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Full Length Research Paper

Genetic diversity, classification and comparative study on the larval phenotypic data in 54 oval cocoon strains of Iran silkworm *Bombyx mori* (Lepidoptera: Bombycidae) gene bank

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The purpose of this experiment **was to investigate genetic diversity, classification and comparative study on the larval phenotypic data in all 54 oval cocoon strains of Iran silkworm *Bombyx mori* (Lepidoptera: Bombycidae) gene bank. The study reveals that the different strains of silkworm *B. mori* showed different performance based on larval phenotypic data. The analysis of variance regarding the studied traits showed that different strains have significant difference for traits (P<0.01). Totally, T1-P (629.757), Baghdadi (620.191), 4-4 (614.826), 110×32 (613.690), and 32 (611.407) showed higher evaluation index values and also 4-4 (5.343), 32 (5.260), 110×32 (5.226), Pink Khorasan (5.155), and T1-P (5.108) showed higher sub-ordinate function values. This study reveals the phylogenetic relationship of oval cocoon strains of Iran germplasm. The dendrograms constructed resolved the 54 silkworm strains into some major clusters. However, the strains of the same origin did not grouped together, demonstrating that they might have from different biological and development performance.**

Keywords: *Bombyx mori*, unweighted pair-group method using arithmetic (UPGMA), sub-ordinate function, larval development, gene bank.

INTRODUCTION

The art of silk production is called sericulture that comprises of cultivation of mulberry, silkworm rearing and post cocoon activities leading to production of silk yarn. Sericulture provides gainful employment, economic development and improvement in the quality of life to the people in rural area and therefore it plays an important role in anti poverty programme and prevents migration of rural people to urban area in search of employment. Hence, several developing nations like China, India, Brazil, Thailand, Vietnam, Indonesia, Egypt, Iran, Sri Lanka, Philippines, Bangladesh, Nepal, Myanmar, Turkey, Papua New Guinea, Mexico, Uzbekistan and some of the African and Latin American countries have taken up sericulture to provide employment to the people in rural area (Sohn, 2003).

Investigation on germplasm varieties is one of the most important part in the maintenance of silkworm germplasm resources, which will be useful for effectively utilizing the silkworm for breeding and genetic research purposes (Sohn, 2003).

Zhao et al. (2007) presented quantitative character jointly controlled by multiple genes and environmental factors, so that it is difficult to distinguish the effect of multiple genes from that of environmental factors. However, we can conduct the selection according to the actual performance or the predicted identification data of the silkworm lines. The wide variation obtained among the strains in respect of studied characters facilitates to

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select for breeding on these principal traits will be useful. The existence of genetic variability in economic characters is obviously a resource for breeding (Dalton, 1987; Kumaresan et al., 2007).

Most of the quantitative traits of commercial importance in silkworm are under complicated polygenic control under the influence of the environment (Rao et al., 2006). For synthesizing the potential polyvoltine cross breeds, usually, the high yielding traits of bivoltine varieties and fitness traits of strains are hybridized as proper selection of potential and homozygous parents is very important (Rao et al., 2006).

Islamic republic of Iran has valuable silkworm genetics resources. There are reports regarding peanut cocoon strains of Iran silkworm germplasm bank (Salehi et al., 2009, 2010a, b, 2010c). However, no report about oval cocoon strains of Iran silkworm germplasm bank especially from the point of larval gain characteristics. The purpose of this experiment is to investigate the genetic diversity, classification and comparative study on the larval phenotypic data in all 54 oval cocoon strains of Iran silkworm *Bombyx mori* (Lepidoptera: Bombycidae) gene bank.

MATERIALS AND METHODS

This study was conducted in Iran Silkworm Research Center (ISRC) and Islamic Azad University, Ghaemshahr Branch, Iran during the year 2008 to 2010. 54 silkworm strains were used in the present study. The strains included were 6/4-6/6, 104, 124-K, 120-K, 108-K, W2-11-19-2(110), W2-11-19-3, 1002-4-C-5, 1002-E-8-3, Guilan-Orange, Khorasan-Orange, Shown, T1-P, T5-P, CS120(7409), BH-4, BH-3, 104×110, 110×104(152), 32×110, 110×32, 18-1, 1538-8-2(114), 1538-14-9(112), 4-4, 32, Tokaee-202, 106, 17, Shaki A×D, 124-16-9(116), Mose.Black-Plain(2), 726(118), 1627-14-4-3, Koming-1(154), 1627-14-2-8, Mos.Black-Black(2), 823, 1640, 102(Shown), W2-13-9(108), 1001, W1-2-7, CS120(N19), Koming-2-5, W2-13-4, Y-5, 127-17, Lemon Khorasan, Lemon Haratee, White Haratee, Yellow Haratee, Pink Khorasan, and Baghdadi.

All silkworm germplasm rearing steps were conducted at Iran Silkworm Research Center (ISRC) as per the standard germplasm conservation program. Their silkworm rearing technique included single batch rearing system. Feeding and other conditions of larval rearing were conducted following the standard procedure (ESCAP, 1993) and all germplasm strains were reared under standards protocols. The quantitative characters viz. larval duration (hour), feeding larval duration (hour), molting larval duration (hour), 1-3 instars larval duration (hour), 1-3 instars feeding larval duration (hour), 1-3 instars molting larval duration (hour), 4-5 instars larval duration (hour), 4-5 instars feeding larval duration (hour), 4-5 instars molting larval duration (hour), 5 instar feeding larval duration (hour) and cocoon spinning duration (hour) were collected and using complete random design (CRD) model and GLM approach of SAS software. The model used for analyzing the data for each strain was $y_{ij}=\mu + G_i + e_{ij}$ where y_{ij} was record or observation from trait, μ was trait average, G_i was group effect (strain) and e_{ij} was residual effects. The angle transformation was used for those data which did not followed normal distribution. The Duncan's Multiple Range Test was used to compare the least-squares means. In addition, evaluation index and sub-ordinate function values were calculated for the studied traits. Evaluation index value (EI) for silkworm strains performance were calculated by using the following formula EI= [(A-B)/C]×10+50 (Mano et al., 1993), where, A is the mean of the particular trait in a strain; B is the overall mean of particular trait in all strains; C is the standard deviation of a trait in all strains; 50 is the constant.

Sub-ordinate function is calculated by utilizing the formula Xu=(Xi-Xmin)/(Xmax-Xmin) (Gower, 1971) where, Xu is the sub-ordinate function; Xi is the measurement of trait of tested strain; Xmin is the minimum value of the trait among all the tested strains; Xmax is the maximum value of the trait among all the tested strains.

The evaluation index and sub-ordinate function values for the all traits were calculated separately and average index value was obtained. Then studied silkworm strains are ranked based on average of evaluation index method and sub-ordinate function method.

Hierarchical agglomerative clustering was done by using NTSYS-pc, version 2.02e (Rohlf, 1998) based on complete, single, Unweighted Pair-Group Method using Arithmetic (UPGMA), UPGMC, FLEXI approaches and SAS-pc (SAS, 1997) based on WARD and average approaches. However, method of average linkage between groups (Romesburg, 1984) under UPGMA average was considered as major and final protocol for data conclusion (Sneath and Sokal, 1973) and the resulting clusters were expressed as dendrograms. The clustering was based on the squared Euclidean distance. The average linkage between two groups is considered as the average of distance between all pairs of cases with one number from each group. Hierarchical clustering analysis was carried out by considering all studied parameters together.

RESULTS

The obtained results are summarized in Tables 1 to 4. From the results, it was clear that different strains of silkworm *B. mori* showed different performance based on larval phenotypic data. The analysis of variance regarding to studied traits, showed that they differed significantly ($P<0.01$) among the different strains studied. The study reveals that the larval duration (hour) of the T1-P (590.000 h), Baghdadi (586.667 h), 106 (581.000 h), Shown (580.667 h), and 18-1 (580.333 h) strains remained significantly at upper level than other strains (Table 1). The feeding larval duration (hour) in Koming-1[154] (507.667 h), 32×110 (507.000 h), T1-P (506.000 h), Baghdadi (501.667 h), and Y-5 (494.333 h) strains increased significantly in comparison with other strains (Table 1). Molting larval duration (hour) remained significantly at upper level in the W2-11-19-2[110] (106.000 h), W2-11-19-3 (106.000 h), 1002-E-8-3 (105.667 h), 1002-4-C-5 (99.333 h) and Guilan-Orange (99.333 h) increased significantly in comparison with other strains (Table 1).

From the results obtained, it is showed that the 1-3 instars larval duration (hour) of the 1538-14-9[112] (296.000 h), CS120[N19] (296.000 h), 4-4 (294.000 h), 32 (294.000 h), and 1002-4-C-5 (286.000 h) strains remained significantly at upper level than other strains respectively (Table 1). The 1-3 instars feeding larval duration (hour) in CS120[N19] (243.000 h), 32×110 (240.000 h), Koming-1(154) (228.000 h), Baghdadi (224.333 h), and 110×104[152] (223.667 h) strains increased significantly in comparison with other strains

Table 1. Mean (± SD) performance of larval traits in studied silkworm pure lines of gene bank.

Pure line \ Trait	Larval duration (h)	Feeding larval duration (h)	Molting larval duration (h)	1-3 Instars larval duration (h)	1-3 Instars feeding larval duration (h)	1-3 Instars molting larval duration (h)	4-5 Instars larval duration (h)	4-5 Instars feeding larval duration (h)	4-5 Instars molting larval duration (h)	5 Instar feeding larval duration (h)	Cocoon spinning duration (h)
6/4-6/6	536.000^{h}±0.000	447.670^{s-u}±1.540	88.333^{ef}±1.154	272.000^{e}±0.000	213.670^{fg}±1.154	58.333^{ef}±1.154	258.000^{gh}±10.392	234.000^{lmn}±0.000	30.000^{bcd}±0.000	145.000^{j}±0.000	0.000^{a}±10.392
104	557.000^{ef}±0.000	449.330^{g-h}±9.237	87.467^{ef}±9.237	272.000^{e}±0.000	220.000^{fg}±0.000	52.000^{ij}±0.000	285.000^{cde}±0.000	249.330^{hi}±9.237	35.667^{ab}±9.237	155.330^{fg}±9.237	0.000^{bc}±12.858
124-K	557.000^{ef}±0.000	455.000^{g-s}±10.583	88.333^{ef}±22.546	271.330^{e}±0.577	205.000^{kl}±1.732	66.333^{c-e}±2.309	285.670^{cd}±0.557	250.000^{hi}±9.539	35.667^{ab}±9.237	150.000^{hij}±0.000	0.000^{abc}±0.000
120-K	557.000^{ef}±0.000	472.000^{gh}±5.196	85.000^{ef}±5.196	271.000^{e}±0.000	211.000^{j-k}±5.196	60.000^{ef}±5.196	286.000^{cd}±0.000	261.000^{def}±0.000	25.000^{e-d}±0.000	150.000^{hij}±0.000	0.000^{c-f}±0.000
108-K	536.000^{h}±0.000	443.000^{u}±0.000	93.000^{ef}±0.000	271.000^{e}±0.000	203.000^{l}±0.000	68.000^{bc}±0.000	265.000^{cd}±0.000	240.000^{lm}±0.000	25.000^{e-d}±0.000	145.000^{j}±0.000	0.000^{abc}±0.000
W2-11-19-2(110)	557.000^{ef}±0.000	451.000^{q-s}±0.000	106.000^{a}±0.000	271.000^{e}±0.000	206.000^{jkl}±0.000	65.000^{ef}±0.000	286.000^{gf}±0.000	245.000^{jkl}±0.000	41.000^{a}±0.000	150.000^{hij}±0.000	0.000^{c-f}±0.000
W2-11-19-3	557.000^{ef}±0.000	451.000^{q-s}±0.000	106.000^{a}±0.000	271.000^{e}±0.000	206.000^{jkl}±0.000	65.000^{ef}±0.000	286.000^{cd}±0.000	245.000^{jkl}±0.000	41.000^{a}±0.000	150.000^{hij}±0.000	0.000^{abc}±0.000
1002-4-C-5	573.000^{cd}±13.856	473.67^{gh}±12.858	99.333^{abc}±2.309	271.000^{bc}±0.000	213.000^{fg}±0.000	73.000^{ab}±0.000	287.000^{cd}±13.856	260.670^{def}±12.858	26.333^{e-d}±2.309	164.670^{bc}±12.858	0.000^{abc}±0.000
1002-E-8-3	550.000^{fg}±12.124	444.330^{tu}±7.637	105.670^{ab}±15.502	276.000^{de}±8.660	206.000^{jkl}±0.000	70.000^{abc}±8.660	274.000^{cd}±10.816	238.330^{lm}±7.637	35.667^{bc}±9.237	148.330^{hij}±2.886	0.000^{abc}±1.154
Guilan-Orange	557.000^{ef}±0.000	458.670^{q-s}±6.110	98.333^{bc}±6.110	286.000^{bc}±0.000	222.000^{cd}±0.000	64.000^{c-f}±0.000	271.000^{ef}±0.000	236.670^{klm}±6.110	34.333^{b}±6.110	146.000^{ij}±4.000	0.000^{abc}±2.309
Khorasan-Orange	557.000^{ef}±0.000	466.330^{lm}±2.886	90.667^{ef}±2.886	286.000^{bc}±0.000	220.330^{fg}±2.886	65.667^{c-e}±2.886	271.000^{f}±0.000	246.000^{i-l}±0.000	25.000^{e-d}±0.000	150.000^{hij}±0.000	0.000^{abc}±2.886
Shown	580.670^{abc}±2.886	487.000^{cde}±8.660	93.667^{ef}±5.773	286.000^{bc}±0.000	217.330^{fg}±5.773	68.667^{bc}±5.773	294.670^{bc}±2.886	269.670^{bc}±2.886	25.000^{e-d}±0.000	172.000^{abc}±0.000	0.000^{bcd}±2.309
T1-P	590.000^{a}±10.392	506.000^{a}±10.392	84.000^{ef}±0.000	286.000^{bc}±0.000	223.000^{bcd}±0.000	63.000^{ef}±0.000	304.000^{ab}±10.392	283.000^{a}±10.392	21.000^{f}±0.000	179.000^{a}±10.392	0.000^{bcd}±2.309
T5-P	557.000^{abc}±0.000	460.000^{qr}±0.000	97.000^{c-e}±0.000	271.000^{e}±0.000	215.000^{fg}±0.000	56.000^{f-h}±0.000	286.000^{cd}±0.000	245.000^{jkl}±0.000	41.000^{a}±0.000	150.000^{hij}±0.000	0.000^{bcd}±2.886
CS120(7409)	560.000^{ef}±0.000	468.000^{h-l}±0.000	92.000^{ef}±0.000	286.000^{bc}±0.000	219.000^{fg}±0.000	67.000^{c-e}±0.000	274.000^{ef}±0.000	249.000^{cde}±0.000	25.000^{e-d}±0.000	153.000^{j-g}±0.000	0.000^{bcd}±0.000
BH-4	557.000^{abc}±0.000	467.330^{ef}±8.504	89.667^{ef}±8.504	281.000^{cd}±8.660	216.670^{fg}±2.081	64.333^{ef}±8.326	276.000^{def}±8.660	250.670^{h-j}±8.962	25.333^{e-d}±0.577	147.000^{ij}±5.196	0.000^{bc}±0.000
BH-3	560.000^{ef}±0.000	467.000^{ef}±0.000	93.000^{ef}±0.000	286.000^{bc}±0.000	219.000^{fg}±0.000	67.000^{c-e}±0.000	274.000^{ef}±0.000	248.000^{hi}±0.000	26.000^{e-d}±0.000	144.000^{k}±0.000	0.000^{bc}±0.000
104×110	557.000^{ef}±0.0000	473.670^{ef}±8.082	83.333^{ef}±8.082	271.000^{e}±0.000	212.670^{g-j}±8.082	58.333^{ef}±8.802	286.000^{cd}±0.000	261.000^{def}±0.000	25.000^{e-d}±0.000	150.000^{hij}±0.000	0.000^{j}±0.000
110×104(152)	579.000^{ef}±0.000	490.670^{ef}±2.886	88.333^{ef}±2.886	286.000^{bc}±0.000	223.670^{bcd}±2.886	62.333^{ef}±2.886	293.000^{bc}±0.000	267.000^{cde}±0.000	26.000^{e-d}±0.000	163.000^{c-f}±0.000	0.000^{c-f}±0.000
32×110	579.000^{abc}±0.000	507.000^{i-j}±0.000	72.000^{i-j}±0.000	286.000^{bc}±0.000	240.000^{a}±0.000	46.000^{jk}±0.000	293.000^{bc}±0.000	267.000^{cde}±0.000	26.000^{e-d}±0.000	163.000^{c-f}±0.000	0.000^{j}±0.000
110×32	579.000^{abc}±0.000	480.670^{bc}±2.309	98.333^{bc}±2.309	286.000^{bc}±0.000	221.670^{d-f}±2.309	64.333^{ef}±2.309	293.000^{bc}±0.000	259.000^{gh}±0.000	34.000^{b}±0.000	163.000^{c-f}±0.000	0.000^{c-f}±0.000
18-1	580.330^{abc}±1.454	491.000^{ef}±3.464	89.333^{ef}±20.309	286.000^{bc}±0.000	221.670^{d-f}±2.309	64.333^{ef}±2.309	294.330^{bc}±1.154	269.330^{bc}±1.154	25.000^{e-d}±0.000	173.330^{ab}±1.154	0.000±13.856
1538-8-2(114)	579.000^{abc}±0.000	489.670^{ef}±2.309	89.333^{ef}±2.309	286.000^{bc}±0.000	221.670^{d-f}±2.309	64.333^{ef}±2.309	293.000^{bc}±0.000	268.000^{bc}±0.000	25.000^{e-d}±0.000	172.000^{abc}±0.000	0.000^{c-f}±0.000
1538-14-9(112)	579.000^{abc}±0.000	482.000^{c-e}±0.000	97.000^{c-e}±0.000	286.000^{a}±0.000	223.000^{bcd}±0.000	73.000^{ab}±0.000	283.000^{cde}±0.000	259.000^{gh}±0.000	24.000^{e-d}±0.000	147.000^{ij}±0.000	0.000^{fg}±1.732
4-4	577.670^{bc}±2.309	479.330^{bc}±10.016	98.333^{bc}±10.969	294.000^{ab}±13.856	220.670^{fg}±2.886	73.333^{ab}±10.969	283.670^{cde}±12.858	258.670^{h-i}±12.858	25.000^{e-d}±0.000	170.670^{abc}±2.309	0.000^{fg}±10.392
32	577.670^{bc}±2.309	480.000^{bc}±10.816	97.667^{bc}±11.590	294.000^{ab}±13.856	220.000^{fg}±3.605	74.000^{a}±10.440	283.670^{cde}±12.858	260.000^{fg}±14.422	23.667^{def}±2.309	169.330^{bcd}±2.309	0.000^{fg}±9.237
Tokaee-202	580.330^{abc}±1.154	492.330^{ef}±1.154	88.000^{ef}±0.000	286.000^{bc}±0.000	223.000^{bcd}±0.000	63.000^{ef}±0.000	295.000^{bc}±0.000	270.000^{bc}±0.000	25.000^{e-d}±0.000	174.000^{ab}±0.000	0.000^{j-g}±0.000
106	581.000 ^{abc}±0.000	489.000^{ef}±5.196	92.000^{ef}±5.196	286.000^{bc}±0.000	220.000^{fg}±5.196	66.000^{c-e}±5.196	295.000^{bc}±0.000	269.000^{bc}±0.000	26.000^{e-d}±0.000	165.000^{bc}±0.000	0.000^{j-g}±0.000
17	579.000 ^{abc}±00.000	488.330^{ef}±2.309	90.667^{ef}±2.309	286.000^{bc}±0.000	220.330^{fg}±2.309	65.667^{c-e}±2.309	293.000^{bc}±0.000	268.000^{bc}±0.000	25.000^{e-d}±0.000	172.000^{abc}±0.000	0.000^{ijh}±0.000
Shaki A×D	544.000 ^{gh}±13.856	454.670^{ef}±15.011	89.333^{ef}±1.154	286.000^{bc}±0.000	222.670^{bcd}±1.154	63.333^{ef}±1.154	258.000^{gh}±13.856	232.000^{mn}±13.856	26.000^{e-d}±0.000	128.000^{k}±13.856	0.000^{ijh}±0.000
124-16-9(116)	560.000^{ef}±0.000	470.670^{gh}±2.309	89.333^{ef}±2.309	286.000^{bc}±0.000	221.670^{d-f}±2.309	63.000^{ef}±0.000	271.000^{ef}±0.000	249.000^{h-i}±0.000	25.000^{de}±0.000	153.000^{g-j}±0.000	0.000^{hij}±0.000
Mose.Black-Plain(2)	557.000^{ef}±0.000	466.330^{lm}±2.309	90.667^{ef}±2.309	286.000^{bc}±0.000	220.330^{fg}±2.309	65.667^{c-e}±2.309	271.000^{f}±0.000	264.000^{l-i}±0.000	25.000^{de}±0.000	150.000^{hij}±0.000	0.000^{hij}±0.000
726(118)	557.000^{ef}±0.000	459.670^{qr}±9.237	97.333^{bc}±9.237	286.000^{bc}±0.000	219.000^{fg}±0.000	67.000^{c-e}±0.000	271.000^{def}±0.000	240.670^{l-m}±9.237	30.333^{bc}±9.237	150.000^{hij}±0.000	0.000^{hij}±0.000
1627-14-4-3	574.000^{cd}±0.000	481.33^{gh}±1.154	92.667^{ef}±1.154	286.000^{bc}±0.000	218.330^{fg}±1.154	67.667^{c-e}±1.154	288.000^{c}±2.886	263.000^{de}±0.000	25.000^{de}±0.000	167.000^{bcd}±0.000	0.000^{hij}±0.000
Koming-1(154)	575.670^{bc}±2.886	507.670^{a}±2.886	68.000^{j}±0.000	271.000^{e}±0.000	228.000^{b}±0.000	43.000^{k}±0.000	304.670^{ab}±2.886	279.670^{l-i}±13.576	25.000^{d-e}±0.000	168.670^{bcd}±2.886	0.000^{hij}±0.000
1627-14-2-8	577.330^{bc}±2.886	485.33^{c-f}±2.886	92.000^{ef}±0.000	286.000^{bc}±0.000	2199.000^{fg}±0.000	67.000^{c-e}±0.000	291.330^{c}±2.886	266.330^{cde}±2.886	25.000^{d-e}±0.000	170.330^{abc}±2.886	0.000^{hij}±0.000

Table 1. Continue.

Mos.Black-Black(2)	557.000^{ef}±0.000	459.000^{q-s}±0.000	98.000^{bc}±1.154	286.000^{bc}±0.000	213.000^{fg}±0.000	73.000^{ab}±0.000	271.000^{f}±0.000	246.000^{l-i}±0.000	25.000^{d-e}±0.000	150.000^{hij}±0.000	0.000^{hij}±0.000
823	564.670^{ed}±24.826	469.000 ^{gh}±25.980	95.667^{ef}±1.154	281.000^{cd}±0.000	211.000^{jk}±10.392	70.000^{abc}±1.732	283.670^{cde}±6.165	258.000^{h-i}±15.588	25.667^{d-e}±0.577	157.000^{fg}±10.392	0.000^{hij}±0.000
1640	557.000^{ef}±0.000	463.000^{m-q}±0.000	94.000^{ef}±0.000	286.000^{bc}±0.000	217.000^{fg}±0.000	69.000^{bc}±0.000	271.000^{f}±0.000	246.0000^{l-i}±0.000	25.000^{d-e}±0.000	150.000^{hij}±0.000	0.000^{hij}±0.000
102(Shown)	550.670^{fg}±1.154	460.000^{qr}±14.798	90.667^{ef}±14.153	279.000^{cde}±13.856	213.000^{fg}±0.000	66.000^{ce}±13.856	271.670^{f}±14.468	247.000^{h-i}±14.798	24.667^{d-e}±0.577	160.000^{fg}±1.732	0.000^{hij}±0.000
W2-13-9(108)	557.000^{ef}±0.000	461.670^{qr}±2.309	95.333^{ef}±2.309	286.000^{bc}±0.000	215.670^{fg}±2.309	7.333^{abc}±2.309	271.000^{f}±0.000	246.000^{l-i}±0.000	25.000^{d-e}±0.000	150.000^{hij}±0.000	0.000^{hij}±0.000
1001	536.000^{h}±0.000	456.670^{q-s}±0.577	79.333^{i-j}±0.577	271.000^{e}±0.000	216.000^{fg}±0.000	55.000^{ghi}±0.000	265.000^{fg}±0.000	240.670^{l-m}±0.577	24.333^{d-e}±0.577	145.670^{ij}±0.577	0.000^{hij}±0.000
W1-2-7	557.000^{ef}±0.000	477.000^{gh}±0.000	80.000^{G-i}±0.000	271.000^{e}±0.000	216.000^{fg}±0.000	55.000^{ghi}±0.000	286.000^{cd}±0.000	261.000^{def}±0.000	25.000^{d-e}±0.000	166.000^{bc}±0.000	0.000^{hij}±2.886
CS120(N19)	562.670^{e}±9.814	483.670^{c-g}±9.814	79.000^{i-j}±0.000	296.000^{a}±0.000	246.000^{a}±0.000	53.000^{hij}±0.000	266.670^{gf}±9.814	240.670^{l-m}±9.814	26.000^{d-e}±0.000	146.670^{ij}±9.814	0.000^{ij}±0.000
Koming-2-5	557.000^{ef}±0.000	456.000^{m-q}±0.000	92.000^{ef}±4.618	286.000^{bc}±0.000	219.000^{fg}±0.000	67.000^{c-e}±0.000	271.000^{f}±0.000	246.000^{l-i}±0.000	25.000^{d-e}±0.000	150.000^{hij}±0.000	0.000^{ij}±5.196
W2-13-4	557.000^{ef}±0.000	459.000^{q-s}±0.000	98.000^{bc}±0.000	86.000^{bc}+0.000	213.000^{fg}±0.000	73.000^{ab}±0.000	271.000^{f}±0.000	246.000^{i-l}±0.000	25.000^{e-d}±0.000	150.000^{hij}±0.000	0.000^{ij}±9.814
Y-5	579.670^{abc}±1.154	494.330^{abc}±5.773	85.333^{ef}±4.618	286.000^{bc}±0.000	223.000^{bcd}±0.000	63.000^{ef}±0.000	293.670^{bc}±1.154	271.330^{bcd}±5.773	22.333^{ef}±4.618	172.670^{abc}±1.154	0.000^{ij}±4.000
127-17	579.000^{abc}±0.000	485.000^{c-f}±4.000	94.000^{ef}±0.000	286.000^{bc}±0.000	217.000^{fg}±4.000	69.000^{bc}±4.000	293.000^{bc}±0.000	368.000^{bc}±0.000	25.000^{e-d}±0.000	172.000^{abc}±0.000	0.000^{ij}±20.074
Lemon Khorasan	579.000^{abc}±0.000	482.670^{gh}±2.309	96.333^{ef}±20.309	286.000^{bc}±0.000	215.670^{fg}±2.309	70.333^{abc}±2.309	293.000^{bc}±0.000	276.000^{cde}±0.000	26.000^{e-d}±0.000	163.000^{c-f}±0.000	0.000^{ij}±0.557
Lemon Haratee	542.330^{gh}±13.578	456.330^{q-s}±5.507	86.000^{ef}±18.357	271.000^{e}±0.000	210.000^{jk}±18.357	63.000^{ef}±18.357	271.330^{f}±13.576	246.330^{i-l}±13.576	25.000^{e-d}±0.000	146.000^{ij}±20.074	28.333^{a}±10.392
White Haratee	579.000^{abc}±0.000	485.330^{c-f}±4.163	93.667^{ef}±4.163	286.000^{bc}±0.000	218.330^{fg}±4.163	67.667^{c-e}±4.163	293.000^{bc}±0.000	267.000^{cde}±0.000	26.000^{e-d}±0.000	163.000^{c-f}±0.000	0.000^{j}±0.000
Yellow Haratee	536.000^{h}±0.000	444.670^{stu}±2.886	91.333^{ef}±2.886	286.000^{bc}±0.000	219.670^{fg}±2.886	66.333^{c-e}±2.886	250.000^{h}±0.000	225.000^{n}±0.000	25.000^{e-d}±0.000	129.000^{k}±0.0000	13.000^{ab}±0.000
Pink Khorasan	579.000^{abc}±0.000	481.670^{gh}±1.154	97.333^{bc}±1.154	286.000^{bc}±0.000	216.330^{fg}±1.154	69.667^{abc}±1.154	293.000^{f}±0.000	265.330^{cde}±2.309	27.667^{cde}±2.309	169.330^{bcd}±2.309	0.000^{k}±0.000
Baghdadi	586.670^{ab}±13.279	501.670^{ab}±21.337	85.000^{ef}±10.583	279.330^{cde}±14.433	224.330^{bc}±16.165	55.000^{ghi}±1.732	307.330^{a}±1.154	277.330^{ab}±2.886	30.000^{bce}±9.539	171.330^{abc}±1.154	1.000^{ab}±1.154

Means in each column followed by the same letters are not significantly different at α=0.01.

Table 2. Evaluation index values for larval traits in studied silkworm pure lines of gene bank.

Pure line \ Trait	Larval duration (h)	Feeding larval duration (h)	Molting larval duration (h)	1-3 Instars larval duration (h)	1-3 Instars feeding larval duration (h)	1-3 Instars molting larval duration (h)	4-5 Instars larval duration (h)	4-5 Instars feeding larval duration (h)	4-5 Instars molting larval duration (h)	5 Instar feeding larval duration (h)	Cocoon spinning duration (h)
6/4-6/6	30.100	34.788	45.924	35.478	43.853	40.798	30.896	34.018	56.102	39.698	48.138
104	44.712	47.795	45.021	35.478	52.749	31.203	52.366	45.701	68.280	48.537	48.138
124-K	44.712	39.191	45.924	34.553	31.679	52.917	52.896	46.209	68.280	43.975	48.138
120-K	44.712	49.396	41.405	34.092	40.107	43.323	53.161	54.590	45.357	43.975	48.138
108-K	30.100	31.987	52.251	34.092	28.870	55.443	36.462	38.590	45.357	39.698	48.138
W2-11-19-2(110)	44.712	36.789	69.877	34.092	33.084	50.898	53.161	42.400	79.740	43.975	48.138
W2-11-19-3	44.712	36.789	69.877	34.092	33.084	50.898	53.161	42.400	79.740	43.975	48.138
1002-4-C-5	55.846	50.397	60.838	54.886	42.916	63.017	53.956	54.337	48.222	56.521	48.138
1002-E-8-3	39.842	32.787	69.425	41.023	33.084	58.473	43.619	37.320	68.280	42.549	48.138
Guilan-Orange	44.712	41.392	59.482	54.886	55.558	49.383	41.233	36.050	65.413	40.554	48.138
Khorasan-Orange	44.712	45.994	49.088	54.886	53.216	51.908	41.233	43.161	45.357	43.975	48.138
Shown	61.181	58.401	53.156	54.886	49.002	56.453	60.053	61.194	45.357	62.794	48.138
T1-P	67.675	69.807	40.049	54.886	56.962	47.868	67.475	71.353	36.762	68.782	48.138

Table 2. Continue.

T5-P	44.712	42.192	57.675	34.092	45.725	37.263	53.161	42.400	79.740	43.975	48.138
CS120(7409)	46.800	46.995	50.896	54.886	51.344	53.928	43.619	45.447	45.357	46.541	48.138
BH-4	44.712	46.594	47.732	47.955	48.067	49.887	45.209	46.717	46.073	41.409	48.138
BH-3	46.800	46.394	52.251	54.886	51.344	53.928	43.619	44.685	47.506	38.843	48.138
104×110	44.712	50.397	39.145	34.092	42.448	40.798	53.161	54.590	45.357	43.975	48.138
110×104(152)	60.021	60.602	45.924	54.886	57.899	46.857	58.727	59.162	47.506	55.095	48.138
32×110	60.021	70.407	23.779	54.886	80.841	22.114	58.727	59.162	47.506	55.095	48.138
110×32	60.021	54.599	59.482	54.886	55.090	49.887	58.727	53.067	64.697	55.095	48.138
18-1	60.948	60.802	47.280	54.886	55.090	49.887	59.787	60.940	45.357	63.934	48.138
1538-8-2(114)	60.021	60.002	47.280	54.886	55.090	49.887	58.727	59.924	45.357	62.794	48.138
1538-14-9(112)	60.021	55.399	57.675	68.750	56.962	63.017	50.776	53.067	43.208	41.409	48.138
4-4	59.093	53.798	59.482	65.977	53.685	63.522	51.306	52.813	45.357	61.654	48.138
32	59.093	54.198	58.579	65.977	52.749	64.532	51.306	53.828	42.493	60.513	48.138
Tokaee-202	60.948	61.602	45.472	54.886	56.962	47.868	60.318	61.448	45.357	64.505	48.138
106	61.413	59.601	50.896	54.886	52.749	52.413	60.318	60.686	47.506	56.806	48.138
17	60.021	59.201	49.088	54.886	53.216	51.908	58.727	59.924	45.357	62.794	48.138
Shaki A×D	35.667	38.991	47.280	54.886	56.495	48.372	30.896	32.494	47.506	25.156	48.138
124-16-9(116)	46.800	48.596	47.280	54.886	55.090	47.868	43.619	45.447	45.357	46.541	48.138
Mose.Black-Plain(2)	44.712	45.994	49.088	54.886	53.216	51.908	41.233	43.161	45.357	43.975	48.138
726(118)	44.712	41.992	58.126	54.886	51.344	53.928	41.233	39.098	56.817	43.975	48.138
1627-14-4-3	56.542	54.999	51.800	54.886	50.407	54.938	54.751	56.114	45.357	58.517	48.138
Koming-1(154)	57.702	70.807	18.356	34.092	63.986	17.569	68.005	68.813	45.357	59.943	48.138
1627-14-2-8	58.861	57.400	50.896	54.886	51.344	53.928	57.402	58.654	45.357	61.368	48.138
Mos.Black-Black(2)	44.712	41.592	59.030	54.886	42.916	63.017	41.233	43.161	45.357	43.975	48.138
823	50.047	47.595	55.867	47.955	40.107	58.473	51.306	52.305	46.791	49.963	48.138
1640	44.712	43.993	53.607	54.886	48.535	56.958	41.233	43.161	45.357	43.975	48.138
102(Shown)	40.306	42.192	49.088	45.182	42.916	52.413	41.764	43.923	44.642	52.529	48.138
W2-13-9(108)	44.712	43.193	55.414	54.886	46.662	58.977	41.233	43.161	45.357	43.975	48.138
1001	30.100	40.191	33.722	34.092	47.130	35.748	36.462	39.098	43.924	40.269	48.138
W1-2-7	44.712	52.398	34.626	34.092	47.130	35.748	53.161	54.590	45.357	57.662	48.138
CS120(N19)	48.656	56.400	33.270	68.750	85.055	32.718	37.788	39.098	47.506	41.124	48.138
Koming-2-5	44.712	45.194	50.896	54.886	51.344	53.928	41.233	43.161	45.357	43.975	48.138
W2-13-4	44.712	41.592	59.030	54.886	42.916	63.017	41.233	43.161	45.357	43.975	48.138
Y-5	60.485	62.803	41.856	54.886	56.962	47.868	59.258	62.463	39.626	63.365	48.138
127-17	60.021	57.200	53.607	54.886	48.535	56.958	58.727	59.924	45.357	62.794	48.138
Lemon Khorasan	60.021	55.800	56.770	54.886	46.662	58.977	58.727	59.162	47.506	55.095	48.138
Lemon Haratee	34.507	39.991	42.761	34.092	38.702	44.838	41.498	43.415	45.357	40.554	115.430
White Haratee	60.021	57.400	53.156	54.886	50.407	54.938	58.727	59.162	47.506	55.095	48.138
Yellow Haratee	30.100	32.988	49.991	54.886	52.281	52.917	24.534	27.161	45.357	26.012	79.014
Pink Khorasan	60.021	55.199	58.126	54.886	47.598	57.968	58.727	57.892	51.088	60.513	48.138
Baghdadi	65.356	67.206	41.405	45.644	58.835	35.748	70.125	67.035	56.102	62.223	50.513

Table 3. Sub-ordinate function values for larval traits in studied silkworm pure lines of gene bank.

Pure line \ Trait	Larval duration (h)	Feeding larval duration (h)	Molting larval duration (h)	1-3 Instars larval duration (h)	1-3 Instars feeding larval duration (h)	1-3 Instars molting larval duration (h)	4-5 Instars larval duration (h)	4-5 Instars feeding larval duration (h)	4-5 Instars molting larval duration (h)	5 Instar feeding larval duration (h)	Cocoon spinning duration (h)
6/4-6/6	0.000	0.000	0.535	0.040	0.267	0.495	0.140	0.155	0.450	0.333	0.000
104	0.000	0.000	0.518	0.040	0.425	0.290	0.610	0.420	0.733	0.536	0.000
124-K	0.000	0.000	0.535	0.013	0.050	0.753	0.622	0.431	0.733	0.431	0.000
120-K	0.000	0.000	0.447	0.000	0.200	0.548	0.628	0.621	0.200	0.431	0.000
108-K	0.000	0.000	0.658	0.000	0.000	0.806	0.262	0.259	0.200	0.333	0.000
W2-11-19-2(110)	0.000	0.000	1.000	0.000	0.075	0.710	0.628	0.345	1.000	0.431	0.000
W2-11-19-3	0.000	0.000	1.000	0.000	0.075	0.710	0.628	0.345	1.000	0.431	0.000
1002-4-C-5	0.000	0.000	0.825	0.600	0.250	0.968	0.645	0.615	0.267	0.719	0.000
1002-E-8-3	0.000	0.000	0.991	0.200	0.075	0.871	0.419	0.230	0.733	0.399	0.000
Guilan-Orange	0.000	0.000	0.798	0.600	0.475	0.677	0.366	0.201	0.667	0.353	0.000
Khorasan-Orange	0.000	0.000	0.597	0.600	0.433	0.731	0.366	0.362	0.200	0.431	0.000
Shown	0.000	0.000	0.675	0.600	0.358	0.828	0.779	0.770	0.200	0.863	0.000
T1-P	0.000	0.000	0.421	0.600	0.500	0.645	0.942	1.000	0.000	1.000	0.000
T5-P	0.000	0.000	0.763	0.000	0.300	0.419	0.628	0.345	1.000	0.431	0.000
CS120(7409)	0.000	0.000	0.632	0.600	0.400	0.774	0.419	0.414	0.200	0.490	0.000
BH-4	0.000	0.000	0.570	0.400	0.342	0.688	0.453	0.443	0.217	0.373	0.000
BH-3	0.000	0.000	0.658	0.600	0.400	0.774	0.419	0.397	0.250	0.314	0.000
104×110	0.000	0.000	0.404	0.000	0.242	0.495	0.628	0.621	0.200	0.431	0.000
110×104(152)	0.000	0.000	0.535	0.600	0.517	0.624	0.750	0.724	0.250	0.686	0.000
32×110	0.000	0.000	0.105	0.600	0.925	0.097	0.750	0.724	0.250	0.686	0.000
110×32	0.000	0.000	0.798	0.600	0.467	0.688	0.750	0.586	0.650	0.686	0.000
18-1	0.000	0.000	0.561	0.600	0.467	0.688	0.773	0.764	0.200	0.889	0.000
1538-8-2(114)	0.000	0.000	0.561	0.600	0.467	0.688	0.750	0.741	0.200	0.863	0.000
1538-14-9(112)	0.000	0.000	0.763	1.000	0.500	0.968	0.576	0.586	0.150	0.373	0.000
4-4	0.000	0.000	0.798	0.920	0.442	0.978	0.587	0.580	0.200	0.837	0.000
32	0.000	0.000	0.781	0.920	0.425	1.000	0.587	0.603	0.133	0.810	0.000
Tokaee-202	0.000	0.000	0.526	0.600	0.500	0.645	0.785	0.776	0.200	0.902	0.000
106	0.000	0.000	0.632	0.600	0.425	0.742	0.785	0.759	0.250	0.725	0.000
17	0.000	0.000	0.597	0.600	0.433	0.731	0.750	0.741	0.200	0.863	0.000
Shaki A×D	0.000	0.000	0.561	0.600	0.492	0.656	0.140	0.121	0.250	0.000	0.000
124-16-9(116)	0.000	0.000	0.561	0.600	0.467	0.645	0.419	0.414	0.200	0.490	0.000
Mose.Black-Plain(2)	0.000	0.000	0.597	0.600	0.433	0.731	0.366	0.362	0.200	0.431	0.000
726(118)	0.000	0.000	0.772	0.600	0.400	0.774	0.366	0.270	0.467	0.431	0.000
1627-14-4-3	0.000	0.000	0.649	0.600	0.383	0.796	0.663	0.655	0.200	0.765	0.000
Koming-1(154)	0.000	0.000	0.000	0.000	0.625	0.000	0.953	0.943	0.200	0.797	0.000
1627-14-2-8	0.000	0.000	0.632	0.600	0.400	0.774	0.721	0.713	0.200	0.830	0.000

Table 3. Continue.

Mos.Black-Black(2)	0.000	0.000	0.789	0.600	0.250	0.968	0.366	0.362	0.200	0.431	0.000
823	0.000	0.000	0.728	0.400	0.200	0.871	0.587	0.569	0.233	0.569	0.000
1640	0.000	0.000	0.684	0.600	0.350	0.839	0.366	0.362	0.200	0.431	0.000
102(Shown)	0.000	0.000	0.597	0.320	0.250	0.742	0.378	0.379	0.183	0.627	0.000
W2-13-9(108)	0.000	0.000	0.719	0.600	0.317	0.882	0.366	0.362	0.200	0.431	0.000
1001	0.000	0.000	0.298	0.000	0.325	0.387	0.262	0.270	0.167	0.346	0.000
W1-2-7	0.000	0.000	0.316	0.000	0.325	0.387	0.628	0.621	0.200	0.745	0.000
CS120(N19)	0.000	0.000	0.289	1.000	1.000	0.323	0.291	0.270	0.250	0.366	0.000
Koming-2-5	0.000	0.000	0.632	0.600	0.400	0.774	0.366	0.362	0.200	0.431	0.000
W2-13-4	0.000	0.000	0.789	0.600	0.250	0.968	0.366	0.362	0.200	0.431	0.000
Y-5	0.000	0.000	0.456	0.600	0.500	0.645	0.762	0.799	0.067	0.876	0.000
127-17	0.000	0.000	0.684	0.600	0.350	0.839	0.750	0.741	0.200	0.863	0.000
Lemon Khorasan	0.000	0.000	0.746	0.600	0.317	0.882	0.750	0.724	0.250	0.686	0.000
Lemon Haratee	0.000	0.000	0.474	0.000	0.175	0.581	0.372	0.368	0.200	0.353	1.000
White Haratee	0.000	0.000	0.675	0.600	0.383	0.796	0.750	0.724	0.250	0.686	0.000
Yellow Haratee	0.000	0.000	0.614	0.600	0.417	0.753	0.000	0.000	0.200	0.020	0.459
Pink Khorasan	0.000	0.000	0.772	0.600	0.333	0.860	0.750	0.695	0.333	0.810	0.000
Baghdadi	0.000	0.000	0.447	0.333	0.533	0.387	1.000	0.902	0.450	0.850	0.035

(Table 1). 1-3 instars molting larval duration (hour) remained significantly at upper level in the 32 (74.000 h), 4-4 (73.333 h), 1538-14-9[112] (73.000 h), Mos.Black-Black[2] (73.000 h), and 1002-4-C-5 (73.000 h) increased significantly in comparison with other strains (Table 1).

From the results obtained, it is showed that the 4-5 instars larval duration (hour) of the Yellow Haratee (250.000 h), Y-5 (293.667 h), White Haratee (293.000 h), W2-13-9[108] (271.000 h), and W2-13-4 (271.000 h) strains remained significantly at upper level than other strains respectively (Table 1). The 4-5 instars feeding larval duration (hour) in T1-P (283.000 h), Koming-1(154) (279.667 h), Baghdadi (277.333 h), Y-5 (271.333 h), and Tokaee-202 (270.000 h) strains increased significantly in comparison with other strains (Table 1). 4-5 instars molting larval duration (hour) remained significantly at upper level in the W2-11-19-2 (41.000 h), W2-11-19-3 (41.000 h), T5-P (41.000 h), 104 (35.667 h), and 124-K (35.667 h) increased significantly in comparison with other strains (Table 1).

From the results obtained, it is showed that the 5 instars feeding larval duration (hour) of the T1-P (179.000 h), Tokaee-202 (174.000 h), 18-1 (173.333 h), Y-5 (172.667 h), and Shown (172.000 h) strains remained significantly at upper level than other strains respectively (Table 1). The and cocoon spinning duration (h) in Lemon Haratee (21.000 h), Yellow Haratee (13.000 h), Baghdadi (1.000 h), 104 (00.000 h), and 124-K (00.000 h) strains increased significantly in comparison with other strains (Table 1).

Also, based on larval growth potential of strains were assessed on different parameters including larval duration (hour), feeding larval duration (hour), molting larval duration (hour), 1-3 instars larval duration (hour), 1-3 instars feeding larval duration (hour), 1-3 instars molting larval duration (hour), 4-5 instars larval duration (hour), 4-5 instars feeding larval duration (hour), 4-5 instars molting larval duration (hour), 5 instar feeding larval duration (hour), and cocoon spinning duration (hour). Recorded characteristics of larval weight using the evaluation index (Tables 2 and 4) and sub-ordinate function (Tables 3 and 4) methods and the details are as follows.

Among germplasm strains, as per the evaluation index method, the strains T1-P (67.675 h), Baghdadi (65.356 h), 106 (61.413 h), Shown (61.181 h), and 18-1 (60.948 h) showed higher evaluation index values for larval duration (hour) (Table 2). Also, as per the evaluation index method, the strains Koming-1[154] (70.807 h), 32×110 (70.407 h), T1-P (69.807 h), Baghdadi (67.206 h), and Y-5 (62.803 h) showed higher

Table 4. Ranking of studied silkworm germplasm based on average of evaluation index method and sub-ordinate function method for larval traits.

Method	Evaluation index method		Sub-Ordinate function method	
Pure lines	**Value**	**Rank**	**Value**	**Rank**
6/4-6/6	439.793	53	2.414	53
104	519.980	42	3.572	41
124-K	508.475	45	3.569	42
120-K	498.257	48	3.076	48
108-K	440.988	52	2.518	52
W2-11-19-2(110)	536.865	26	4.189	22
W2-11-19-3	536.865	27	4.189	23
1002-4-C-5	589.074	20	4.888	15
1002-E-8-3	514.539	43	3.918	31
Guilan-Orange	536.802	28	4.138	25
Khorasan-Orange	521.671	39	3.721	39
Shown	610.616	6	5.074	6
T1-P	629.757	1	5.108	5
T5-P	529.073	32	3.887	32
CS120(7409)	533.951	30	3.928	30
BH-4	512.495	44	3.485	45
BH-3	528.395	33	3.811	35
104×110	496.813	49	3.020	50
110×104(152)	594.819	19	4.686	21
32×110	580.678	22	4.137	26
110×32	613.690	4	5.226	3
18-1	607.050	9	4.943	9
1538-8-2(114)	602.107	13	4.870	16
1538-14-9(112)	598.422	16	4.915	13
4-4	614.826	3	5.343	1
32	611.407	5	5.260	2
Tokaee-202	607.505	8	4.934	11
106	605.411	11	4.918	12
17	603.262	12	4.915	14
Shaki A×D	465.881	51	2.819	51
124-16-9(116)	529.623	31	3.796	36
Mose.Black-Plain(2)	521.671	40	3.721	40
726(118)	534.251	29	4.081	27
1627-14-4-3	586.450	21	4.711	19
Koming-1(154)	552.768	23	3.518	44
1627-14-2-8	598.234	17	4.869	17
Mos.Black-Black(2)	528.020	34	3.967	28
823	548.546	24	4.157	24
1640	524.557	37	3.833	34
102(Shown)	503.093	47	3.476	46
W2-13-9(108)	525.711	36	3.877	33
1001	428.874	54	2.055	54
W1-2-7	507.614	46	3.222	47
CS120(N19)	538.503	25	3.789	37
Koming-2-5	522.825	38	3.765	38
W2-13-4	528.020	35	3.967	29
Y-5	597.711	18	4.704	20
127-17	606.148	10	5.027	7
Lemon Khorasan	601.746	14	4.954	8
Lemon Haratee	521.144	41	3.522	43
White Haratee	599.437	15	4.865	18
Yellow Haratee	475.241	50	3.062	49
Pink Khorasan	610.157	7	5.155	4
Baghdadi	620.191	2	4.938	10

evaluation index values for feeding larval duration (hour) (Table 2).

Meanwhile, as per the evaluation index method, the strains W2-11-19-2[110] (69.877 h), W2-11-19-3 (69.877 h), 1002-E-8-3 (69.425 h), 1002-4-C-5 (60.838 h), and Guilan-Orange (59.482 h) showed higher evaluation index values for molting larval duration (hour) (Table 2). Among germplasm strains, as per the evaluation index method, the strains 1538-14-9[112] (68.75 h), CS120 (N19) (68.75 h), 4-4 (65.977 h), 32 (65.977 h), and 1002-4-C-5 (54.886 h) showed higher evaluation index values for 1-3 instars larval duration (hour) (Table 2). Also, as per the evaluation index method, the strains CS120[N19] (85.055 h), 32×110 (80.841 h), Koming-1[154] (63.986 h), Baghdadi (58.835 h), and 110×104[152] (57.899 h) showed higher evaluation index values for 1-3 instars feeding larval duration (hour) (Table 2).

Meanwhile, as per the evaluation index method, the strains 32 (64.532 h), 4-4 (63.522 h), 1002-4-C-5 (63.017 h), 1538-14-9[112] (63.017 h), and Mos.Black-Black[2] (63.017 h) showed higher evaluation index values for 1-3 instars molting larval duration (hour) (Table 2).

Among germplasm strains, as per the evaluation index method, the strains Baghdadi (70.125 h), Koming-1[154] (68.005 h), T1-P (67.475 h), Tokaee-202 (60.318 h), and 106 (60.318 h) showed higher evaluation index values for 4-5 instars larval duration (h) (Table 2). Also, as per the evaluation index method, the strains T1-P (71.353 h), Koming-1[154] (68.813 h), Baghdadi (67.035 h), Y-5 (62.463 h), and Tokaee-202 (61.448 h) showed higher evaluation index values for 4-5 instars feeding larval duration (h) (Table 2).

Meanwhile, as per the evaluation index method, the strains W2-11-19-2[110] (79.74 h), W2-11-19-3 (79.74 h), T5-P (79.74 h), 104 (68.28 h), and 124-K (68.28 h) showed higher evaluation index values for 4-5 instars molting larval duration (hour) (Table 2). Among germplasm strains, as per the evaluation index method, the strains T1-P (31.548 h), Tokaee-202 (31.548 h), 18-1 (110.853 h), Y-5 (31.548 h), and Shown (31.548 h) showed higher evaluation index values for 5 instars feeding larval duration (hour) (Table 2). Also, as per the evaluation index method, the strains, Lemon Haratee (115.43 h), Yellow Haratee (79.014 h), Baghdadi (50.513 h), and 104 (48.138 h) showed higher evaluation index values for and cocoon spinning duration (hour) (Table 2).

Totally, T1-P (629.757), Baghdadi (620.191), 4-4 (614.826), 110×32 (613.690), and 32 (611.407) showed higher evaluation index values (Table 4). Among germplasm strains, as per the evaluation index method, all the strains showed same evaluation index values (0.000 h) for larval duration (hour) (Table 2). Also, among germplasm strains, as per the evaluation index method, all the strains showed same evaluation index values (0.000 h) for feeding larval duration (hour) (Table 2).

Meanwhile, as per the evaluation index method, the strains W2-11-19-2[110] (1.000), W2-11-19-3 (1.000), 1002-E-8-3 (0.991), 1002-4-C-5 (0.825), and Guilan-Orange (0.798) showed higher evaluation index values for molting larval duration (h) (Table 2). Among germplasm strains, as per the evaluation index method, the strains 1538-14-9[112] (1.000), CS120[N19] (1.000), 4-4 (0.920), 32 (0.920), and 1002-4-C-5 (0.600) showed higher evaluation index values for 1-3 instars larval duration (hour) (Table 2). Also, as per the evaluation index method, the strains CS120[N19] (0.290), 32×110 (0.753), Koming-1[154] (0.753), Baghdadi (0.548), and 110×104[152] (0.806) showed higher evaluation index values for 1-3 instars feeding larval duration (hour) (Table 2).

Meanwhile, as per the evaluation index method, the strains 32 (1.000), 4-4 [111] (0.978), 1002-4-C-5 (0.968), 1538-14-9[112] (0.968), and Mos.Black-Black[2] (0.968) showed higher evaluation index values for 1-3 instars molting larval duration (hour) (Table 2). Among germplasm strains, as per the evaluation index method, the strains Baghdadi (1.000), Koming-1[154] (0.953), T1-P (0.942), Tokaee-202 (0.785), and 106 (0.785) showed higher evaluation index values for 4-5 instars larval duration (hour) (Table 2). Also, as per the evaluation index method, the strains T1-P (1.000), Koming-1[154] (0.943), Baghdadi (0.902), Y-5 (0.799), and Tokaee-202 (0.776) showed higher evaluation index values for 4-5 instars feeding larval duration (hour) (Table 2).

Meanwhile, as per the evaluation index method, the strains W2-11-19-2[110] (1.000), W2-11-19-3 (1.000), T5-P (1.000), 104 (0.733), and 124-K (0.733) showed higher evaluation index values for 4-5 instars molting larval duration (hour) (Table 2). Among germplasm strains, as per the evaluation index method, the strains T1-P (1.000), Tokaee-202 (0.459), 18-1 (0.035), Y-5 (0.000), and shown (0.000) showed higher evaluation index values for 5 instar feeding larval duration (h) (Table 2). Also, as per the evaluation index method, the strains Lemon Haratee (0.112), Yellow Haratee (0.121), Baghdadi (0.135), 6/4,6/6 (0.193), and 104 (0.212) showed higher evaluation index values for and cocoon spinning duration (hour) (Table 2). Totally, 4-4 (5.343), 32 (5.260), 110×32 (5.226), Pink Khorasan (5.155), and T1-P (5.108) showed higher sub-ordinate function values (Table 3).

DISCUSSION

The cluster analysis revealed a clear division into some groups and sub-groups (Figures 1 to 7). Various methods generated similar dendrograms. This study reveals the phylogenetic relationship of oval cocoon strains of Iran germplasm. Based on the data from studied characters, we constructed dendrograms that resolved the 54 silkworm strains into some major clusters. However, the strains of the same origin did not grouped together, demonstrating that they might have different biological

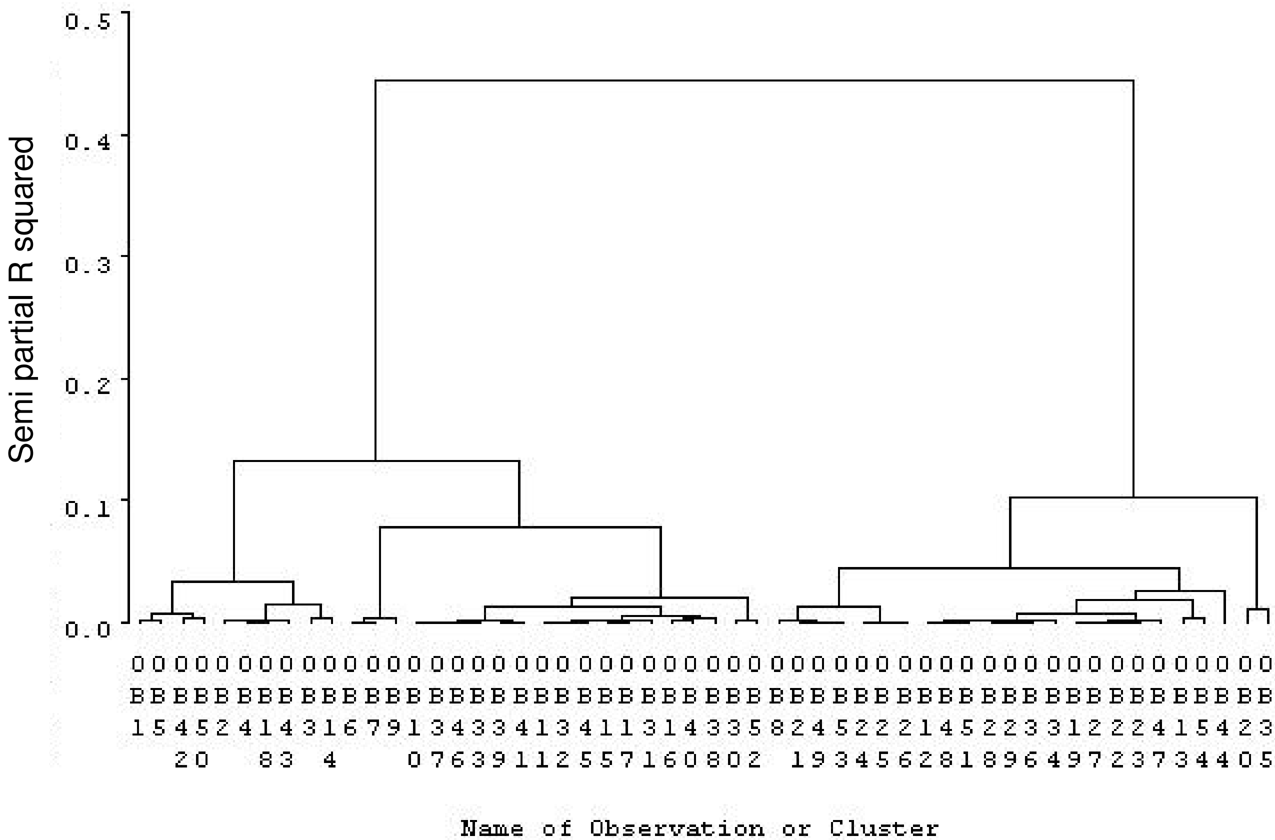

Figure 1. Cluster analysis based on all 37 studied larval development traits for 54 silkworm strains according to the grouping from WARD method using SAS.

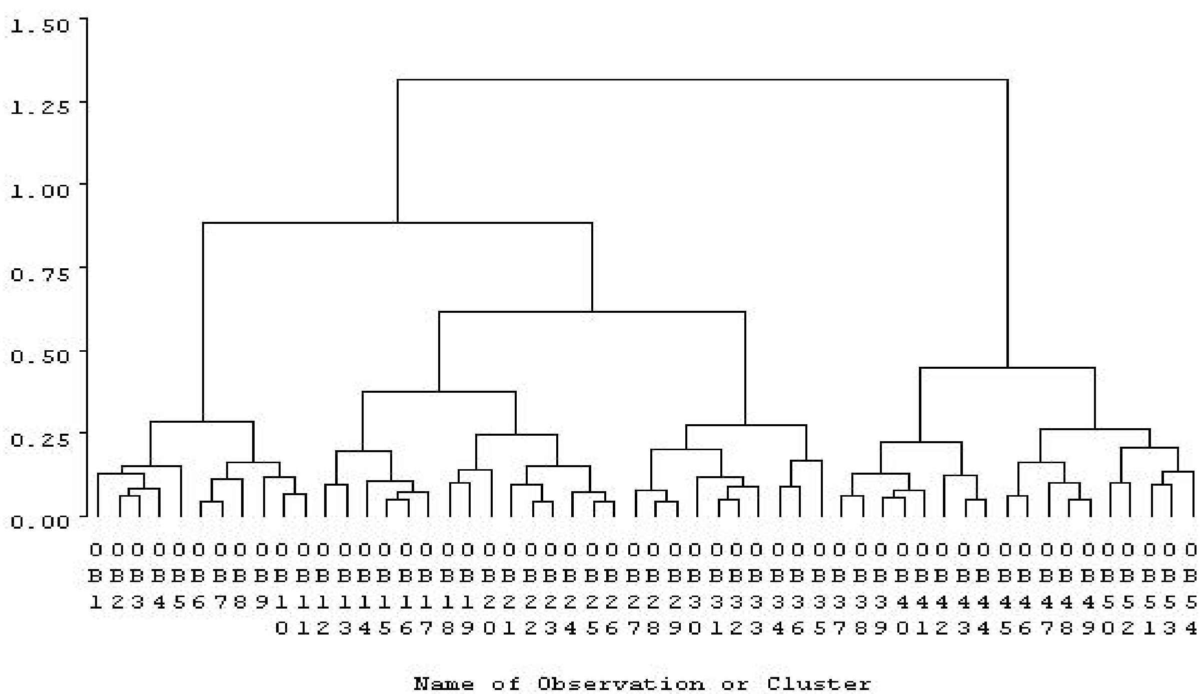

Figure 2. Cluster analysis based on all 37 studied larval development traits for 54 silkworm strains according to the grouping from average method using SAS.

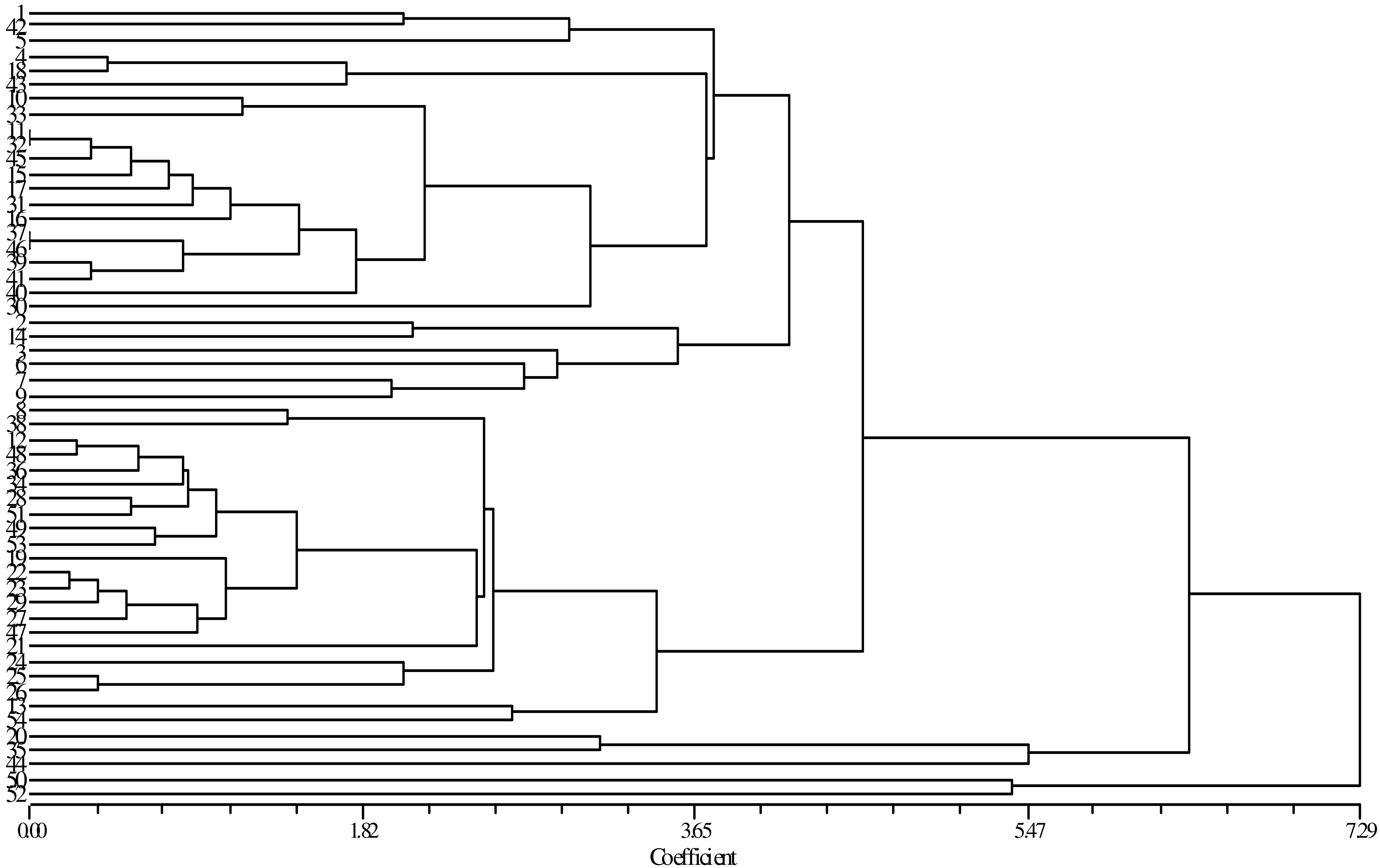

Figure 3. Cluster analysis based on all 37 studied larval development traits for 54 silkworm strains according to the grouping from complete method using NTSYS.

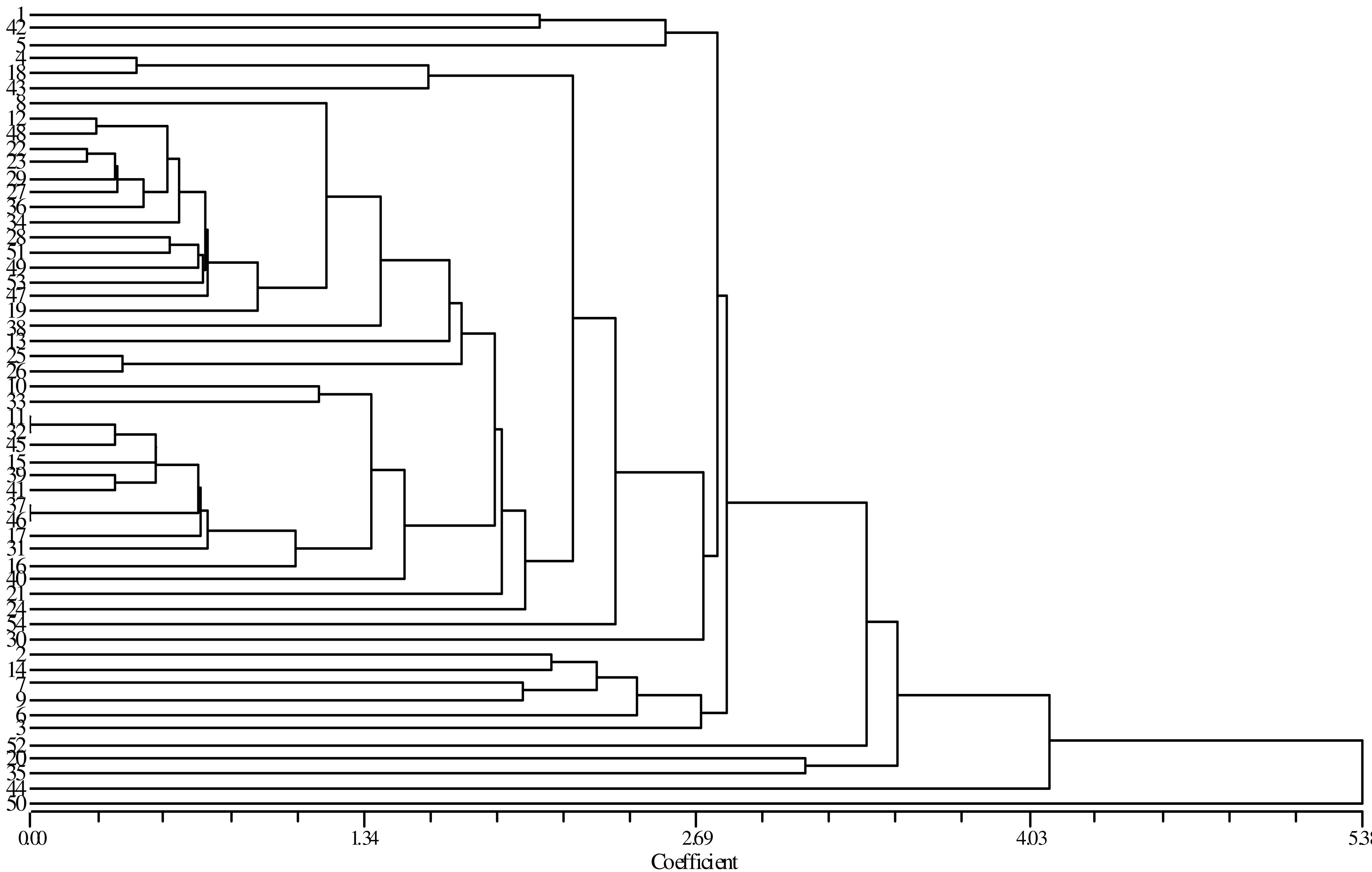

Figure 4. Cluster analysis based on all 37 studied larval development traits for 54 silkworm strains according to the grouping from single method using NTSYS.

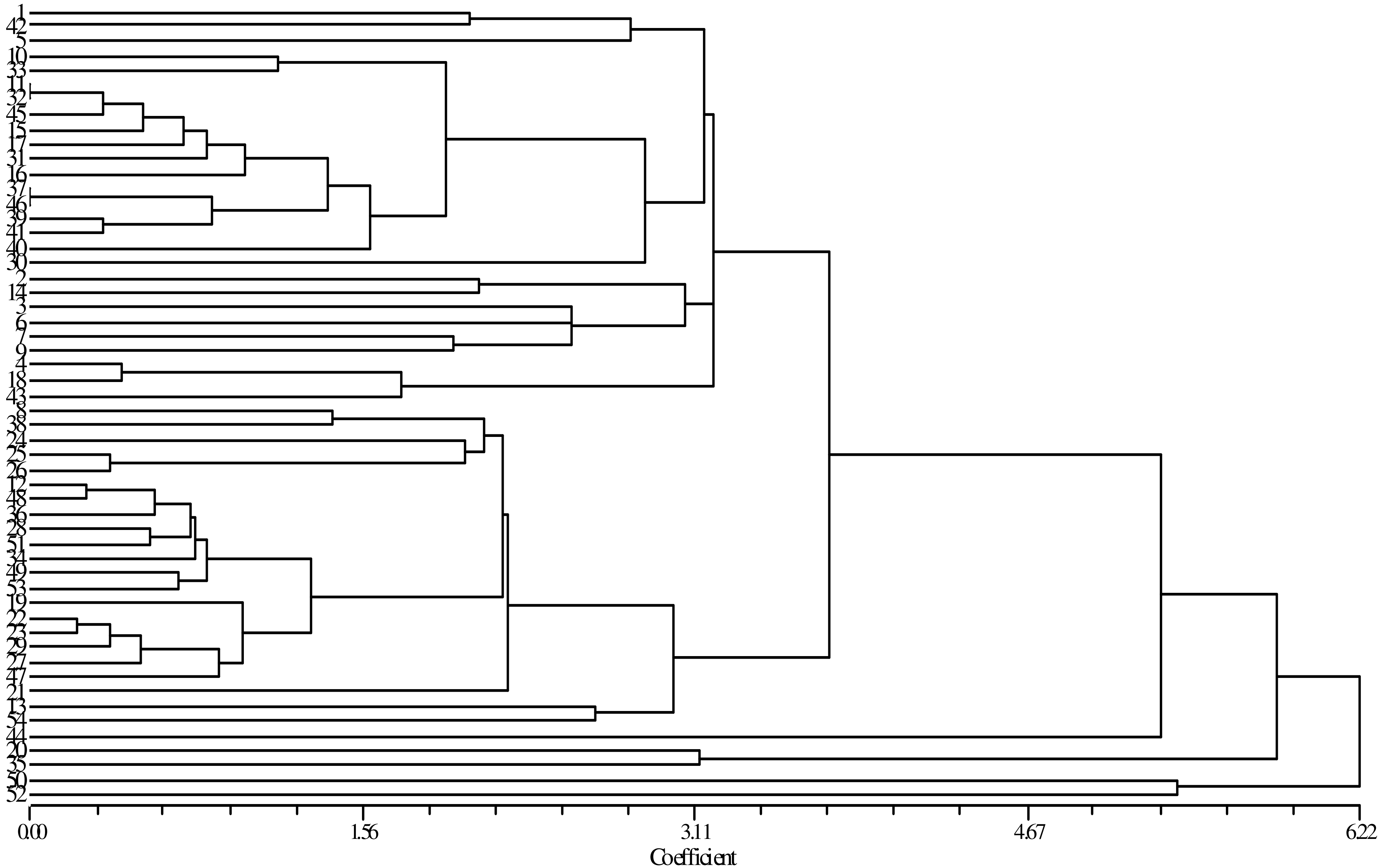

Figure 5. Cluster analysis based on all 37 studied larval development traits for 54 silkworm strains according to the grouping from UPGMC method using NTSYS.

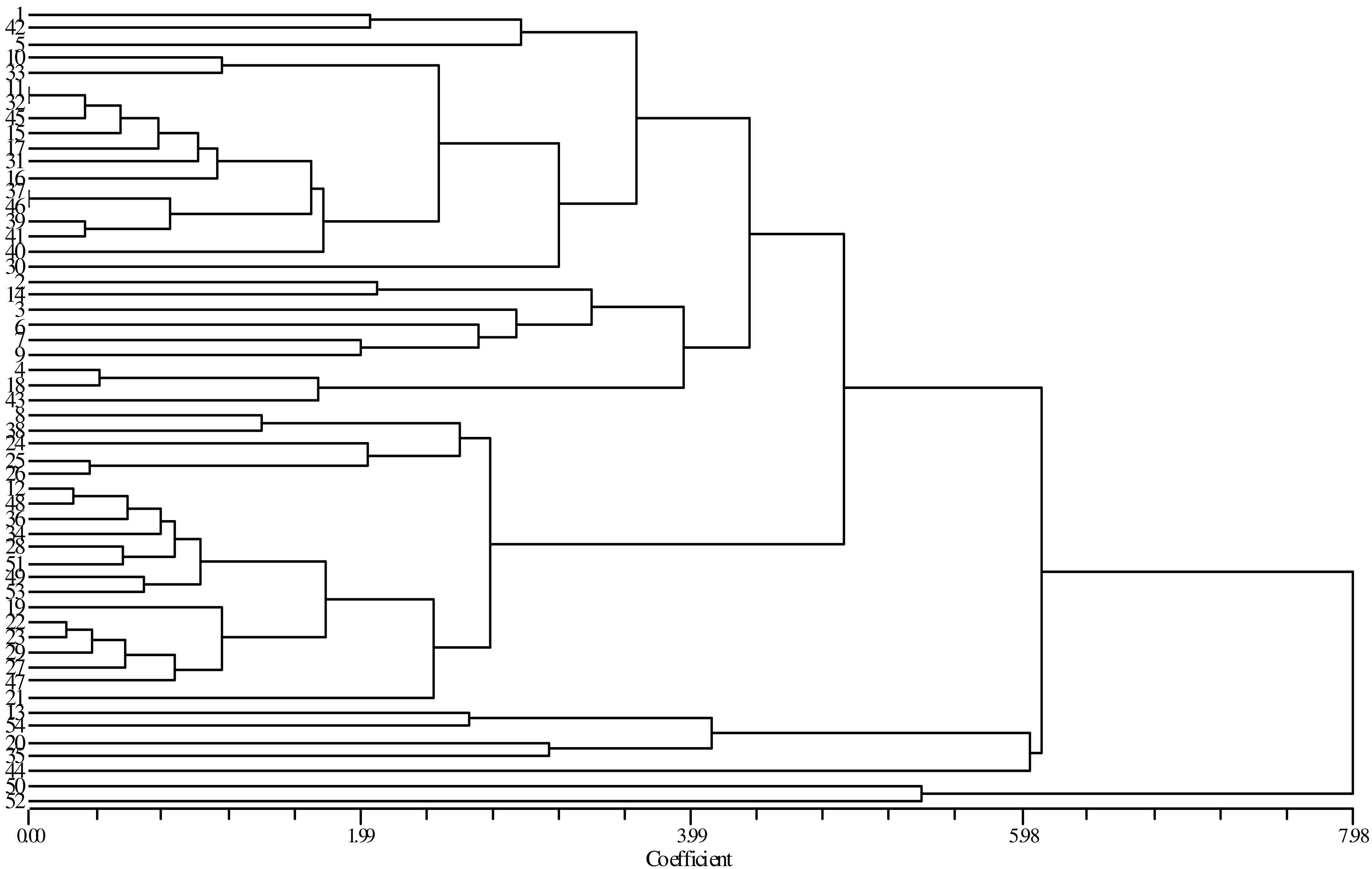

Figure 6. Cluster analysis based on all 37 studied larval development traits for 54 silkworm strains according to the grouping from FLEXI method using NTSYS.

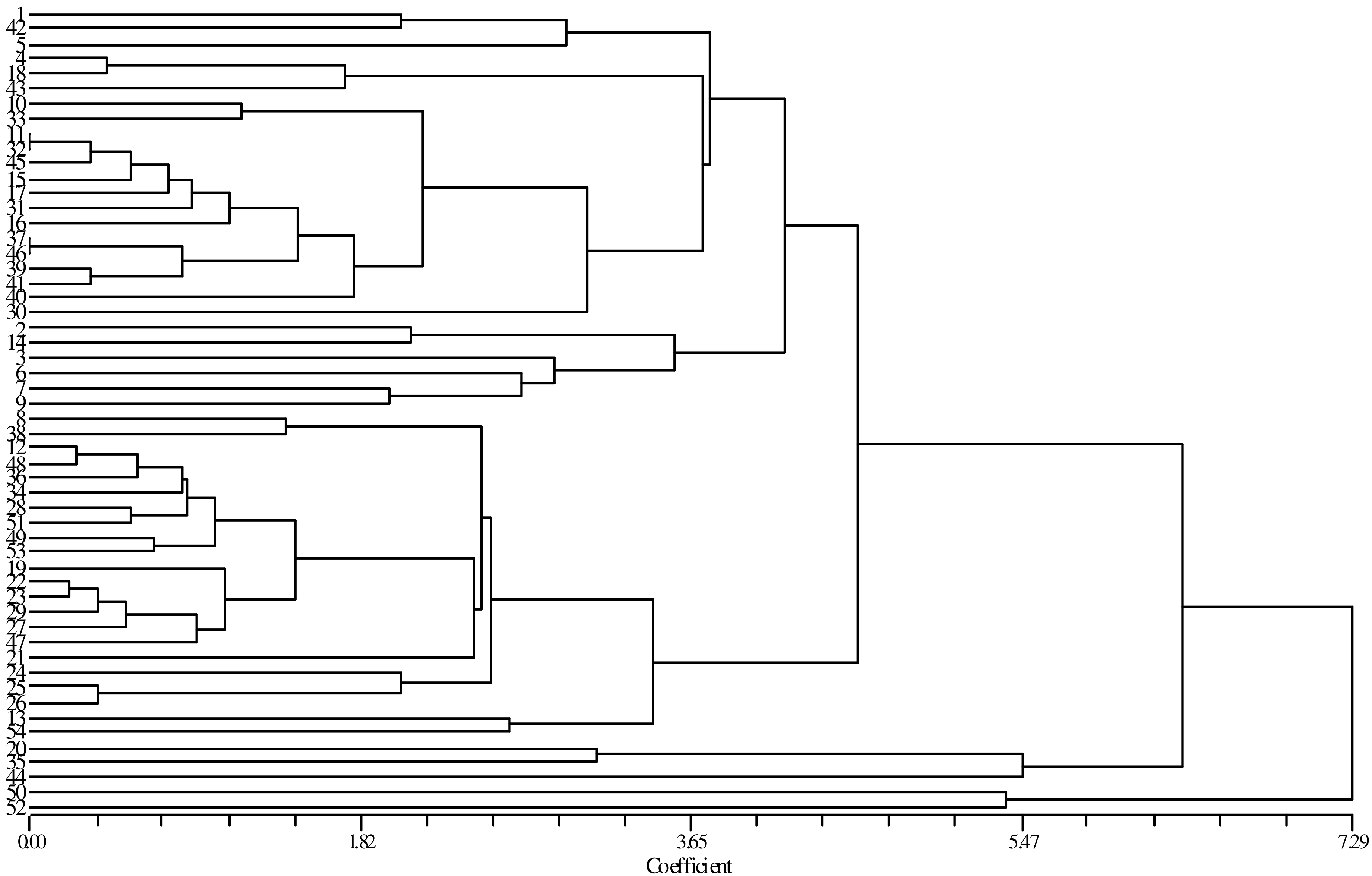

Figure 7. Cluster analysis based on all 37 studied larval development traits for 54 silkworm strains according to the grouping from UPGMA (Unweighted Pair Group Method Average) method using NTSYS.

and development performance. Main clusters divided into some sub-groups included various strains. Some strains were grouped together and far from other silkworm strains, indicating they might be suitable for future crossings, maintenance of parental strains and hybridizations with peanut cocoon strains so as to maximize heterosis and to avoid depression inbreeding.

B. mori strains have been reared in different regions of the world and different strains have evolved because of changes in their phenotype and genotype over time (Mirhosseini et al., 2007). Based on one hypothesis, all the strains during a long period have been differentiated from a monovoltine Chinese variety (Chatterjee and Data, 1992; Mirhosseini et al., 2007).

Li et al. (2007) performed ISSR amplification to analyze the genetic relationship among different silkworm strains maintained at Sericultural Research Institute (SRI-CAAS) of China. They identified the monovoltine, bivoltine and polyvoltine strains, which clustered separately (Li et al., 2007; Dhanikachalam et al., 2008).

Nei (1973) stated genetic distance is "that difference between two entities that can be described by allelic variation" (Mohammadis and Prasanna, 2003). This definition was later elaborated by Nei (1987) as "the extent of gene differences… between populations or species that is measured by some numerical quantity" (Mohammadis and Prasanna, 2003).

Systematic studies of resource material are very important for the classification and characterization of varieties and also for the selection of promising parents to be utilized in genetic breeding programs. Therefore, characterization of each germplasm bank and access to the maximum amount of information is essential for their appropriate utilization in the future (Zanatta et al., 2009).

Researchers emphasized that the high genetic variation might not give always a high genetic diversity in the inbreeding population of same species. This further confirmed the earlier report that the genetic diversity is not always related with geographical diversity (Ramamohana and Nakada, 1998). It is obvious that the silkworm germplasm contributes the potential raw materials for breeding having wide genetic variation in their genotypic expression besides additive effect due to inbreeding (Kumaresan et al., 2007).

Chatterjee and Data (1992) presented it is worth noting that sometimes a cluster includes members having different countries of origin (Kobayashi, 1990; Chatterjee and Data, 1992). Also, they believed clustering on the basis of estimates of phenotype does not always reflect geographical distance, has also been pointed out by researchers working on the clustering of plant materials. For example, as Chatterjee and Data (1992) presented Spagnoletti and Qualset (1987) pointed out that geographical position does not correspond with the phenotypic grouping for the origin of spike characteristics in Duram wheat.

Chattarijee and Datta (1992) utilized the biochemical markers to classify 54 silkworm strains with different geographical origins. They also obtained similar results on some strains with different origin in one group and also strains with the same origin in different groups.

In conclusion, our results confirm and complemented previous papers regarding importance of evaluation and classification of Iranian silkworm strains based on economical and biological characters (Salehi et al., 2009, 2010a, b, 2010c). The different studies previously shown need major revision, and it should be given in the form of discussion rather than in the form of review of literature.

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