56 ± 8.17^{ab}	3.60 ± 1.52^{a}
107-K	5.67 ± 1.20^{bc}	1.92 ± 0.26b^{c}	1.90 ± 0.26^{abc}	3.33 ± 1.45^{bcde}	8.40 ± 4.03^{bcd}	1.23 ± 0.58^{bcd}
103	6.00 ± 1.53^{bc}	1.97 ± 0.50b^{c}	1.73 ± 0.66^{abc}	5.33 ± 2.60^{abcd}	11.88 ± 6.50^{abcd}	1.80 ± 0.87^{bcd}
T5-M	5.00 ± 2.00^{bc}	2.23 ± 1.23b^{c}	2.23 ± 1.23^{abc}	2.33 ± 1.86^{cde}	2.09 ± 1.26^{d}	0.83 ± 0.69^{cd}
101433-1-4	5.02 ± 1.73^{bc}	2.16 ± 0.84b^{c}	1.81 ± 1.04^{abc}	1.00 ± 0.58^{de}	3.04 ± 1.75^{d}	0.35 ± 0.20^{cd}

*Means in each row followed by the same letters are not significantly different at $p < 0.05$.

middle cocoon percentage in the twenty studied varieties was between 1.00 and 8.67. Among the studied varieties, the highest level of middle cocoon mortality belonged to [111] 1126 (8.67 mg/dl), and [31] variety (1.00 mg/dl) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were not significant ($p > 0.05$).

Low cocoon number

The obtained results showed that the amount of low cocoon percentage in the twenty studied varieties was between 0.63 and 16.05. Among the studied varieties, the highest level of low cocoon percentage belonged to F6 × 101 (16.05), and [7409] variety (0.63) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were not significant ($p > 0.05$).

Low cocoon percentage

The obtained results showed that the amount of low cocoon mortality in the twenty studied

Table 4. Mean comparison (± SEM) of productive parameters in twenty studied silkworm varieties.

Variety	Parameter					
	Double cocoon mortality (%)	Total mortality (%)	Female cocoon weight	Female cocoon shell weight	Female cocoon shell percentage (%)	Male cocoon weight
31	0.67 ± 0.44^{bc}	16.17 ± 3.07^{e}	1.42 ± 0.13^{bcd}	0.27 ± 0.01^{bcd}	19.38 ± 1.38^{bc}	1.20 ± 0.03^{abc}
1005	0.27 ± 0.27^{bc}	19.30 ± 2.32^{cde}	1.60 ± 0.06^{abc}	0.30 ± 0.02^{abc}	18.77 ± 0.77^{bcde}	1.34 ± 0.04^{ab}
113 (2029)	0.63 ± 0.63^{bc}	33.63 ± 3.96^{abcd}	1.35 ± 0.02^{d}	0.25 ± 0.01^{cd}	18.68 ± 0.49^{bcde}	1.13 ± 0.01^{c}
153 (Xihang-1)	0.20 ± 0.20^{bc}	11.57 ± 3.54^{e}	1.43 ± 0.10^{abcd}	0.26 ± 0.02c^{d}	17.95 ± 0.42^{bcdef}	1.18 ± 0.07^{bc}
5118×10133-3-3	0.13 ± 0.13^{bc}	7.57 ± 7.37^{e}	1.42 ± 0.13^{bcd}	0.27 ± 0.04^{bcd}	19.04 ± 0.87^{bcde}	1.21 ± 0.11^{abc}
F6×101	0.25 ± 0.14^{bc}	22.02 ± 0.84^{bcde}	1.45 ± 0.07^{abcd}	0.28 ± 0.02^{bcd}	19.32 ± 0.32^{bcd}	1.23 ± 0.08^{abc}
1433-15	1.20 ± 0.80^{bc}	32.40 ± 5.89^{abcd}	1.32 ± 0.07^{d}	0.23 ± 0.01^{d}	17.64 ± 0.27^{cdef}	1.11 ± 0.06^{c}
1126 (111)	0.83 ± 0.83^{bc}	38.23 ± 8.25^{a}	1.62 ± 0.06^{ab}	0.35 ± 0.01^{a}	21.62 ± 0.22^{a}	1.27 ± 0.03^{abc}
113-K	0.10 ± 0.10^{bc}	18.27 ± 2.64^{de}	1.41 ± 0.06^{bcd}	0.24 ± 0.01^{d}	16.75 ± 0.43^{f}	1.19 ± 0.05^{bc}
1003-4	0.17 ± 0.09^{bc}	8.33 ± 5.17^{e}	1.44 ± 0.09^{abcd}	0.25 ± 0.02^{cd}	17.63 ± 0.47^{cdef}	1.25 ± 0.07^{abc}
M2-6-18 (109)	1.63 ± 0.41^{ab}	22.57 ± 3.01^{bcde}	1.43 ± 0.07^{abcd}	0.27 ± 0.02^{bcd}	19.15 ± 0.33^{bcd}	1.22 ± 0.03^{abc}
M2-6-22 (107)	0.33 ± 0.33^{bc}	20.73 ± 1.23^{cde}	1.43 ± 0.05^{abcd}	0.26 ± 0.01^{cd}	18.44 ± 0.30^{bcdef}	1.20 ± 0.05^{c}
151 (103×M-1-1)	0.40 ± 0.00^{bc}	22.62 ± 0.07^{bcde}	1.62 ± 0.00^{ab}	0.31 ± 0.00^{abc}	19.17 ± 0.06^{bcd}	1.34 ± 0.00^{ab}
Xihang 2/3	0.10 ± 0.10^{bc}	34.70 ± 4.51^{abc}	1.39 ± 0.05^{bcd}	0.25 ± 0.01^{cd}	18.16 ± 0.31^{bcdef}	1.09 ± 0.02^{c}
M-1-1×103	0.30 ± 0.30^{bc}	11.47 ± 2.90^{e}	1.30 ± 0.06^{d}	0.26 ± 0.01^{cd}	19.74 ± 0.16^{b}	1.11 ± 0.01^{c}
7409	2.83 ± 0.82^{a}	36.80 ± 5.88^{ab}	1.32 ± 0.08^{d}	0.26 ± 0.02^{cd}	19.71 ± 0.35^{b}	1.09 ± 0.05^{c}
107-K	0.47 ± 0.12b^{c}	11.20 ± 3.16^{e}	1.44 ± 0.04^{abcd}	0.25 ± 0.01^{cd}	17.45 ± 0.16^{def}	1.23 ± 0.04^{abc}
103	0.57 ± 0.43^{bc}	19.13 ± 5.85^{cde}	1.37 ± 0.04^{cd}	0.23 ± 0.00^{d}	17.16 ± 0.35^{ef}	1.17 ± 0.02^{bc}
T5-M	0.83 ± 0.69^{bc}	22.53 ± 9.17^{bcde}	1.27 ± 0.05^{d}	0.24 ± 0.02d	18.41 ± 0.81^{bcdef}	1.16 ± 0.08^{bc}
101433-1-4	0.00 ± 0.00^{bc}	9.78 ± 0.95^{e}	1.66 ± 0.03^{a}	0.33 ± 0.01^{ab}	19.64 ± 0.22^{b}	1.37 ± 0.05^{a}

*Means in each row followed by the same letters are not significantly different at $p < 0.05$.

varieties was between 0.63 is 5.27%. Among the studied varieties, the highest level of low cocoon mortality belonged to F6 × 101 (5.27%), and [7409] variety (0.63%) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Low cocoon mortality

The obtained results showed that the amount of low cocoon mortality in the twenty studied varieties was between 0.6 and 4.13%. Among the studied varieties, the highest level of low cocoon mortality belonged to [111] 1126 (4.13%), and [7409] variety (0.60%) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were not significant ($p < 0.05$).

Double cocoon number

The obtained results showed that the amount of

Table 5. Mean comparison (± SEM) of productive parameters in twenty studied silkworm varieties.

Variety	Parameter						
	Male cocoon shell weight (g)	Male cocoon shell percentage (%)	Average of cocoon weight (g)	Sum of cocoon weight for male and female (g)	Average of shell cocoon weight (g)	Sum of shell cocoon weight (g)	Cocoon shell percentage (%)
31	0.25 ± 0.01[cd]	21.00 ± 0.50[cd]	1.31 ± 0.08[bcd]	2.62 ± 0.15[bcd]	0.26 ± 0.01[bcd]	0.52 ± 0.02[cd]	20.03 ± 0.96[cd]
1005	0.31 ± 0.02[d]	23.05 ± 1.05[abc]	1.47 ± 0.05[ab]	2.93 ± 0.10[ab]	0.30 ± 0.02[ab]	0.61 ± 0.04[abc]	20.70 ± 0.74[abc]
113 (2029)	0.25 ± 0.01[cd]	22.21 ± 0.66[abcd]	1.24 ± 0.02[d]	2.48 ± 0.03[cd]	0.25 ± 0.01[cd]	0.50 ± 0.02[d]	20.23 ± 0.52[d]
153 (Xihang-1)	0.25 ± 0.02[cd]	21.22 ± 0.51[cd]	1.31 ± 0.08[bcd]	2.61 ± 0.16[bcd]	0.25 ± 0.02[bcd]	0.51 ± 0.04[cd]	19.43 ± 0.41[cd]
5118×10133-3-3	0.27 ± 0.03[abcd]	22.08 ± 0.94[bcd]	1.32 ± 0.12[bcd]	2.64 ± 0.25[bcd]	0.27 ± 0.04[bcd]	0.54 ± 0.07[cd]	20.43 ± 0.87[cd]
F6×101	0.28 ± 0.02[abcd]	22.37 ± 0.54[abcd]	1.34 ± 0.08[abcd]	2.68 ± 0.15[abcd]	0.28 ± 0.02[abcd]	0.56 ± 0.04[bcd]	20.72 ± 0.44[bcd]
1433-15	0.26 ± 0.01[bcd]	23.41 ± 2.30[abc]	1.22 ± 0.06[d]	2.43 ± 0.13[cd]	0.25 ± 0.00[cd]	0.49 ± 0.00[d]	20.27 ± 1.07[d]
1126 (111)	0.32 ± 0.01[ab]	25.07 ± 0.39[a]	1.45 ± 0.05[abc]	2.89 ± 0.10[abc]	0.33 ± 0.01[abc]	0.67 ± 0.03[a]	23.10 ± 0.15[a]
113-K	0.23 ± 0.01[d]	19.69 ± 0.34[d]	1.30 ± 0.06[bcd]	2.60 ± 0.11[bcd]	0.24 ± 0.01[bcd]	0.47 ± 0.02[d]	18.10 ± 0.36[d]
1003-4	0.26 ± 0.02[cd]	20.50 ± 1.32[cd]	1.35 ± 0.08[abcd]	2.69 ± 0.15[abcd]	0.26 ± 0.02[abcd]	0.51 ± 0.05[cd]	18.97 ± 0.87[cd]
M2-6-18 (109)	0.27 ± 0.01[abcd]	22.37 ± 0.48[abcd]	1.33 ± 0.04[bcd]	2.65 ± 0.07[bcd]	0.27 ± 0.01[bcd]	0.55 ± 0.03[bcd]	20.63 ± 0.38[bcd]
M2-6-22 (107)	0.26 ± 0.01[bcd]	21.67 ± 0.33[bcd]	1.32 ± 0.05[bcd]	2.63 ± 0.10[bcd]	0.26 ± 0.01[bcd]	0.52 ± 0.02[cd]	19.90 ± 0.21[cd]
151 (103×M-1-1)	0.30 ± 0.00[abc]	22.30 ± 0.06[abcd]	1.48 ± 0.00[ab]	2.96 ± 0.01[ab]	0.30 ± 0.00[ab]	0.61 ± 0.00[abc]	20.61 ± 0.06[abc]
Xihang 2/3	0.23 ± 0.00[d]	21.22 ± 0.84[cd]	1.24 ± 0.02[d]	2.49 ± 0.04[cd]	0.24 ± 0.01[cd]	0.49 ± 0.02[d]	19.47 ± 0.38[d]
M-1-1×103	0.27 ± 0.02[abcd]	24.45 ± 1.27[ab]	1.21 ± 0.03[d]	2.42 ± 0.07[cd]	0.26 ± 0.01[cd]	0.53 ± 0.03[cd]	21.90 ± 0.52[cd]
7409	0.24 ± 0.01[d]	21.92 ± 0.65[bcd]	1.21 ± 0.06[d]	2.42 ± 0.13[cd]	0.25 ± 0.01[cd]	0.50 ± 0.03[d]	20.70 ± 0.25[d]
107-K	0.26 ± 0.02[bcd]	21.38 ± 0.68[cd]	1.34 ± 0.04[abcd]	2.67 ± 0.08[abcd]	0.26 ± 0.01[abcd]	0.51 ± 0.03[cd]	19.27 ± 0.61[cd]
103	0.25 ± 0.01[cd]	21.11 ± 0.18[cd]	1.27 ± 0.03[cd]	2.53 ± 0.06[cd]	0.24 ± 0.00[cd]	0.48 ± 0.01[d]	18.97 ± 0.18[d]
T5-M	0.25 ± 0.02[cd]	21.73 ± 1.12[bcd]	1.22 ± 0.02[d]	2.43 ± 0.04[cd]	0.24 ± 0.01[cd]	0.49 ± 0.03[d]	20.00 ± 0.92[d]
101433-1-4	0.32 ± 0.01[a]	23.33 ± 0.08[abc]	1.52 ± 0.04[a]	3.04 ± 0.08[a]	0.32 ± 0.01[a]	0.64 ± 0.02[ab]	21.27 ± 0.07[ab]

*Means in each row followed by the same letters are not significantly different at $p < 0.05$.

double cocoon number in the twenty studied varieties was between 0.60 and 9.00. Among the studied varieties, the highest level of double cocoon number belonged to [111] 1126 (9.00), and [7409] variety (0.60) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Double cocoon weight

The obtained results showed that the amount of double cocoon weight in the twenty studied varieties was between 2.14 and 35.12 g. Among the studied varieties, the highest level of weight belonged to [151] (12.66 g), and 5118 variety (2.14 g) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Double cocoon percentage

The obtained results showed that the amount of double cocoon percentage in the twenty studied varieties was between 0.13 and 3.33%. Among the studied varieties, the highest level of double cocoon percentage belonged to White Haratee (3.33%), and Yellow Haratee variety (0.13%) remained at lower level than other varieties .

Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Double cocoon mortality

The obtained results showed that the amount of double cocoon mortality in the twenty studied varieties was between 0.00 and 2.83%. Among the studied varieties, the highest level of double cocoon mortality belonged to [7409] (2.83%), and 4-1-101433 variety (0.00%) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Total mortality

The obtained results showed that the amount of total mortality in the twenty studied varieties was between 4.30 and 17.55%. Among the studied varieties, the highest level of total mortality belonged to [7409] (17.55%), and 4-1-101433 variety (4.30%) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were not significant ($p > 0.05$).

Female cocoon weight

The obtained results showed that the amount of female cocoon weight in the twenty studied varieties was between 1.13 and 1.37%. Among the studied varieties, the highest level of female cocoon weight belonged to 4-1-101433 (1.37%), and [2029] 113 variety (1.13%) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Female cocoon shell weight

The obtained results showed that the amount of female cocoon shell weight in the twenty studied varieties was between 0.16 and 0.35 g. Among the studied varieties, the highest level of female cocoon shell weight belonged to [111] 1126 (0.16 g), and M-1-1 × 103 variety (0.16 g) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Female cocoon shell percentage

The obtained results showed that the amount of female cocoon shell percentage in the twenty studied varieties was between 16.75 and 21.62%. Among the studied varieties, the highest level of female cocoon shell percentage belonged to [111] 1126 (18.09%) and k-113 variety (11.43%) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Male cocoon weight

The obtained results showed that the amount of male cocoon weight in the twenty studied varieties was between 1.13 and 1.37 g. Among the studied varieties, the highest level of male cocoon weight belonged to 4-1-101433 (1.13 g), and [2029] 113 variety (1.37 g) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Male cocoon shell weight

The obtained results showed that the amount of male cocoon shell weight in the twenty studied varieties was between 0.18 and 0.32 g. Among the studied varieties, the highest level of male cocoon shell weight belonged to 4-1-101433 (0.18 g), and k-113 variety (0.32 g) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Male cocoon shell percentage

The obtained results showed that the amount of male cocoon shell percentage in the twenty studied varieties was between 19.69 and 32.05%. Among the studied varieties, the highest level of male cocoon shell percentage belonged to 1005 (19.69%), and k-113 variety (32.05%) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Average of cocoon weight

The obtained results showed that the amount of average of cocoon weight in the twenty studied varieties was between 1.21 and 1.52. Among the studied varieties, the highest level of average of cocoon weight belonged to 4-1-101433 (1.52), and M-1-1 × 103 variety (1.21) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Sum of cocoon weight for male and female

The obtained results showed that the amount of sum of cocoon weight for male and female in the twenty studied varieties was between 2.56 and 3.05 g. Among the studied varieties, the highest level of sum of cocoon weight for male and female belonged to 4-1-101433 (3.05 g), while Lemon Khorasan variety (2.56 g) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Average of shell cocoon weight

The obtained results showed that the amount of average of shell cocoon weight in the twenty studied varieties was between 0.24 and 0.33 g. Among the studied varieties, the highest level of average of shell cocoon weight belonged to [111] 1126 (0.29 g) and some other varieties remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Sum of shell cocoon weight

The obtained results showed that the amount of sum of shell cocoon weight in the twenty studied varieties was between 0.32 and 0.67 g. Among the studied varieties, the highest level of sum of shell cocoon weight belonged to [111] 1126 (0.67 g), and lemon haratee variety (0.32 g) remained at lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between studied varieties for this trait were significant ($p < 0.05$).

Cocoon shell percentage

The obtained results showed that the amount of cocoon shell percentage in the twenty studied varieties was between 18.10 and 23.11%. Among the studied varieties, the highest level of cocoon shell percentage belonged to [111] 1126 (23.11%), while k-113 variety (18.10%) remained at a lower level than other varieties. Other varieties were between these two groups. Meanwhile, statistical differences between the studied varieties for this trait were significant ($p < 0.05$).

Also, there are similar reports about silkworm and other insects (Zhao et al, 2007; Ramesha et al., 2009; Ramesha et al., 2010). Meanwhile, Satenahalli et al. (1988) studied variation among seven silkworm pure lines and their hybrids based on larval weight, cocoon weight, cocoon shell weight, and length of cocoon fibers and reported that the hybrid Saniish-18 × NB7 was superior based on cocoon weight (2.49 g) and cocoon shell weight (0.469 g). Ksham et al. (1995) have reported that the heritability for quantitative traits was comparatively higher and ranged from 48 to 64% with little tendency for the standard error to increase with the estimate, while the range of heritability for fitness traits was much lower (18 to 25%). The data supported the classical hypothesis that the fitness traits would exhibit lower heritabilities as compared to the traits in other categories. Bhargava et al. (1993) have reported that heritability was very high (71.4 and 86.7%) for larval duration, single-shell weight, filament length, larval weight and single-cocoon weight. Moderate heritability (< 70%) was observed for cocoon yield (65.3%) and shell ratio (69.8%), indicating that these 2 characters were influenced by the environment. Ashoka and Govindan (1990) have showed high heritability as well as genetic gain for cocoon weight and shell weight indicating additive gene action and moderate to high heritability and low genetic gain for shell percentage, implying that this may be predominantly under control of non additive gene action. Rangaiah et al., (1995) indicated high heritability for shell percentage and shell weight, while moderate along with high genetic advance for cocoon weight.

On the other hand, Saha et al. (2002) also studied the temperature and humidity suitable for silkworm embryo development, and they have developed a method that silkworm egg hatching rate in hot and dry summer seasons as much increase and improve production efficiency per unit will be followed. Their studies found that different temperature and relative humidity required to achieve maximum yield silkworm egg hatching, is 25°C and 75 to 80%, respectively. They found that farmers often do not follow these factors and therefore, the rate and uniformity of hatching larvae in villages is far weaker than the standard level of production, and these factors has reduced the production of cocoon yield. The system developed by them was able to use very low cost in hot and dry summer conditions, the required amount of heat decreased as much as 6 to 7°C and relative humidity increase to 40%. They reported that the development of this system leads to increased levels of cocoon production in villages. Effect of temperature and humidity has been proven on the emergence of silkworm moth.

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