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CLASIFICATION OF SELECTED ROMANIAN BREEDS AND HYBREDS OF SILKWORM USING MULTIPLE TRAIT EVALUATION INDEX METHOD

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Abstract

Mulberry silkworm (Bombyx mori L.) is a species with high economical and scientific value, acknowledged at international level, as well as at national level. Extensive research was conducted on the local silkworm breeds and hybrids, on both biological and technological parameters, yet no classification was done. The main purpose of the current research is to attempt to implement a classification of 17 breeds and hybrids of the silkworm using a statistical analysis method called Evaluation Index Method that takes into consideration multiple economical and technological traits. The biological and technological traits that were taken into consideration are: prolificacy (number of eggs/laying, hatching percent), evaluation of the larvae (weight), duration of the larval period, evaluation of the raw silk cocoon and the dried silk cocoon (dimension, weight of the cocoon, weight of chrysalis, weight of the silk shell). The results of the present study will result in a clear classification, based on their economical value and the breeds and hybrids that have a cumulative value of the index higher than 50, will be considered economical valuable.

Key words*: silkworms, parameters, evaluation, classification*

INTRODUCTION

Silk is a sought after textile due to its elegance, softness and ecological nature it detains. The silk is widely used, from textile industry to the medical and technological industries, making it a valuable animal product worth rearing.

The origin of the silk fabric is the silk cocoon, which, are produced mostly by the silkworm *Bombyx mori* L, mainly known as the mulberry silkworm (Popescu, 2013).

Not only it is a source for important textile fabrics, but this insect is also considered an important biological model used in many fields of research, including genetics (Furdui et al, 2010, Furdui et al., 2014).

In order to assure the best results by obtaining good and healthy larvae and valuable cocoons, it is important that the proper rearing technique is implemented, the needed microclimate conditions are assured and feed requirements must be met (Furdui et al, 2010). In the case of the Romanian Sericulture industry, it can be stated that is as known a long development with its success and failures, its development being aided by a favorable environmental conditions, suitable for silkworm rearing. After 1990, the industry has continued to decline and, in the present time, the main activities are focused preservation of the biological silkworm breeds and mulberry breeds) that, despite being rather productive, do need improvements focused on increased silk production capacity. The silkworm breeds are currently managed by the Global Center of Excellence for Advanced Research in Sericulture and Promotion of Silk Production, (GCEARS–PSP) established at the University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca

(Mărghitaș et al, 2005, Dezmirean el al., 2013; Dezmirean et al., 2018).
The sericultural gene pool plays a pivotal role in conservation or/and diversification of species. The GCEARS–PSP creates programs for local adapted biological material preservation (Matei et al, 2008).
The classification of the silkworm breeds and hybrids plays an important economical role as it offers a perspective of the valuable technological characteristics of the analyzed breeds and hybrids (focused on silk and on important byproducts).
The present study has the role to present the results obtained from the rearing of breeds and hybrids of silkworms. The obtained results will provide a classification trough Multiple Trait Evaluation Index, a classification method that takes into consideration a cumulus of economical and technological traits (Sudhkara et al, 2001; Buhroo et al, 2017).
The importance will be focused on the breeds with maximal values as they will be considered economical important.

MATERIALS AND METHODS

The experiments took place at the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, within the Global Center of Excellence for Advanced Research in Sericulture and Promotion of Silk Production, (GCEARS–PSP). Rearing of the silkworms was done in a specially arranged room (magnanery) at the Faculty of Animal Husbandry and Biotechnologies/ Sericulture Department, under proper implemented rearing techniques (Mărghitaș et al., 2003), respecting the microclimate requirements as stated in Table 1:

Table 1. Optimal rearing temperature and humidity requirements (Furdui et al., 2010)

Instar	Temperature	Humidity
I-II	26-28°C	80-85%
III	25-26°C	75-80%
IV-V	23-24°C	65-70%

The breeds and hybrids, part of the genetic sericultural resources of the University of Agricultural and Veterinary Medicine Cluj-Napoca, selected for the current research are as follows (Mărghitaș et al, 2009, Dezmirean et al., 2010; Dezmirean et al., 2018, ,):

- White cocoon breeds: AB, AO 33, B1, C122, J90, JH3, N5, P4/T, S8;
- Coloured cocoon Breeds: Galben de Băneasa, Auriu Chinezesc, RG 90, E27;
- White cocoon commercially established hybrids: AC/t, AC29/T, AJ 5F, CTK.

The measurements were performed for the evaluation of the following biological and technological characteristics:

- Eggs: number of eggs/laying, hatching percent;
- Larvae: larval duration, larvae weight (5th instar, day 7);
- Chrysalis: weight; raw and dried silk;
- Cocoons: cocoon weight, chrysalis weight, silk shell weight, silk ratio (%).

The results were analysed statistically and then analysed under the Evaluation Index (a novelty classification method in Romania, but an established statistical analysis method in India) for the classification of the analysed breeds and hybrids.
The formula of the Evaluation index is as follows (Sudhkara et al, 2001; Buhroo et al, 2017):

$$EI = \frac{A - B}{C} X10 + 50$$

Where:
A = the mean value of a trait within a species,
B = the mean value of a trait for all breeds and hybrids analyzed,
C = the standard deviation of a feature for all breeds and hybrids,
10 = standard unit,
50 = fixed value.

In the case of negative traits, such as larval period, the formula changes as follows (Sudhkara et all, 2001; Buhroo et al, 2017):

$$EI = \frac{B - A}{C} X10 + 50$$

According to this Indicator, breeds and hybrids that have a value of the EI index higher than 50, are considered of great economical value (Sudhkara et al, 2001; Buhroo et al, 2017).

RESULTS AND DISCUSSIONS

The obtained results concerning fecundity and hatching percent are presented in Table 2.

Table 2. Fecundity and Hatching percent of studied silkworm breeds and hybrids (2017)

		Fecundity	Hatching (%)
Breeds (White cocoon)	AB	641	94.93
	AO33	568	97.23
	B1	645	93.61
	C122	648	93.65
	J90	620	90.48
	JH3	684	89.77
	N5	650	94.61
	P4/T	647	96.56
	S8	611	91.49
Breeds (coloured cocoon)	Auriu Chinezesc	522	95.21
	E27	479	84.98
	Galben de Băneasa	575	90.14
	RG 90	442	93.16
Hybrids	AC/T	695	92.36
	AC29/T	654	95.16
	AJ5/F	612	91.78
	4. CTK	634	95.73
$\bar{X}$		607.47	92.99
$S_{\bar{x}}$		69.79	3.04

From the analysis of these parameters it can be stated that, from the white cocoon breeds, JH3 have the higher prolificacy with 684 eggs/laying, followed by N5 with 650 eggs/laying and P4/T 647 egg/laying. The breeds C122 with 648 eggs/laying and a hatching percent of 93.65% and AB with 641 eggs/laying and a hatching percent of 94.93% appear to be most valuable.

The lowest values are registered by AO 33 with 568 eggs/laying with a high hatching percent of 97%.

In the case of coloured cocoon breeds, taking into account both fecundity and hatching, it can be stated that the valuable breeds are Auriu Chinezesc with 522 eggs/laying and a hatching percent of 95.21% and Galben de Băneasa with 575 eggs/laying and a hatching percent of 90.14%

In the case of the analysed hybrids, in can be observed that the number of eggs/laying and hatching percent are rather valuable as all hybrids registered high values in both parameters.

Other researchers have analysed white cocoon breeds and white cocoon hybrids.

On the fecundity parameters most the breeds and hybrids recorded values slightly higher than in other studies, but in terms of hatching percent, the recorded values are close, with variations of only 1 to 6%.

The average values in terms of the profilacity and hatchability parameters, diferences in time placement of the study affects these parameteres, as it is stated by Dezmirean et al, 2015.

Acording to studies done on the entire silkworm *Bombyx mori* gene pool, the fecundity values lye inbetween 318 and 584 eggs/laying, average values lowered by the tropical orgin silkworm breeds. Localy adapted and/or obtained breeds and highbreeds record values above the mentiod average. As these breeds have been localy adapted, their values have grown closer to the native group values (490-710 eggs/laying). For the hatching (%) parameter in can be stated that all the studied breeds and hybrids have values close to the whole gene pool hatching average value of 83.9-99.1%, with the exception of the AB breed and RG 90 breed (Matei, 2007; Matei et al, 2009; Mărghitaș et al., 2009 ; Dezmirean et al., 2010; Furdui, et all, 2010; Dezmirean et al, 2015; Dezmirean et al, 2018).

Table 3. Duration of the larval stage of studied silkworm breeds and hybrids

		Larval period (Days)
Breeds (White cocoon)	AB	33.060
	AO33	31.956
	B1	32.959
	C122	32.941
	J90	32.957
	JH3	32.956
	N5	32.958
	P4/T	32.951
	S8	32.956
Breeds (colored cocoon)	Auriu Chinezesc	32.959
	E27	28.942
	Galben De Băneasa	31.958
	RG 90	32.038
Hybrids	AC/T	32.953
	AC29/T	32.958
	AJ5/F	32.956
	CTK	32.956
$\bar{X}$		32.554
$S_{\bar{x}}$		1.007

From the table 3, it can be stated that all the studied breeds and hybrids have similar larval period, with the exception of the coloured breed E27, where the shortest larval stage is registered with the value of 28.942 days.

The recorded larval periods are longer by an average of 2 to 4 days in comparison to other studies, close to the values registered by the native breeds and Japanese breeds from the silkworm native gene pool (Matei et al, 2009; Mărghitaş et al., 2009; Dezmirean et al, 2010).
The average weight of the silkworm larvae can be economical valuable, especially in the food and animal fodder industry, therefore from this perspective, the average weight it's not only a trait for comparison, but a trait to consider from an economical perspective.

Table 4. Average larval weight studied silkworm breeds and hybrids

		Larvae weight
Breeds (White cocoon)	AB	2.9607
	AO33	2.8074
	B1	3.1972
	C122	2.7078
	J90	3.0987
	JH3	2.9270
	N5	3.2894
	P4/T	3.2728
	S8	3.0178
Breeds (collored cocoon)	Auriu Chinezesc	2.4508
	E27	2.5645
	Galben de Băneasa	2.7473
	RG 90	3.5567
Hybrids	AC/T	3.2738
	AC29/T	3.8585
	AJ5/F	2.8167
	CTK	2.6852
$\bar{X}$	3.0137	3.0137
$S_{\bar{x}}$	0.5407	0.5407

From the table above, it can be stated that from the white cocoon breeds the most valuable are N5 with an average weight of 3.2894 g, followed by P4/T (3.2728 g) and J90 (3.0987 g). The lowest average weight is registered by C122 with the average weight of 2.7078 g. From the colored cocoon breeds, the most valuable breeds are RG 90 (3.5567) and Galben de Băneasa (2.7473g), and the lowest value is registered by Auriu Chinezesc breed with the average value of 2.4508 g.
From the studied hybrids the most valuable one is AC29/T with an average weight of 3.8585 g and least valuable hybrid is AJ5/F with the average value of 2.8167g.
Taking into consideration other studies done on selected breeds and hybrids, where similar values were obtained, with the exceptions of a few breeds (B1 and S8) and hybrids (AC/T), the registered values were lower, on average by 1 gram in comparison with the recorded values of other research projects (Matei, 2007; Furdui et al., 2010).
Differences in weight can also be influenced by the day of sample collection. In the present study, samples were collected and measurements made in the 7th day of the 5th instar of the larval period.

Table 5. Average values of raw silk cocoon parameters for the studied silkworm breeds and hybrids

		Cocoon Weight (g)	Chrysalis weight (g)	Silk Shell Weight (g)	Silk Ratio (%)
Breeds (White cocoon)	AB	1.5083	1.1810	0.3274	23.46
	AO33	1.8190	1.4530	0.3579	19.95
	B1	2.0052	1.5996	0.3900	19.56
	C122	1.7357	1.3930	0.3322	19.25
	J90	1.6988	1.3458	0.3475	20.72
	JH3	1.7822	1.4437	0.3366	18.92
	N5	1.8003	1.4477	0.3412	19.13
	P4/T	1.8210	1.4539	0.3554	19.97
	S8	1.7937	1.4814	0.3067	17.18
Breeds (collored cocoon)	Auriu Chinezesc	1.7958	1.4876	0.2987	16.78
	E27	1.1904	1.0212	0.1710	14.48
	Galben de Băneasa	1.7234	1.4041	0.2557	15.17
	RG 90	1.9263	1.5819	0.3343	17.42
Hybrids	AC/T	1.7171	1.3698	0.3394	19.93
	AC29/T	2.2207	1.7935	0.4167	18.87
	AJ5/F	1.8843	1.5112	0.3672	19.59
	CTK	2.0498	1.6577	0.3810	18.59
$\bar{X}$		1.7902	1.4473	0.3321	18.66
$S_{\bar{x}}$		0.3383	0.2830	0.0706	3.00

After the results from the table 5 were analyzed, it can be observed that from the white silk cocoon breeds, the breeds with the heavier silk cocoons are B1 with an average weight of 2.0052 g, followed by P4/T (1.8210 g) and AO33 (1.8190 g). AB and S8 have cocoon weight values well above 0.300 g, a very valuable aspect.
The most valuable breed with coloured cocoons is RG 90 with an average cocoon weight of 1.9263 and the least valuable breed is E27 with the cocoon average weight of 1.1904 g. From the white cocoon hybrids, the most valuable is CTK with a cocoon weight of 2.0498 and the least valuable hybrid is AC/T with a cocoon average weight of 1.7171 g.
The chrysalis may be important economical by-products as it is a source of natural fat and protein content. Economically, the most important white cocoon breeds are B1 (1.5996 g), followed by S8 (1.4876 g) and P4/T (1.4816g). In the case of the coloured cocoon

breeds, the average chrysalis weight is between 1.0212 g (E27) and 1.5819 (RG90) . In the case of the hybrids, the average chrysalis weight is registered between 1.3698 (AC/T) and 1.7935 (AC29/T).

In terms one of the most important economical traits, the weight of silk shell, it can be stated that for the white cocoon breeds, the minimal value is recorded by S8 breed with a minimal value of 0.3067 g and the maximal value is recorded by the breed B1 with the average weight of 0.3900 g.

In the case of the coloured cocoon breeds the values are registered between 0.1710 for E27 and 0.3343 g for RG 90.

For the analysed hybrids the differences between them are quite visible as well as the average shell weight is situated between 0.3394 for AC/T and 0.4169 g for AC29/T.

In the case of the silk content percent, for the white silk cocoon breeds the values are between 17.18% for S8 and 23.46% for AB, for coloured silk cocoons breeds the values are situated between 14.8% for E27 and 17.42%. for RG90 and for the hybrids are between 17.42 for AC/T and 19.93% for AC 29/T.

Table 6. Average values of dried silk cocoon parameters for the studied silkworm breeds and hybrids

		Dried Cocoon Weight (g)	Dried Chrysalis weight (g)	Dried Silk Shell Weight (g)	Silk Ratio (%)
Breeds (White cocoon)	AB	0.6077	0.3032	0.3012	51.18
	AO33	0.6662	0.3284	0.3328	51.95
	B1	0.7983	0.4198	0.3643	45.79
	C122	0.5814	0.2923	0.2833	48.47
	J90	0.6536	0.3216	0.3230	49.13
	JH3	0.5640	0.2794	0.2738	48.77
	N5	0.6893	0.3483	0.3332	48.48
	P4/T	0.6893	0.3483	0.3332	48.48
	S8	0.6364	0.3227	0.2986	48.13
Breeds (coloured cocoon)	Auriu Chinezesc	0.6430	0.3571	0.2802	43.99
	E27	0.3974	0.2265	0.1636	41.31
	Galben de Băneasa	0.5559	0.3182	0.2298	40.97
	RG 90	0.5980	0.3233	0.2657	44.50
Hybrids	AC/T	0.6011	0.2977	0.2943	49.06
	AC29/T	0.7780	0.3795	0.3900	50.15
	AJ5/F	0.7403	0.3687	0.3536	47.82
	CTK	0.6577	0.3301	0.3164	48.25
$\bar{X}$		0.6370	0.3273	0.3005	47.12
$S_{\bar{x}}$		0.1365	0.0740	0.0728	4.73

Concerning the weight of silk cocoon, for the white cocoon breeds the values are situated between 0.5814 g for C122 and 0.7983 g for B1, for the coloured cocoon breeds the values are situated between 0.3974 g for E27 and 0.6430 g for Auriu Chinezesc and in the case of the hybrids the values registered are between 0.6011 g for AC/T and 0.7780 for AC29/T.

In the case of the dried chrysalis weight, for the white cocoon breeds the values are situated between 0.2794 g for JH3 and 0.4198 g for B1, for the coloured cocoon breeds the values are situated between 0.2265 g for E27 and 0.3571 g for Auriu Chinezesc and in the case of the hybrids the values registered are between 0.2977 g for AC/T and 0.3795 for AC29/T.

In the case of the dried silk shell weight, for the white cocoon breeds the values are situated between 0.2833 g for C122 and 0.3643 g for B1, for the coloured cocoon breeds the values are situated between 0.1636 g for E27 and 0.2802 g for Auriu Chinezesc and in the case of the hybrids the values registered are between 0.2943 g for AC/T and 0.3900 for AC29/T.

In the case of the silk ratio percent, for the white cocoon breeds the values are situated between 45.79% for B1 and 51.95% for AO 33, for the coloured cocoon breeds the values are situated between 40.97% for Galben de Băneasa and 44.50% for RG90 and in the case of the hybrids the values registered are between 47.82% for AJ 5F and 50.15% for AC29/T.

In the case of other studies made on the current breeds, it can be stated, that, in the case of the white cocoon breeds and hybrids, the overall results registered are similar with many other performed studies on selected breeds and hybrids, mainly the following parameters: raw cocoon weight, raw silk shell weight and dried silk shell weight.

In the case of the dried cocoon parameters, the overall cocoon weight differs, as one influencing factor is the duration of the drying period and the implemented protocol. (Bențea et all, 2006; Matei, 2007; Furdui et al. 2010; Pașca et al., 2010; Mărghitaș et al, 2011; Dezmirean et al, 2018;).

According to the latest studies, the results, focused on all analysed traits excluding the weight of the chrysalis, obtained in the current study and the cited research are overall similar (Dezmirean et al, 2018).

The similarity in registered values can also be observed when a comparison is done with averages values of the studied parameters for

the silkworm breeds and hybrids of the native gene pool.

The raw cocoon average weight registers values between 1.538 g and 2.144 g. The studied breeds and hybrids recorded similar values.

The raw cocoon shell weight registers values between 0.306 g and 0.469 g. The studied breeds and hybrids recorded similar values with the exception the following breeds: E27 and Galben de Baneasa (Coloured cocoon breeds).

The raw cocoon silk ratio registers values between 17,60% and 23.59%. The studied breeds and hybrids recorded similar values with the exception the following breeds: E27 and Galben de Baneasa (Coloured cocoon breeds).

The dried cocoon average weight registers values between 0.778 g and 1.105 g. The studied breeds and hybrids recorded similar minimal values with the exception of the coloured cocoon breeds.

The dried cocoon silk ratio registers values between 37.1% and 43%. The studied breeds and hybrids recorded similar values or higher (Matei et al, 2008; Matei et al, 2010).

When observing the results from the current study and the results from previous studies, although the microclimate conditions were rather similar, differences can still be observed.

Annual and seasonal differences in climate can affect the technological parameters and biological properties of the silkworm breeds and hybrids. Variations in humidity and heat, parameters of the rearing room microclimate can also affect the silkworm and their biological and technological parameters. Another factor that influences the development of the silkworm development is the quality of mulberry leafs (Rahmathulla, 2012).

It is easy to look at a number of breeds and hybrids of the silkworm *Bombyx mori L*. and identify per trait promising lines, but from an economical perspective, when by-products are considered important to it is necessary to have an inclusive classification of the analysed breeds and hybrids, in order to identify the most successful one. In this context, an inclusive index has been applied, Multiple Trait Evaluation Index, what has been widely used for classification and selection of promising breeds and hybrids of silkworms. After the calculation of the individual index (per trait, per breed/hybrid), the average value of the considered traits is calculated and analysed breeds and hybrids are calculated. If the average value is greater than 50, the breed is considered valuable and suitable for commercial exploitation (Buhroo et al., 2017). This method of statistical classification was applied to the current study as well.

Table 7. Evaluation Index Method for fecundity and hatchability for the studied silkworm breeds and hybrids

		Fecundity	Hatching (%)
Breeds (White cocoon)	AB	54.80	56.37
	AO33	44.34	63.93
	B1	55.38	52.03
	C122	55.81	52.16
	J90	51.80	41.75
	JH3	60.97	39.41
	N5	56.09	55.32
	P4/T	55.66	61.73
	S8	50.51	45.07
Breeds (coloured cocoon)	Auriu Chinezesc	37.75	57.29
	E27	31.59	23.67
	Galben de Băneasa	45.35	40.63
	RG 90	26.29	50.55
Hybrids	AC/T	62.54	47.93
	AC29/T	56.67	57.13
	AJ5/F	50.65	46.02
	CTK	53.80	59.00

Fecundity and hatchability can be used to asses and forecast the cocoon production, therefore at this stage all breeds and hybrids are valuable, the coloured breed has low values as it competes with white cocoon breeds, and falls behind Galben de Băneasa.

Table 8. Evaluation Index Method for larval period and silkworm's larvae weight for the studied silkworm breeds and hybrids

		Duration of the larvae period	Larvae weight
Breeds (White cocoon)	AB	54.80	56.37
	AO33	44.34	63.93
	B1	55.38	52.03
	C122	55.81	52.16
	J90	51.80	41.75
	JH3	60.97	39.41
	N5	56.09	55.32
	P4/T	55.66	61.73
	S8	50.51	45.07
Breeds (coloured cocoon)	Auriu Chinezesc	37.75	57.29
	E27	31.59	23.67
	Galben de Băneasa	45.35	40.63
	RG 90	26.29	50.55
Hybrids	AC/T	62.54	47.93
	AC29/T	56.67	57.13
	AJ5/F	50.65	46.02
	CTK	53.80	59.00

The larval period doesn't vary a lot, the only exception being the E27 breed. The Index for the larval weight reflects the results obtained in Table 4.

Table 9. Evaluation Index for raw cocoon parameters for the studied silkworm breeds and hybrids

		Cocoon Weight	Chrysalis weight	Silk Shell Weight	Silk Ratio (%)
Breeds (White cocoon)	AB	41.67	40.59	49.34	66.01
	AO33	50.85	50.20	53.66	53.39
	B1	56.35	55.38	58.21	52.64
	C122	48.39	48.08	50.01	51.60
	J90	47.30	46.41	52.18	55.98
	JH3	49.76	49.87	50.64	50.75
	N5	50.30	50.01	51.29	50.97
	P4/T	50.91	50.23	53.31	52.86
	S8	50.10	51.20	46.41	44.80
Breeds (collored cocoon)	Auriu Chinezesc	50.16	51.42	45.27	43.24
	E27	32.27	34.94	27.19	35.67
	Galben de Băneasa	48.02	48.47	39.19	37.26
	RG 90	54.02	54.76	50.31	45.64
Hybrids	AC/T	47.84	47.26	51.03	53.68
	AC29/T	62.72	62.23	61.98	50.35
	AJ5/F	52.78	52.26	54.97	52.76
	CTK	57.67	57.43	56.93	49.76

Table 10. Evaluation Index Method for dried cocoon parameters for the studied silkworm breeds and hybrids

		Cocoon Weight	Chrysalis weight	Silk Shell Weight	Silk Ratio (%)
Breeds (White cocoon)	AB	46.75	50.04	58.21	50.43
	AO33	50.15	54.40	55.68	52.42
	B1	62.50	58.73	46.79	55.07
	C122	45.28	47.58	53.14	48.81
	J90	49.23	53.06	54.59	50.15
	JH3	43.53	46.28	52.80	48.53
	N5	52.85	54.46	52.37	52.58
	P4/T	52.85	54.46	52.37	53.45
	S8	49.38	49.69	49.44	48.56
Breeds (collored cocoon)	Auriu Chinezesc	54.03	47.16	42.56	46.66
	E27	36.39	31.11	37.62	37.21
	Galben de Băneasa	48.77	40.22	37.97	44.05
	RG 90	49.47	45.16	44.32	48.97
Hybrids	AC/T	46.01	49.10	53.64	50.79
	AC29/T	57.06	62.28	56.04	58.82
	AJ5/F	55.60	57.26	51.18	51.81
	CTK	50.38	52.14	51.88	52.30

Analyzing these values, it can easily be seen the most valuable breeds and hybrids, in terms of silk content (as it is one of the most important economical traits): in the case of the raw cocoon, for the white cocoon breeds is B1, followed by AO33 and AB breeds, for the coloured cocoons is RG90, and for the hybrids is AC 29/T and in the case of the dried cocoon, for the white cocoon breeds is B1, N5, P4/T, followed by AB and AO33, for the coloured cocoons are Auriu Chinez (due to the possibility of lower water loss during drying process) and RG90, and for the hybrids is AC 29/T

As the values of the trait index are calculated for each breed and hybrid is it logical to asses that it reflects the situation discussed above, when the analysis of the values of the traits was made.

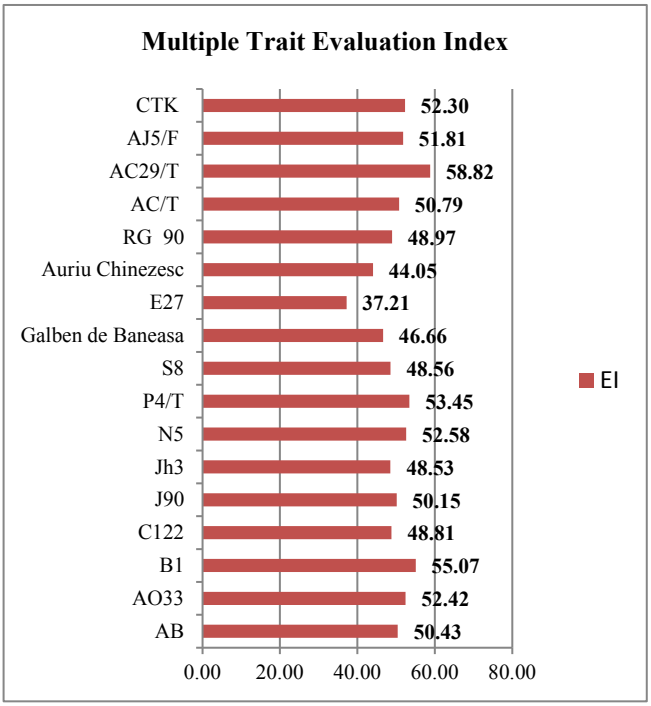

Fig. 1. Multiple Traits Evaluation Index. Classification of the analysed breeds and hybrids

The productivity of chosen breeds used to be attributed mainly to the ability to produce silk itself (silk shell and silk content ratio), but in recent studies it has been noticed that the overall productivity of a breed or hybrid is affected by totality of 21 component traits, therefore it is important to use an Index that takes into account more than one trait at a time. In this context, to respond to the need to proper identify successful breeds and hybrids, the Multiple Trait Evaluation Index was developed and implemented.

A classification of all analysed breeds and hybrids has been made under the argument that all analysed breeds and hybrids have been well established, and despite the differences given by the specific characteristics, the most

important aspect for a farmer it is the overall productivity (Bhat et al,.2017).
Overall almost all breeds and hybrids had values of their afferent index over 50, providing evidence of the value of the local sericultural *Bombyx mori* gene pool.
Based on the values obtained, the following can be stated: the most valuable white cocoon breed is B1 (55.27), the most valuable coloured silk cocoon breed is Auriu Chinezesc (47.27), followed by RG90 (46.81), and the most valuable hybrid is Ac29/T (58.29 – highest recorded value of the Index.

CONCLUSIONS

The Multiple Trait Evaluation Index Method offers the possibility to easily oversee the classification not only on their overall economical value, but for individual or subgroups of biological and technological traits as well.
Therefore in can be stated that most valuable breeds per trait for the eggs parameters:

- No eggs/laying: white cocoon breeds – all but AO33 , coloured cocoon breeds – Galben de Baneasa and Auriu chinez, white cocoon hybrids – AC/T and AC29/T;
- Fecundity: white cocoon breeds – all but J90, JH3 and S8, coloured cocoon breeds – Galben de Baneasa and Auriu chinez, white cocoon hybrids – AC/T and AC29/T.

In the case of the larval duration, the differences are minimal, being shorter for the coloured cocoon groups.
Concerning the larval weight, if by-products are an important aspect of it, from the white cocoon breeds, N5 and AO33 are rather valuable. From the hybrids AC29/T is the most valuable. From the coloured cocoon group, RG has recorded values over 50.
In terms of the raw cocoon parameters, considering all afferent traits, the most valuable white cocoon breeds are considered all valuable, as only S8 has visible lower values; the most valuable coloured cocoon breeds are the native breeds Galben de Baneasa and RG 90; the most valuable white cocoon hybrids are considered all valuable.
In terms of the dried cocoon parameters, considering all afferent traits, the most valuable white cocoon breeds are the most valuable white cocoon breeds are considered all valuable, as only C122 ad J90 breeds have visible lower values; the most valuable coloured cocoon breeds are the native breeds Galben de Baneasa and RG 90; the most valuable white cocoon hybrids are considered all valuable.
Differences between the raw cocoon parameters and dried cocoon parameters classification can be given by the rate and amount of lost water during the cooking process.
More studies need to be performed on the coloured cocoon breeds and the breeds that have scored an EI under 50, but the silk shell Index is over 50, such as AO 33, C122 and AJ 5F.
Taking into consideration the overall economical value, looking at the values obtained, the hybrids have maximal values, the top being represented by AC29/T.
From the white cocoon breeds, the commercial established breeds like AB. AO33 or B1, maintain their economical value over time, as their overall score of the Index is situated over 50, their value being in their high production stability in different rearing periods.
Newly or less studied breeds like N5 or P4/T also have relative high scores.
When compared to other performed studies, we may conclude, even though some exceptions occurred, that the development of the breeds and hybrids was rather normal.
The differences between the groups are due to different genotypes of the simple breeds, as well as differences in genotypes between the parental breeds of the commercial hybrids and those of the coloured cocoon breeds.
As a classification method, the Multiple Trait Evaluation Index is suitable and flexible for the Romanian *Bombyx mori* gene pool, but more studies done replications in different environmental conditions are needed to establish a long lasting classification of the silkworm breeds and hybrids.

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