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Relationship between Season and Efficiency of Individual Selection in Six Peanut and Oval Lines of Silkworm

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***Abstract*— Selection is one of the best breeding approaches in silkworm breeding. An investigation was conducted for study of relationship between season and efficiency of individual selection in six peanut and oval pure lines of silkworm. Silkworm rearing technique included single batch rearing system. Feeding and other conditions of larval rearing were conducted following the standard procedure. Individual selection system based on cocoon weight was conducted as selected group in the zero generation. For each pure line, in zero generation, about 500 individuals recorded for each line from point of cocoon weight trait and the one percentage of individuals in each sex lines which had the highest cocoon weight selected as parents of selected group at next generation. These individuals mated together and formed selected groups of first generations. Meanwhile for each pure line in zero generation, individuals who had the cocoon weight averages equal to population average were selected as random groups. Individuals and offspring in selected and random groups selected and mated randomly without any phonotypical and genotypic selection in first, second, third and fourth generations. Twelve full sib families from each group and pure line were reared in each generation. Totally, 27 economical traits were recorded and analyzed. In each pure line and generation, 12 families were reared so that 25 male and 25 female full sib cocoons were individually recorded for cocoon traits per family. Thus, there are 15552 family data included 4 generations × 6 pure lines × 2 treatments (random and selected groups) × 12 families (replications) × 27 family traits. These data recorded in two autumn and spring seasons. Their records analyzed at four successive generations. From obtained results, it was showed lines at spring had higher response than autumn from point of most important traits. For resistance characters, responses to selection for alive larvae number were 23.08 and 19.72 at spring and autumn respectively. Responses to selection for pupae vitality percentage in best cocoon were -0.304 and -1.486% at spring and autumn respectively. Responses to selection for pupae vitality percentage in middle cocoon were 0.074 and -2.627 at spring and autumn respectively. It is concluded responses to selection for important resistance traits in silkworm pure lines at spring is higher than autumn significantly ($P<0.05$). Thus, commercial pure lines showed higher phenotypic response in spring rearing period compared to autumn one for production traits.**

***Index Terms*—Bombyx mori, performance, season, selection**

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I. Introduction

Silkworm is an economical and helpful insect and is reared by many farmers throughout world. It is an important economic insect since it is the producer of silk. It is estimated that more than 3000 silkworm strains are available all over the world due to various ongoing breeding programmes. It is entirely dependent on humans for its reproduction and no longer occurs naturally in the wild. Sericulture has been practiced for at least 5,000 years in China. It was domesticated from the wild silkmoth *Bombyx mandarina* which has a range from northern India to northern China, Korea, Japan and far eastern Russia. Success in sericulture depends largely on major factors like, breed, seed and feed. The silkworm breeds play an important role for high cocoon yield and silk quality. If the cocoons, which form the basic raw material for raw silk, are from bivoltines will definitely be superior with high silk content. The breeding of silkworms cannot have originated before the Neolithic as the tools necessary to make use of the silk thread on a large scale only have become available since then. The domesticated and wild species can still breed and so hybridize together. The full genome of the silkworm was published in 2008 by the International Silkworm Genome Consortium.

On the other hand, the aim of silkworm breeding is to improve economic traits in order to increase the profit of silk producers and other sections of sericulture industry. In sericulture numerous traits are considered as important. The importance of these traits in various parts of this industry is different. The reproductive traits are considered important for egg producers while cocoon producers are interested in improved production potential, cocoon shell percentage and disease resistance [1].

Selection is one of the best breeding approaches in silkworm breeding [2]. Individual selection in parent lines can improve their offspring performance. But, this improvement is affected to environmental factors specially season. Thus this experiment was conducted for estimate and comparing of individual selection effects in three Peanut commercial pure lines of silkworm including 31, 103, and 107 and three Oval commercial pure lines of silkworm including 32, 104 and 110 at two spring and autumn seasons.

II. Materials and Methods

The present investigation has been performed on six silkworm commercial pure lines which were produced in Iran Silkworm Research Center including peanut lines of 31, 103, and 107 and oval lines of 32, 104, and 110. Silkworm rearing technique included single batch rearing system. Feeding and other conditions of larval rearing were conducted following the standard procedure [3].

For investigation on season effects on efficiency of individual selection system and performance response in three oval and three peanut lines silkworm pure lines separately, experiment was conducted in two seasons included spring and autumn. All six studied silkworm pure lines were reared during four generations. Each line was reared in two selected and random groups. Individual selection system based on cocoon weight was conducted as selected group in the zero generation. For each pure line, in zero generation, about 500 individuals recorded in each sex from point of cocoon weight trait and the one percentage of individuals in each sex which had the highest cocoon weight selected as parents of selected group at next generation. These individuals mated together and formed selected groups of first generations. Meanwhile for each pure line in zero generation, individuals who had the cocoon weight averages equal to population average were selected as random groups. Individuals and offspring in selected and random groups selected and mated randomly without any phonotypical and genotypic selection in first, second, third and fourth generations. Twelve full sib families from each group and pure line were reared in each generation.

Phenotypic change of resistance, productive and reproductive traits was recorded and evaluated in the studied pure lines at four successive generations collectively. In each pure line and generation, 12 families were reared so that 25 male and 25 female full sib cocoons were individually recorded for cocoon traits per family. Thus, there are 15552 family data included 4 generations × 6 pure lines × 2 treatments (random and selected groups) × 12 families (replications) × 27 family traits. These data recorded in two autumn and spring seasons. Furthermore data above 70% or below 30%, undergone inverse sin transformation (Z=Arcsin Pij1/2) and data between 0-1, undergone square transformation ($P^{1/2}$). All data obtained from the experiment were subjected to ANOVA using the General Linear Model (GLM) procedures of the Statistical Analysis System Institute [4]. Treatment means were compared by Duncan New Multiple Range Test (DNMRT).

III. Results and Discussion

Obtained results are summarized in Tables 1-3. From the obtained results, it was clear that different pure lines of silkworm *Bombyx mori* showed different performance in different seasons. The analysis of variance regarding to studied traits, showed that different pure lines haven significant different for mant traits in two seasons (P<0.01). From obtained results, it was showed lines at spring had higher response than autumn from point of most important traits. For resistance characters, responses to selection for alive larvae number were 23.08 and 19.72 at spring and autumn respectively. Responses to selection for pupae vitality percentage in best cocoon were -0.304 and -1.486% at spring and autumn respectively. Responses to selection for pupae vitality percentage in middle cocoon were 0.074 and -2.627 at spring and autumn respectively. Thus it is concluded responses to selection for important resistance traits in silkworm pure lines at spring is higher than autumn significantly (P<0.05). Thus, commercial pure lines showed higher phenotypic response in spring rearing period compared to autumn one for production traits.

Positive correlations show that as breeders change the mean of one character towards the higher side, the other also goes up with it, while in the negative as the mean value of one character goes up, the value for the other character goes down. In silkworm, most of the correlations between different characters have been worked out by selection experiments. These studies have shown that direct selection for one trait has correlation with the other quantitative characters. The correlation of some characters was found to be negative while in others it was positive [5].

Responses to selection for produced cocoon number were 23.18 and 18.78 at spring and autumn respectively. Responses to selection for best cocoon number were 14.61 and 6.04 at spring and autumn respectively. Responses to selection for middle cocoon number as a negative character was 7.933 and 11.217 at spring and autumn respectively. Responses to selection for low cocoon number as another negative trait was 0.633 and 2.217 at spring and autumn respectively (P<0.05). Responses to selection for double cocoon number as a negative trait was 0.0000 and -0.6957 at spring and autumn respectively (P<0.05). Responses to selection for low cocoon percentage as a negative trait were -0.0723 and 0.4141% at spring and autumn respectively. Responses to selection for best cocoon weight were 34.21 and 24.13 g at spring and autumn respectively. Responses to selection for single best cocoon weight were 0.0471 and -0.1688 at spring and autumn respectively. Responses to selection for 10000 larvae cocoon weight were 326.1 and 102.5 g at spring and autumn respectively (P<0.05). Responses to selection for larval duration were 0.0417 and -2.087 hours at spring and autumn respectively (P<0.05).

Individual selection based on cocoon weight had not negative effect on economical and important reproduction traits. Selection response of un-hatched eggs percentage was 0.882 and 1.468% respectively for spring and autumn rearing seasons. Responses to selection for un-hatched eggs percentage were -0.3058 and -0.5891% at spring and autumn respectively. Responses to selection for unfertilized eggs percentage were -0.5770 and -0.8798% at spring and autumn respectively (P<0.05).

Results demonstrated that there is a positive genetic correlation between cocoon weight and other economical traits which was in accordance with other studies for our pure lines [6-8]. Similar results report by other researchers such as [9] and [10]. On the other hand, Increasing of selection pressure on cocoon weight will cause total produced eggs to rise. Environmental conditions in autumn season decrease egg lying of moths, significantly. Identification of genetic relationship among productive and reproductive traits is necessary before constructing an effective breeding program.

Meanwhile, heritability have important role in obtained results. Reference [11] showed 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 (18-25%). The data supported the classical hypothesis that the fitness traits would exhibit lower heritabilities compared to the traits in other categories. Reference [12] have reported that heritability was very high (71.4-86.7%) 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. References [1] and [13] have reported similar results. Reference [14] 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. Reference [15] indicated high heritability for shell percentage and shell weight while moderate along with high genetic advance for cocoon weight.

Silkworm breeders have uncovered the fact that some characters or aspects of them affect other characters. Each of these characters has its own optimal mean value which is commensurate with the adaptive fitness of the strain [5]. The interrelationships between characters are expressed in statistical terms, as correlations, which show how one variable changes as the other changes [5].

As conclusion it is concluded responses to selection for production traits in silkworm pure lines at spring is higher than spring significantly. Also the main reason for improvement of many traits refers to positive correlation between production and other important traits at silkworm opposite some another animals. Thus breeding programs and individual selection for cocoon weight at pure lines can improve total benefit and economical gains.

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TABLE 1. EFFECT OF SEASON ON SELECTION RESPONSES FOR ON RESISTANCE, PRODUCTION AND REPRODUCTION TRAITS IN SIX OVAL AND PEANUT PURE LINES IN SUCCESSIVE GENERATIONS*

Trait Season	**Spring**	**Autumn**
Alive Larvae Number (no)	23.08	19.72
Alive Pupae Number (no)	18.58	73.50
Pupae Vitality Percentage (%)	-0.85	13.64
Pupae Vitality Percentage in Best Cocoon (%)	-0.304	-1.486
Pupae Vitality Percentage in Middle Cocoon (%)	0.074	-2.627
Produced Cocoon Number (no)	23.18	18.78
Best Cocoon Number (no)	14.61	6.04
Middle Cocoon Number (no)	7.933	11.217
Low Cocoon Number (no)	0.633	2.217
Double Cocoon Number (no)	0.0000	-0.6957
Best Cocoon Percentage (%)	-0.633	1.969
Middle Cocoon Percentage (%)	1.044b	6.772a
Low Cocoon Percentage (%)	-0.0723	0.4141
Double Cocoon Percentage (%)	2.117	-0.271
Best Cocoon Weight (gr)	34.21	24.13
Double Cocoon weight (gr)	-2.602	0.018
Single Best Cocoon Weight (gr)	0.0471	-0.1688
10000 Larvae Cocoon Weight (gr)	326.1	102.5
Larval Duration (hr)	0.0417a	-2.087b
Hatched Larvae (no)	41.96	12.28
Un-hatched Eggs (no)	0.267	-4.935
Unfertilized Eggs (no)	-2.458	-4.543
Hatched Eggs Percentage (%)	0.882	1.468
Un-hatched Eggs Percentage (%)	-0.3058	-0.5891
Unfertilized Eggs Percentage (%)	-0.5770	-0.8798
Hatchability Percentage (%)	0.3358	0.6683
Total Produced Eggs (no)	39.77a	2.87b

* There is significant difference between the numbers that are shown with the different letters in each row. Each group of data without any letter has got no significant differences.

TABLE 2. EFFECT OF SEASON ON SELECTION RESPONSES FOR ON RESISTANCE, PRODUCTION AND REPRODUCTION TRAITS IN THREE OVAL PURE LINES IN SUCCESSIVE GENERATIONS*

Trait Season	**Spring**	**Autumn**
Alive Larvae Number (no)	24.75	44.35
Alive Pupae Number (no)	22.60	33.13
Pupae Vitality Percentage (%)	0.393	-2.462
Pupae Vitality Percentage in Best Cocoon (%)	1.711	-1.060
Pupae Vitality Percentage in Middle Cocoon (%)	27.65	44.39
Produced Cocoon Number (no)	19.79	25.39
Best Cocoon Number (no)	8.417	16.565
Middle Cocoon Number (no)	1.125	0.957
Low Cocoon Number (no)	-1.688	1.478
Double Cocoon Number (no)	0.405	6.410
Best Cocoon Percentage (%)	0.489b	11.410a
Middle Cocoon Percentage (%)	0.2494	-0.3217
Low Cocoon Percentage (%)	-1.1415	0.2670
Double Cocoon Percentage (%)	45.83	59.51
Best Cocoon Weight (gr)	45.83	59.51
Double Cocoon weight (gr)	-6.608	0.087
Single Best Cocoon Weight (gr)	0.0354	-0.3695
10000 Larvae Cocoon Weight (gr)	-11.19	8.79
Larval Duration (hr)	1.625a	-4.174b
Hatched Larvae (no)	56.67	24.17
Un-hatched Eggs (no)	0.354	-4.087
Unfertilized Eggs (no)	-5.375	-4.826
Hatched Eggs Percentage (%)	1.243	1.870
Un-hatched Eggs Percentage (%)	-0.3463	-0.7696
Unfertilized Eggs Percentage (%)	-0.8973	-1.1009
Hatchability Percentage (%)	0.3910	0.8078
Total Produced Eggs (no)	51.65	15.26

* There is significant difference between the numbers that are shown with the different letters in each row. Each group of data without any letter has got no significant differences.

TABLE 3. EFFECT OF SEASON ON SELECTION RESPONSES FOR ON RESISTANCE, PRODUCTION AND REPRODUCTION TRAITS IN THREE PEANUT PURE LINES IN SUCCESSIVE GENERATIONS*

Trait Season	**Spring**	**Autumn**
Alive Larvae Number (no)	35.65**a**	-4.91**b**
Alive Pupae Number (no)	25.38	113.87
Pupae Vitality Percentage (%)	-2.28	30.05
Pupae Vitality Percentage in Best Cocoon (%)	-1.562	-0.510
Pupae Vitality Percentage in Middle Cocoon (%)	-1.556	-4.194
Produced Cocoon Number (no)	33.06a	-6.83b
Best Cocoon Number (no)	20.46a	-13.30b
Middle Cocoon Number (no)	10.729	5.870
Low Cocoon Number (no)	0.979	3.478
Double Cocoon Number (no)	0.896	-2.870
Best Cocoon Percentage (%)	-1.249	-2.471
Middle Cocoon Percentage (%)	1.554	2.133
Low Cocoon Percentage (%)	-0.210	1.150
Double Cocoon Percentage (%)	-0.0962	-0.8096
Best Cocoon Weight (gr)	42.28a	-11.25b
Double Cocoon weight (gr)	-0.1132	-0.0350
Single Best Cocoon Weight (gr)	0.04608	0.03178
10000 Larvae Cocoon Weight (gr)	473.3	196.2
Larval Duration (hr)	-1.146	0.000
Hatched Larvae (no)	41.35	0.39
Un-hatched Eggs (no)	-0.167	-5.783
Unfertilized Eggs (no)	-0.313	-4.261
Hatched Eggs Percentage (%)	0.882	1.066
Un-hatched Eggs Percentage (%)	-0.5346	-0.4087
Unfertilized Eggs Percentage (%)	-0.3473	-0.6587
Hatchability Percentage (%)	0.5663	0.5287
Total Produced Eggs (no)	40.88	-9.52

* There is significant difference between the numbers that are shown with the different letters in each row. Each group of data without any letter has got no significant differences