Seasonal Variations in the Silk Yield Contributing Characters of Forty-two Strains of the Silkworm, *Bombyx mori* (Lepidoptera: Bombycidae)[1]

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ABSTRACT Forty-two strains of the silkworm, *Bombyx mori* (L.), collected from China, Japan, Vietnam, South Korea, Brazil, India, and France were reared in the spring, summer and autumn seasons during 1991-92 at the Regional Station of Central Sericultural Research and Training Institute, Coonoor, Tamilnadu State, India. Analyses were made on five silk yield-contributing characters, namely pupation rate, cocoon weight, shell weight, cocoon shell ratio, and silk filament length. Results indicated the superiority of the following strains for all the above mentioned characters: 14M and JC2P (in spring); NBJPO and JC2P (in summer); and M2, NBJPO and SPJ2 (in autumn). The importance of rearing a given strain of silkworm in the optimal season for its maximum economic value in terms of silk yield is discussed.

KEY WORDS *Bombyx mori,* sericulture, silk yield.

Commercial exploitation of the silkworm, *Bombyx mori* L., has resulted in the production of 72,879 metric tons of raw silk per year (Currie 1991). World silk production has doubled during the last 30 years in spite of artificial fibers replacing silk for the same uses (Cherry 1987). India is the second largest producer of cocoons and silk thread after China (Bhargava et al. 1992). Some European countries like France, Italy, and Spain, which formerly had a fairly large scale of sericulture, are no longer engaged in mulberry planting and silkworm rearing. There are approximately 2,000 different strains of *B. mori* used in silk production and twenty-one characters of this species are recognized as contributing to silk yield quantitatively or qualitatively (Thigarajan et al. 1993a). These are: 1) fecundity; 2) per cent hatch; 3) mortality of young age larvae; 4) mortality of late-age larvae; 5) total larval duration, i.e., rearing period; 6) fifth instar duration; 7) cocoon yield number per 10,000 larvae brushed which is the process of separating the newly-hatched larvae by gently and carefully from the empty egg shells or egg sheets and transferring them to

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the rearing trays with the help of a soft brush; 8) cocoon yield (weight per 10,000 larvae brushed); 9) pupation rate; 10) single cocoon weight; 11) single shell weight; 12) cocoon shell ratio, i.e., ratio of single shell weight to single cocoon weight expressed in percentage; 13) mature larval body weight; 14) floss percentage (floss is the foundation layer of the cocoon with the entangled filaments from which a continuous filament, i.e., silk fiber, cannot be obtained; 15) single cocoon filament length (length of silk thread from a single cocoon); 16) Denier (single cocoon filament weight); 17) filament size; 18) reelability percentage (the percentage of silk reeled easily without any break out of the average single cocoon filament length); 19) raw silk percentage (the quantity of silk reeled from the fresh cocoons expressed in percentage); 20) neatness of silk thread; 21) boil-off ratio of silk thread (silk thread is reeled from the cocoons by boiling them in water so that the gummy materials are dissolved and the silk thread can be reeled without breakage. (The term is used in the silk industry to classify the grade of raw silk with respect to reeling and weaving.) While some of these characters are heritable, others are determined by environmental factors.

The domestic and international demand for silk has always been greater than the supply. In India, the average cocoon yield from indigenous strains of silkworm is about 30 kg/100 dfl (dfl = disease free laying; one dfl equals approximately 500 eggs with an average 80% eclosion). In Japan, however, the average cocoon yield is 60 kg/100 dfl. If the yield in India could be increased to 45 kg/100 dfl, overall silk production would increase by 50% (Thiagarajan et al. 1991). This may be achieved by employing exotic silkworm strains and exploiting the favorable seasons for rearing particular strains for better cocoon yield. However, this is currently not practiced in India. To solve this problem and achieve maximal harvest, it is essential to select a few superior strains of silkworm in relation to seasonal performance. In Japan, there are 19 strains suitable for spring rearing (May-June) and 22 strains suitable for summer (July-August) and autumn (September-October) rearings (Shimizu and Tazima 1972). The purpose of this study was to evaluate the performance of different strains of silkworm available to us in relation to their performance in spring, summer, and autumn.

Materials and Methods

Rearing experiments were conducted in the spring, summer, and autumn during 1991-92 at the Regional Sericultural Research Station, Coonoor, located in the Nilgiri Hills of Tamilnadu State, India. All 42 strains of silkworm (Table 1) were reared in a randomized block design. Each group evaluated consisted of larvae from a single laying by an individual female. For each strain three replications were made by using one laying per replication. All the larvae were retained until spinning. Each experimental tray was placed in a rearing stand; the positions of the trays were changed regularly two times a day to reduce effects of environmental factors. The silkworms were reared inside the rearing houses as in the method described in an earlier paper (Bhargava et al. 1993a). Duration of experimental rearings were 26 d in summer, 27 d in spring, and 28 d in autumn with three replications of each strain. The maximum-minimum air temperature inside the rearing house recorded during spring, summer, and autumn seasons were 25.7-12.0, 25.3-14.5, and 22.2-13.2°C, respectively. The mean relative humidity in

Table 1. Mean values (n = 150) for five characters in 42 strains of silkworm (*Bombyx mori* L.) reared in spring, summer, and autumn seasons.*

S1. No.	Strain	Geographical origin	Season	Pupation rate (%)	Cocoon weight (g)	Shell weight (g)	Cocoon shell ratio (%)	Silk filament length (m)
1	C108	China	Spring	81.00	1.80	0.32	17.78	840
			Summer	97.83 c	1.78 a	0.25 a	14.04 c	821 a
			Autumn	88.67 b, c	1.83 a, a	0.31 a, a	16.94 a, b	933 a, b
2	C120	China	Spring	89.75	1.52	0.32	21.05	935
			Summer	85.00 a	1.47 a	0.28 a	19.05 b	929 a
			Autumn	77.50c, b	1.64 a, b	0.34 a, a	20.73 a, b	1012 a, a
3	C130	China	Spring	89.64	1.60	0.32	20.00	1104
			Summer	97.17 b	1.74 b	0.30 a	17.24 c	978 b
			Autumn	76.50 c, c	1.59 a, b	0.31 a, a	19.50 a, b	1039 a, a
4	C150	China	Spring	89.00	1.62	0.28	17.28	829
			Summer	86.33 a	1.62 a	0.29 a	17.90 a	963 b
			Autumn	83.00 a, a	1.60 a, a	0.34 a, a	21.25 c, c	1001 c, a
5	Dong-34	China	Spring	85.00	1.46	0.23	15.75	787
			Summer	82.17 a	1.38 a	0.25 a	18.12 c	855 a
			Autumn	94.50 c, c	1.45 a, a	0.25 a, a	17.24 a, a	882 a, a
6	Dong-306	China	Spring	95.00	1.68	0.26	15.48	889
			Summer	97.00 a	1.69 a	0.31 a	18.34 c	994 a
			Autumn	79.00 c, c	1.66 a, a	0.33 a, a	19.88 c, a	1042 b, a
7	Hu-204	China	Spring	82.45	1.14	0.18	15.79	677
			Summer	93.83 c	1.21 a	0.18 a	14.88 a	727 a
			Autumn	94.50 c, a	1.23 a, a	0.21 a, a	17.07 a, c	737 a, a

Table 1. Continued.

S1. No.	Strain	Geographical origin	Season	Pupation rate (%)	Cocoon weight (g)	Shell weight (g)	Cocoon shell ratio (%)	Silk filament length (m)
8	247	China	Spring	74.93	1.37	0.26	18.98	872
			Summer	79.17 a	1.54 b	0.29 a	18.83 a	901 a
			Autumn	94.50 c, c	1.57 c, a	0.31 a, a	19.75 a, a	950 a, a
9	Nanung-6D	China	Spring	56.81	1.45	0.27	18.62	976
			Summer	84.17 c	1.67 c	0.28 a	16.77 b	845 b
			Autumn	93.50 c, c	1.62 b, a	0.28 a, a	17.28 a, a	940 a, a
10	CJ3P	Japan	Spring	85.50	1.75	0.37	21.14	1194
			Summer	93.17 b	1.77 a	0.34	19.21 b	1079 b
			Autumn	83.88 a, c	2.13 c, c	0.39 a, a	18.31 c, a	1059 b, a
11	J1M	Japan	Spring	84.75	1.62	0.31	19.14	928
			Summer	85.67 a	1.74 a	0.33 a	18.97 a	1193 c
			Autumn	96.00 b, c	1.60 a, b	0.32 a, a	20.00 a, a	987 a, b
12	J2M	Japan	Spring	85.50	1.92	0.38	19.79	1060
			Summer	95.00 c	1.78 b	0.30 a	16.85 c	890 c
			Autumn	92.00 b, a	1.71 c, a	0.32 a, a	18.71 a, b	967 b, b
13	J2P	Japan	Spring	84.75	1.70	0.37	21.77	1035
			Summer	85.67 a	1.89 c	0.33 a	17.46 c	1018 a
			Autumn	91.50 b, a	1.76 a, c	0.34 a, a	19.32 c, b	832 c, b
14	JC2P	Japan	Spring	94.75	1.75	0.36	20.57	1077
			Summer	92.17 a	1.69 a	0.37 a	21.89 a	1192 b
			Autumn	85.50 b, a	2.01 c, c	0.42 a, a	20.90 a, a	1102 a, a
15	J122	Japan	Spring	90.75	1.76	0.32	18.18	923
			Summer	88.83 a	1.95 c	0.31 a	15.90 c	938 a
			Autumn	95.50 a, b	1.77 a, c	0.31 a,a	17.51 a, a	946 a, a

Table 1. Continued.

Sl. No.	Strain	Geographical origin	Season	Pupation rate (%)	Cocoon weight (g)	Shell weight (g)	Cocoon shell ratio (%)	Silk filament length (m)
16	M2	Japan	Spring	95.25	1.45	0.29	20.00	1003
			Summer	95.17 a	1.66 b	0.33 a	19.88 a	1079 a
			Autumn	97.50 a, a	2.06 c, c	0.43 c, b	20.87 a, a	1191 b, a
17	N4	Japan	Spring	68.88	1.65	0.30	18.18	994
			Summer	64.67 a	1.41 b	0.28 a	19.86 a	1067 a
			Autumn	50.67 c, c	1.62 a, c	0.38 b, c	23.46 c, c	1229 c, b
18	14M	Japan	Spring	92.00	1.75	0.40	22.86	1254
			Summer	89.00 a	1.84 a	0.38 a	20.65 b	1044 c
			Autumn	83.21 b, a	1.74 a, a	0.36 a, a	20.69 b, a	1147 a, a
19	36PC	Japan	Spring	87.62	1.73	0.38	21.97	1276
			Summer	75.67 c	1.86 b	0.35 a	18.81 c	1033 c
			Autumn	84.33 a, b	2.05 c, b	0.37 a, a	18.05 c, a	1039 c, a
20	39P	Japan	Spring	67.75	1.80	0.34	18.89	1010
			Summer	81.17 c	1.76 a	0.30 a	17.05 b	931 a
			Autumn	96.33c, c	1.89 b, b	0.31 a, a	16.40 c, a	1026 a, a
21	44FM	Japan	Spring	62.00	1.87	0.33	17.65	912
			Summer	71.58 b	2.04 b	0.34 a	16.67 a	932 a
			Autumn	75.84 c, a	2.09 b, a	0.40 b, a	19.14 a, b	1036 b, a
22	Showa	Japan	Spring	74.85	1.65	0.30	18.18	1037
			Summer	71.33 a	1.94 c	0.38 b	19.59 a	1071 a
			Autumn	61.47 c, c	2.11 c, b	0.43 c, a	20.38 b, a	1268 c, b
23	SPC1	Japan	Spring	79.50	1.50	0.30	20.00	1063
			Summer	83.50	1.73 c	0.30 a	17.34 c	900 b
			Autumn	92.50 c, b	1.62 b, a	0.28 a, a	17.28 b, a	1102 a, b

Table 1. Continued.

Sl. No.	Strain	Geographical origin	Season	Pupation rate (%)	Cocoon weight (g)	Shell weight (g)	Cocoon shell ratio (%)	Silk filament length (m)
24	SPJ1	Japan	Spring	95.00	1.65	0.30	18.18	1030
			Summer	83.33 c	1.84 c	0.36 a	19.57 a	872 b
			Autumn	90.00 a, b	1.63 a, c	0.31 a, a	19.02 a, a	1125 b, c
25	SPJ2	Japan	Spring	72.75	1.70	0.30	17.65	963
			Summer	84.00 c	1.72 a	0.35 a	20.35 c	928 a
			Autumn	93.00 c, b	1.63 a, a	0.37 b, a	22.70 c, b	1177 c, c
26	SN1	Japan	Spring	60.25	1.80	0.34	18.89	956
			Summer	88.67 c	1.79 a	0.31 a	17.32 a	949 a
			Autumn	79.17 c, b	1.68 a, a	0.35 a, a	20.83 b, c	1242 c, c
27	SN2	Japan	Spring	66.00	1.75	0.38	21.71	1033
			Summer	63.83 a	1.89 b	0.36 a	19.05 c	1084 a
			Autumn	85.83 c, c	2.08 c, b	0.42 a, a	20.19 a, a	1079 a, a
28	NJ1	Japan	Spring	58.25	1.83	0.37	20.22	1107
			Summer	89.17 c	1.86 a	0.37 a	19.89 a	1170 a
			Autumn	84.50 c, a	2.05 c, b	0.41 a, a	20.00 a, a	1240 b, a
29	JZHMC	Brazil	Spring	92.00	1.70	0.29	17.06	863
			Summer	84.50 b	1.99 c	0.38 b	19.10 b	1059 b
			Autumn	81.50 b, a	1.99 c, a	0.38 b, a	19.10 b, a	1129 c, a
30	JZHPO	Brazil	Spring	91.00	1.62	0.30	18.52	1151
			Summer	95.17 a	1.76 b	0.30 a	17.05 a	993 c
			Autumn	76.50 c, c	2.16 c, c	0.39 b, b	18.06 a, a	1087 a, a
31	NBJPO	South Korea	Spring	56.25	1.90	0.33	17.37	943
			Summer	90.17 c	1.94 a	0.41 b	21.13 c	1159 b
			Autumn	83.00 c, b	2.10 a, a	0.43 c, a	20.48 c, a	1215 c, a

Table 1. Continued.

Sl. No.	Strain	Geographical origin	Season	Pupation rate (%)	Cocoon weight (g)	Shell weight (g)	Cocoon shell ratio (%)	Silk filament length (m)
32	European	France	Spring	92.40	1.50	0.30	20.00	967
			Summer	91.67 a	1.75 b	0.32 a	18.29 a	1164 b
			Autumn	86.00 b, a	1.96 c, b	0.39 b, b	19.90 a, a	1242 c, a
33	BL	Vietnam	Spring	87.00	1.41	0.24	17.02	713
			Summer	86.83 a	1.68 c	0.22 a	13.10 c	823 a
			Autumn	89.02 a, a	1.56 b, a	0.23 a, a	14.74 c, a	919 b, a
34	644	Vietnam	Spring	56.50	1.52	0.28	18.42	843
			Summer	88.67 c	1.52 a	0.30 a	19.74 a	879 a
			Autumn	85.19 c, a	1.53 a, a	0.30 a, a	19.61 a, a	900 a, a
35	4792	Vietnam	Spring	68.38	0.93	0.13	13.98	590
			Summer	90.33 c	1.12 b	0.13 a	11.61 b	515 a
			Autumn	91.12 c, a	0.82 a, b	0.10 a, a	12.20 b, a	452 a, a
36	7042	Vietnam	Spring	75.50	1.50	0.30	20.00	958
			Summer	94.00 c	1.72 b	0.28 a	16.40 c	897 a
			Autumn	85.59 c, b	1.80 c, a	0.32 a, a	17.78 b, a	788 b, a
37	JA1	India	Spring	44.25	1.67	0.35	20.10	1202
			Summer	96.33 c	1.67 a	0.32 a	19.16 a	1128 a
			Autumn	87.00 c, c	2.04 c, c	0.41 a, b	20.10 a, a	1111 a, a
38	JB2	India	Spring	95.65	1.78	0.32	17.98	1107
			Summer	83.83 c	2.12 c	0.40 b	18.87 a	1175 a
			Autumn	83.47 c, a	1.97 b, b	0.41 b, a	20.81 c, b	1164 a, a
39	NB1	India	Spring	95.75	1.75	0.33	18.86	1023
			Summer	96.33 a	1.90 b	0.31 a	16.32 b	838 c
			Autumn	94.50 a, a	1.67 a, c	0.30 a, a	17.96 a, a	967 a, b

Table 1. Continued.

S1. No.	Strain	Geographical origin	Season	Pupation rate (%)	Cocoon weight (g)	Shell weight (g)	Cocoon shell ratio (%)	Silk filament length (m)
40	PBL1	India	Spring	78.50	1.80	0.33	18.83	999
			Summer	82.83 c	1.85 a	0.33 a	17.84 a	963 a
			Autumn	96.17 c, c	2.10 c, c	0.41 b, b	19.52 a, a	1050 a, a
41	SH2	India	Spring	71.60	1.68	0.36	21.43	1285
			Summer	75.17 a	1.85 b	0.38 a	20.54 a	1271 a
			Autumn	65.05 a, b	2.09 c, c	0.40 a, a	19.14 b, a	1101 b, b
42	SSOP	India	Spring	91.75	1.60	0.36	21.87	954
			Summer	97.50 a	1.72 a	0.34 a	19.77 b	1100 b
			Autumn	86.17 a, c	2.07 c, c	0.41 a, b	19.81 b, a	1052 a, a
	L.S.D.	($P < 0.05$)		6.13	0.12	0.07	1.73	113

* Differences in the means of strain between season:
a – nonsignificant; b - $P < 0.005$; c – $P < 0.01$.

spring, summer, and autumn was 47.5, 67.6, and 74.2%, respectively. The total rainfall received during the autumn (September-October 1991), spring (March-April 1992), and summer (May-June 1992) seasons was 304.9, 52.6 and 144.2 mm, respectively.

Observations (n = 150) were made on five characters which contribute to silk yield, namely: 1) pupation rate; 2) cocoon weight; 3) shell weight; 4) cocoon shell ratio, and; 5) silk filament length.

Analysis of variance of the five characters for 42 strains in three seasons and the strains x season interaction was done. A simple method for making a decision on each character based on least significant difference as described by Arunachalam and Bandyopadhayay (1984) was followed for each character for ranking of the strains. The population means were arranged in groups based on LSD. The uppermost group containing the population with the highest means was given a score of 1, the next best a score of 2, and so on. If 'k' was the number of groups for a particular character, the populations in group 1 were given a score of 1/k, those in group 2, a score of 2/k and so on, to obtain standardized scores across the characters. The individual scores for each character were totalled to provide a total score for each population. The populations were then ranked in descending order of the numerical values of total scores. The method consists of the following steps:

1) The performance of each character is seen from its mean value in the particular entry or season and a score (actual score) is allotted to that character. This is to say, a high mean value will get a score of 1; moderate value 2; low value 3, and so on.

2) Next, the actual score given for a particular character is converted into a standard score by dividing actual score obtained with the number of scores applied. For example, in pupation rate there are a total of 4 scores. Thus, the standard score will be actual score/4.

3) Finally, a score or rank S_i is obtained for each entry (there are 3 entries in each strain, which stand for [i] spring, [ii] summer, and [iii] autumn) by multiplying the standard score by the number of characters (which is 5 in this study) $S_i = S_{ij}$ (where j = number of characters).

Results and Discussion

The average rearing performance together with the least significant difference values of five characters of the forty-two strains of silkworm in spring, summer, and autumn seasons are shown in Table 1. Analysis of variance, i.e., the mean squares for all the five characters, is given in Table 3.

All of the five characters contribute to the silk yield in the entire growth phase of the silkworm. However, the pupation rate is the most important. The economic value of a silkworm strain is decided, to a large extent, by this character. The remaining characters, in the order of importance, are as follows: cocoon shell ratio, cocoon weight, silk filament length, and shell weight. Furthermore, a silkworm strain with > 85% pupation rate and > 20% cocoon shell ratio is considered to be economically important. Hence, it is essential to enlist those strains (Table 2) whose *per se* performance is significantly ($P < 0.01$) better than the average. The *per se* performance of a given strain for each character was assessed individually and the per cent increase in a character of a given strain over the character mean of strains is shown in parentheses (Table 2).

Based on LSD values, the silkworm strains found to be superior in the order of merit for the five silk yield-contributing characters were found to be most suitable to rear during particular seasons: 14M and JC2P in spring, NBJPO and JC2P in summer, and M2, NBJPO and SPJ2 in autumn. These strains performed well for most of the silk yield-contributing characters, especially pupation rate and cocoon shell ratio. However, as illustrated in Tables 1 and 2, the remaining strains also are useful for one or the other characters.

The results of season-specific performance of different strains with respect to characters reported in this study are in agreement with earlier reports (Venugopala Pillai 1979, Pershad et al. 1986, Bhargava et al. 1993b, Thiagarajan et al. 1993b). The results of the analysis of variance (Table 3) showed significant differences among seasons, among strains, and strains/seasons interaction for all of the five characters studied. These data indicate that not only heredity but also environmental factors influence the performance of a given strain for the characters studied.

In this study the silkworms were reared under standard laboratory conditions of temperature and humidity. Hence, the seasonal variations noted in the silk yield contributing characters of different strains may be attributed only to a certain extent to physical factors such as temperature and relative humidity, which are known to affect the growth of silkworms (Gabriel and Rapusas 1976). First and second instars reared at 26-28°C and 80-90% RH were found to be healthier as older larvae than those reared in other temperature and humidity regimes. Temperature, relative humidity, and ventilation during the spinning of silkworms influence the quality of cocoon, especially the shell. The length of silk thread of a cocoon may also vary in the given strain in different seasons (Ueda et al. 1969). A recent experiment conducted by Zhu (1990) showed that physical properties such as cocoon weight, shell weight, and length of silk filament are greatest when mature *B. mori* are kept at 21 - 24°C and 67% relative humidity. The main reason for variation in the performance of a given strain in different seasons may be due to the leaf quality in different agroclimatic conditions. In this study, all of the strains of silkworm were fed with leaves of the same variety, i.e., of MR2 variety. In different seasons the nutritional values and moisture content of the leaf may not be the same, which can influence the growth of the silkworm and cocoon characters.

Since silkworm domestication began, breeders have been interested in developing strains with more silk in their cocoons. The breeders of sericulturally advanced countries like China, Japan, and South Korea always preferred to develop season-specific silkworm strains. Mano et al. (1991) suggested that the cross N147 × C145 with high cocoon shell weight and long length of silk filament, as a suitable silkworm race for spring season. He et al. (1991) developed Xuhua and Qiuxing, two silkworm strains with high silk yielding performance for summer and autumn rearings. Similarly, the south Korean silkworm breeders (Sohn et al. 1990) developed Samkwangjam, an F_1 silkworm cross variety suitable for summer-autumn rearing with high silk yielding ability.

Table 2. Top ranking strains of silkworm (*Bombyx mori* L.) in the order of merit* in three seasons.

Characters	Seasons		
	Spring	Summer	Autumn
Pupation rate (%)	NB1 (14.1), JB2 (13.98), M2 (13.5), SPJ1 & Dong-306 (13.2), JC2P (12.91), European (10.1), 14 M (9.63), JZHMC (0.63), SSOP (9.33), JZHPO (8.44), J122 (8.14)	C108 (16.57), SSOP (16.18), C130 (15.79), Dong-306 (15.59), JA1 & NB1 (14.79), M2 & JZHPO (13.41), J2M (13.20), 7042 (12.01), Hu-204 (11.81), CJ3P (11.02), JC2P (9.83), European (9.23), 4792 (7.64), NBJPO (7.45)	M2 (16.18), 39P (14.79), PBL1 (14.6,) J1M (14.39), J122 (13.80), NB1, 247, Dong-34 and Hu-204 (12.61), Nanung-6D (11.42), SPJ2 (10.82), SPC1 (10.22), J2M (9.63), J2P (9.03), 4792 (8.58)
Cocoon Weight (g)	J2M (11.63), NBJPO (10.47), 44 FM (8.72)	JB2 (23.26), 44FM (18.60), JZHMC (15.7), J122 (13.37), Showa & NBJPO (12.79), NB1 (10.47), J2P & SN2 (9.88), NJ1 & 36PC (8.14), PBL1 & SH2 (7.56), 14M & SPJ1 (6.98).	JZHPO (25.58), CJ3P (23.84), Showa (22.67), NBJPO & PBL1 (22.09), , 44FM & SH2 (21.51), SN2 (20.93), SSOP (20.35), M2 (19.77), NJ1 & 36PC (19.19), JA1 (18.6), JC2P (16.86), JZHMC (15.70), JB2 (14.53), European (13.95), 39P (9.88)
Shell weight (g)	14M (25.0), 36 PC (18.75), J2M & SN2 (18.75)	NBJPO (28.12), JB2 (25.0), JZHMC, Showa & SH2 (18.75)	M2, Showa & NBJPO (34.37), SN2 & JC2P (31.25), JA1, JB2, PBL1, NJ1 & SSOP (28.12), SH2 & 44FM (25.0), CJ3P, European & JZHPO (21.87), JZHMC & N4 (18.75)

Table 2. Continued.

Characters	Seasons		
	Spring	Summer	Autumn
Cocoon shell ratio (%)	14M (22.05), 36PC (17.3), SSOP (16.76), J2P (16.23), SN2 (15.91), SH2 (14.42), CJ3P (12.87), C120 (12.39), JC2P (9.82)	SN2 & C120 (17.08), JC2P (16.87), NBJPO (12.81), 14M (10.25), SH2 (9.66)	N4 (25.25), 44FM (21.89), SPJ2 (21.2), C150 (13.45), JC2P (11.59), M2 (11.43), SN1 (11.21), JB2 (11.11), C120 (10.68), 14M (10.46), NBJPO (9.34)
Silk filament length (m)	SH2 (28.24), JA1 (19.96), CJ3P (19.16), J2HPO (14.87)	SH2 (26.85), J1M (19.06), JC2P (18.96), JB2 (17.27), NJ1 (16.77), European (16.17), NBJPO (15.67), JA1 (12.57)	Showa (26.55), NBJPO (24.85), European & SN1 (23.95), NJ1 (23.75), N4 (22.65), M2 (18.86), SPJ2 (17.47), JB2 (16.17), 14M (14.47), JZHMC (12.67), SPJ1 (12.28)

*Significantly ($P \leq 0.01$) more than the average values.
Note: The figures in parentheses indicate the per cent increase in a character of a given strain over the character mean.

Table 3. Mean squares for five characters in *Bombyx mori* L.

Source of variation	df	Pupation rate	Cocoon weight	Shell Weight	Cocoon shell ratio	Silk filament length
Between strains	41	523.629*	0.3732*	0.0089*	7.094*	50147*
Between seasons	2	1748.5*	0.8109*	0.0137*	12.545*	36775*
Strains × Seasons	82	1036.73*	0.5346*	0.0103*	9.373*	41093*
Error	334	67.729	0.01115	0.00051	0.633	2193

*Significant at 1% level.

Prior to this work, no attempt was made in India to note the season-specific performance of silkworm strains. Hence, the results of this study, which has determined the strains of silkworm that are most suitable for rearing during particular seasons are important to sericulture in India. Thus, to obtain maximal harvest of a cocoon crop, it is suggested that a particular strain should be reared during the season in which the environmental conditions are most favorable for its survival. Thus, knowing that variations in parents caused by environmental conditions can be produced in progeny, we can successfully exploit the cocoon crops from strains 14M and JC2P (both in spring), NBJPO and JC2P (both in summer), and M2, NBJPO, and SPJ2 (all in autumn).

Finally, it is suggested that these high-yielding strains can be obtained readily, if some rearers or sericulture stations want to establish cultures of them.

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