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Preliminary Report on the Breeding of Robust and Resistant-NPV and High Quality Silkworm Race "Shengming No. 1" for Summer-autumn Rearing

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Seveval Chinese and Japanese varieties with good characters were used in the breeding. After 5 years (15 generations), a pair of robust and high quality silkworm variety with NPV resistance was bred by means of a combination of crossing and pedigree selection complemented by the selection of NPV resistance. The variety was identified jointly nationwide in 2003 and 2004, and appraised by National Mulberry and Silkworm Appraising Committee. Results are as follows: its cocooning rate is over 93%, shell rate 23-25%, filament length 1200-1300 meters, reelability 75-88%, Length of non-broken cocoon filament 900-1100 meters, raw silk rate 17-19%, neatness 95-97 points, and cocoon crop, cocoon shell weight and raw silk weight per 10 000 larvae is higher than those of the control variety by 7-10%, 14-19% and 14-18%, respectively. The variety is not only robust, resistant to high temperature and NPV, easy to rear, uniform in hatching, molting and maturing, but also lays more eggs, and its fecundity is high. It is suitable to rear in the Yangtze River Basin, the Yellow River basin and the Pearl River basin of China.

Key words: Silkworm, Variety, Resistant-NPV, Breeding

Introduction

Silk is famed as the queen of fibre. Silk fabrics are in people's good graces from ancient time to the present, which leads to the fast development of sericultural industry. However, to the present, two major mulberry silkworm diseases, nosemosis and virosis, remain uncontrolled. Virosis caused by *Bombyx mori* nuclear polyhedrosis virus (BmNPV) is highly contagious and the most serious of the three viroses in sericulture, which causes great losses to silkworm farmers. Sericulturists have long hoped that they can find out materials resistant to NPV and then breed resistant varieties. But no silkworm variety with good resistance has been bred so far mainly in that they haven't found out the basic materials resistant to the disease. In view of it, based on the basic silkworm varieties available, we screened out the basic materials resistant to NPV, namely six Chinese and Japanese strains, by performing resistant NPV medium lethal concentration (LC_{50}) test on more than 700 varieties from Silkworm Germplasm Resource. Mainly through systematic selection, a pair of silkworm variety named "Shengming No.1" resistant to NPV was bred by employing crossing and directional selection methods. The breeding techniques are as follows:

Materials and Methods

Parent selection

Chinese variety: the variety was crossed by using C_{03}, a Chinese strain with high raw silk weight, excellent silk quality and good comprehensive characters, as female parent, and B_3, a robust Chinese strain with good resistance to NPV, as male parent. It is a bivoltine variety with multivoltine blood that molts four times, and its hibernating eggs and egg shells are dark green and yellowish in color, respectively. Every moth lays more than 450 eggs which hatch uniformly. The newly hatched larvae are blackish brown in color and have a high tendency to stay

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collectively. Molting is uniform and fast in each instar. The grown larvae are greenish white in color, big and strong, and they eat and move fast, mount and mature uniformly. The cocoon is oval and uniformly shaped with normal wrinkles and white in color. Cocoon shell rate is 21-22%. Cocoon filament length is 1100-1200 meters and cocoon filament has a high-class merit of reelability and neatness. Emergence of the moths and laying of eggs occur in a short time period, and eggs attach to the egg cards well.

Japanese variety: the variety was crossed by using 854B, a Japanese strain with multivoltine blood, moderate resistance and good resistance to NPV, as female parent, and 874, another Japanese strain with high raw silk weight and excellent silk quality, as the male parent. It is a bivoltine variety that molts four times, and its hibernating eggs are brownish purple in color and egg shells are white. Every moth lays more than 500 eggs which hatch uniformly. Newly-hatched larvae with a strong escaping behavior are blackish brown in color. Molting is slow but uniform in each instar. Grown larvae are big and strong, and eat fast and mount uniformly. The cocoon is slightly peanut shaped and white in color. Cocoon shell rate is 22 -23%. Cocoon filament is long and has a high-class merit of reelabity and neatness. Moths lay high number of eggs that attach to the egg cards well.

Arrangement of breeding environment and keys of breeding techniques

Emphasis should be laid on the survival rate in the breeding of silkworm variety for summer-autumn rearing. On the premise that the survival rate doesn't decrease, the fecundity of varieties should be taken into account. In addition, we should not only handle properly the relationship between robustness and fecundity, but also the negative relationship between robustness and cocoon crop, silk quality and so on, and should not pursue the silk quality and silk yield at the cost of robustness and the number of eggs. So we should pay great importance to the balance between robustness and silk yield. In the breeding, we should adopt harsh raising environment (high temperature and high humidity), and control the selection intensity of the whole cocoon weight and cocoon shell weight to the extent that the two characters which are negatively correlated can be improved continuously in relative balance, thus achieving the goal that the quality and quantity of silk can be increased continuously, and at the same time, robustness is not decreased. So the selected variety can be improved and reach a new balance in habitus, cocoon quality, silk quality, resistance and so on.

The breeding of the variety satisfied the breeding requirements of varieties for summer-autumn rearing (Zhao, 2004; He *et al.*, 1998). At the initial stage of breeding, we prepared many materials, and combined them to make several hybrid combinations. According to the special weather conditions of summer and autumn and the difference of silkworms' instar, we created harsh environment (high temperature and high humidity) to enhance the selection of favorable gene, and the selection of robustness was the most important which ensured that the pupation rate was above the average of varieties and the death rate was below the average of varieties. Through the forecast evaluation, we laid emphasis on the precise selection of the single batch combined with the system selection. The criteria are to select excellent batch from excellent system, and to select good individuals from excellent batch. In spring, the emphasis was to select individuals with quality cocoon and silk while watching their vigor. In summer and autumn, the emphasis was to select individuals with high resistance while thinking of excellent individuals. When setting up the system, we made the environment as consistent as possible in order to minimize environmental error, thus leading to precise selection.

Result

Breeding procedure

Generation F_1 was raised in the spring of 1998. We adopted the method of mixing collection of many batches and rearing 0.2-0.3 g of newly hatched larvae in each batch. We took individual selection in rearing. Because of heterosis, generation F_1 larvae were strong and big with heavy cocoon weight. During larval stage, late molters and small weak silkworms were eliminated. In seed cocoon period, based on the principle that cocoon weight and cocoon shell weight is positively correlated, we firstly chose 100 female ones and 100 male ones through naked eyes and selected big, good shaped and hard cocoons for individual weighing. We selected individuals by giving priority to shell ratio and shell weight with due consideration to cocoon weight and adopted mixed seed production method. During eggs production, we left 100 healthy females and 100 male pupae in each batch, and eliminated earlier emerged moths and caudal moths.

From the perspective of genetics, gene segregation in generations F_2-F_3 is remarkable and difference between the individuals is large, therefore the effect would be better if we strengthen individual selection. We chose the materials through a combination of direct and indirect selection, and strong directional selection was conducted all over the period. In generations F_4-F_6, we used single batch rearing. 4-5 batches were reared for each variety and 40-50 standard cocoons were chosen for individual weighing. Considering that the qualities of silk and cocoon are quantitatively inherited characters both controlled by multigenes and affected by environment greatly, in generations F_4-F_6 we used the same batches crossing method to allow the effective genes controlling the qualities of silk and cocoon to combine fully.

Since generation F_7, we began to 1) take different batches crossing method in order to make the characters stable. 2) integrate breeding environment. 3) enlarge rearing batches. 4) set up small systems. 5) lay emphasis on the selection of good batches from good systems. When selecting batches, we selected those with large number of eggs and hatching well, while eliminating those developing badly during rearing. At seed cocoon period, we made a detailed investigation into every index, reeling appraisal, comprehensive evaluation and selected two better batches for each variety, especially those batches with high quality of silk and cocoon, and then weighed them individually. Those cocoons whose cocoon weight, cocoon shell weight and shell rate were all above the average level were kept as parents for reproducing offspring. The achievements of breeding pedigree are shown in Table 1 and Table 2.

During the whole course of breeding, on the basis of attaching importance to a balanced development of all economic characters, we especially made the silk quality standout, and at the same time gave consideration to robustness. In later stages, we laid especial emphasis on robustness. In the breeding of each generation, individuals with strong resistance to NPV were selected in the form of the combination of near isogenic lines through generations. By adding NPV at the concentration of 10^7, healthy silkworms that survived were screened out and selected for rearing. As for hybrid combinations, the same concentration of NPV was added in order to examine the NPV resistance of hybrid combinations (Zhao *et al.*, 1996).

Combination and Breeding Achievements of F_1 hybrid
General combining ability (GCA) and NPV resistance were tested from 2001 to the eighth generation using the incomplete diallel crossing method. The result showed that GCA of 854BP was the best among the Japanese strains. Then specific combining ability (SCA) was tested. We combined several Chinese strains and Japanese strains both with good resistance to NPV, and found that (C03×B2) × (854B × 874) was the best. Its cocoon filament quality, cocoon yield and other properties were all improved, its seed productivity was good as well, and it was named "Shengming No.1". Since NPV resistance was controlled by multigenes of major dominant gene, the NPV resistance of combinations of Chinese varieties and Japanese varieties was improved greatly. Compared with pure varieties, the NPV resistance of hybrid combinations was improved a lot as well, and economic characters of them also met the requirements of breeding targets (Table 3).

In 2003 and 2004, all the economic and technological targets reached the requirements of breeding. The cocoon filament length was 1100-1300 meters, the reelability over 75%, and the neatness over 95 points.

The variety is bivoltine and molts four times. Egg color of crossing hybrid is grayish green, and the number of eggs per gram is about 1700. Egg color of reciprocal crossing hybrid is grayish purple or purplish brown, and the number of eggs per gram is about 1700-1800. It is uniform in hatching, molting and mounting. Duration of all instars in spring and autumn is 26-28d and 23-25d, respectively. Duration of the fifth instar is 7-9d. The body of the fifth instar is strong and big, and the body color of them changes from greenish white to greenish gray with normal marking. Its cocoon shape is super big and uniform, cocoon color is white, and cocoon weight is heavy. The moth is big, its mating ability is good, and the number of eggs laid by a moth is over 500.

The variety is a variety with characters of good resistance, high yield, excellent silk quality, and strong resistance to NPV, and easy to rear in early autumn when the temperature and humidity are high. In order to exert its productivity, and to improve its silk quality, the following rules should be followed:

(1) After silkworm eggs are sent out, they should be transported well, and the starting embryo for incubating and incubating conditions should be also controlled well. In particular, when they are dispensed to silkworm farmers, supplementary incubation should be carried out so that they can hatch uniformly (Zhao, 2002).

(2) The standards for temperature and humidity in each instar are as follows: The temperature for the first and second instars is 27-28°C, and depression of wet bulb is 0.5-1°C; the third instar is 25-26°C, and depression of wet bulb is 1-2°C; the fourth instar is 24-25°C, and depression of wet bulb is 2°C; the fourth instar is 24-25°C, and depression of wet bulb is 2°C; the fifth instar is 23-24°C, and depression of wet bulb is 23°C.

(3) Young silkworms have the characters of phototaxis and tending to stay collectively, so silkworm bed should be rearranged and rearing trays should be changed in time to avoid mulberry leaves being unevenly eaten, thus maintaining the uniformity in their development and regularity of their body. The leaves for the first feeding after each molting should be fresh, tender and nutritious to avoid missing silkworm.

(4) Disinfection and disease control should be carried out in each stage, and technology management should be strengthened as well in order to avoid pathogens.

Table 1. Japan strains main achievement what were bred out

Year	Reading season	Generation	Reading type	Dration of the fifth (d:h)	Duration of all instars (d:h)	Larva-pupa rate	Rate of dead worm cocoon (%)	Cocoon weight (g)	Cocoon shell weight (g)	Ratio of cocoon shell (%)	Cocoon filament lenth (m)	Unwiding radio (%)	Non-broken lenth of a bave (m)	Size (D)
1997	Spring	F1	○	8:12	27:12	94,24	2.3	1.98	0.412	20.81	1290	70.32	907	3.01
	Autumn	F2	○	7:12	24:18	90.21	3.6	1.73	0.391	22.60	1089	70.21	765	2.78
1998	Spring	F3	○	8:12	27:06	95.34	2.4	1.94	0.423	21.80	1232	73.45	905	3.12
	summer	F4	□	7:18	23:06	88.26	8.1	1.72	0.392	22.79	1198	74.23	889	2.89
	Autumn	F5	□	7:18	25:00	81.33	10.2	1.98	0.423	21.36	1189	79.45	945	2.67
1999	Spring	F6	□	8:18	27:00	94.23	5.1	2.12	0.434	20.47	1300	86.32	1122	2.99
	summer	F7	□	7:06	25:12	87.21	8.9	1.78	0.423	23.76	1090	75.34	821	2.56
	Autumn	F8	□	6:18	25:00	89.31	7.3	1.713	0.389	22.71	1105	74.65	825	2.79
2000	Spring	F9	□	8:18	28:06	90.21	6.9	1.923	0.456	23.71	1273	88.56	1127	2.86
	Autumn	F10	□	7:18	24:12	82.21	11	1.973	0.454	23.01	1178	79.89	941	2.81
2001	Spring	F11	□	8:15	26:12	95.33	2.5	1.932	0.463	23.96	1236	82.88	1024	2.73
	Autumn	F12	□	7:15	26:15	89.89	5.8	1.965	0.489	24.89	1102	80.12	883	2.45
2002	Spring	F13	□	9:00	27:06	97.32	1.2	1.918	0.467	24.35	1267	87.33	1106	2.78
	summer	F14	□	7:06	25:00	93.78	3.6	1.947	0.463	23.78	1105	79.35	877	2.67
	Autumn	F15	□	7:15	25:12	94.2	4.5	1.961	0.472	24.07	1146	78.99	905	2.73

Table 2. China strains main achievement what were bred out

Year	Reading season	Generation	Reading type	Dration of the fifth (d:h)	Duration of all instars (d:h)	Larva-pupa rate (%)	Rate of dead worm cocoon (%)	Cocoon weight (g)	Cocoon shell weight (g)	Radio of cocoon shell (%)	Cocoon filament lenth (m)	Unwiding radio (%)	Non-broken lenth of a bave (m)	Size (D)
1997	Spring	F1	○	8:21	27:21	91.21	8.3	1.91	0.417	21.88	1188	83.32	990	2.89
	Autumn	F2	○	7:15	24:12	87.15	7.6	1.66	0.367	22.15	1049	78.23	821	2.78
1998	Spring	F3	○	9:00	28:00	91.5	5.9	1.94	0.431	22.22	1201	78.89	947	3
	summer	F4	□	7:15	23:15	91.45	7.1	1.77	0.401	22.66	1189	75.34	896	2.56
	Autumn	F5	□	7:06	24:15	89.23	7.9	1.58	0.345	21.84	1098	76.45	839	2.65
1999	Spring	F6	□	8:12	26:21	95.89	2.1	2.05	0.465	22.68	1203	79.87	961	2.67
	summer	F7	□	6:21	23:00	90.38	6.9	1.69	0.389	23.02	1102	77.29	852	2.54
	Autumn	F8	□	7:15	23:15	90.21	7.2	1.94	0.456	23.51	1112	79.32	882	2.58
2000	Spring	F9	□	8:15	26:18	95.21	1.1	1.98	0.423	21.36	1210	83.21	1007	2.92
	Autumn	F10	□	7:06	23:21	89.89	10	1.68	0.372	22.14	1095	80.34	880	2.61
2001	Spring	F11	□	8:06	26:12	97.23	1.3	1.82	0.422	23.17	1193	79.37	947	2.68
	Autumn	F12	□	7:15	23:15	88.31	9.2	1.66	0.389	23.45	1023	79.98	818	2.59
2002	Spring	F13	□	8:21	27:21	98.45	0.9	1.823	0.422	23.15	1190	81.12	965	2.75
	summer	F14	□	7:06	23:06	93.29	6.1	1.70	0.379	22.28	1089	80.38	875	2.64
	Autumn	F15	□	7:12	23:21	92.89	5.2	1.73	0.385	22.23	1109	81.45	903	2.63

Table 3. Shengming no.1 main achievement what were bred out in laboratory

Year	Reading type	Duration of the fifth (d:h)	Duration of all instars (d:h)	Larva-pupa rate (%)	Rate of dead worm cocoon (%)	Cocoon weight (g)	Cocoon shell weight (g)	Cocoon shell rate (%)	Cocoon filament lenth (m)	Unwiding ratio (%)	Non-broken lenth of a bave (m)	Size (D)	Neatness (D)
2003 (spring)	Direct cross	8:06	27:12	95.78	1.2	2.03	0.504	24.83					
	Reverse cross	8:18	28:00	96.21	1.5	2.12	0.515	24.29	1301	80.21	1044	2.93	94
	Average	8:12	27:18	96.00	1.4	2.08	0.510	24.55					
2003 (Autumn)	Direct cross	7:15	24:18	93.45	4.5	1.89	0.472	24.97					
	Reverse cross	7:15	25:00	92.38	5.0	1.96	0.494	25.20	1209	81.02	980	2.82	95
	Average	7:15	24:21	92.92	4.75	1.93	0.483	25.09					
2004 (spring)	Direct cross	8:21	27:00	98.29	1.0	2.09	0.512	24.50					
	Reverse cross	8:21	28:00	96.37	2.2	2.14	0.514	24.02	1289	85.34	1100	2.87	94
	Average	8:21	27:12	97.33	1.60	2.12	0.513	24.26					
2004 (Autumn)	Direct cross	6:21	24:15	92.12	5.1	1.89	0.489	24.14					
	Reverse cross	7:15	25:06	94.38	4.2	1.97	0.491	24.20	1202	84.03	1010	2.81	94
	Average	7:06	24:23	93.25	4.65	1.93	0.49	24.17					

(5) The mulberry leaves for collected newly-hatched larvae and the first feeding after each molting should be suitable and incompletely mature, but the mulberry leaves for old instars should be completely mature. The leaves for all instars should be as fresh as possible. Do not feed leaves that are bad, fermented and warm.

(6) Because of the uniformity in mounting, you should prepare the mounting work in advance. Ventilation should be enhanced to reduce the rate of non cocooning silkworm and improve silk quality.

Appraisement

The variety was appraised by National Mulberry and Silkworm Appraising Committee in two successive years (Table 4). From the table, we can see that, its cocooning rate is over 93%, shell rate 23-25%, filament length 1200 -1300 meters, reelability 75-88%, Length of non-broken cocoon filament 900-1100 meters, raw silk rate 17-19%, neatness 95-97 points, and cocoon crop, cocoon shell weight and raw silk weight per 10,000 larvae is higher than those of the control variety by 7-10%, 14-19% and 14-18%, respectively. Its all economic and technical norms have exceeded those set by the state. The variety has the following characters: good habitus, easy rearing, resistance to fluoride, high temperature and NPV, uniformity in hatching, molting and mounting, excellent silk quality, high cocoon crop, a high number of eggs laid by a moth, and high fecundity.

Achievements of the trial in rural areas. The variety was appraised by several institutions in 2003 and 2004, and at the same time, trials of the vareity were carried out in rural areas of Anhui, Jiangsu, Shandong and Henan Provinces of China. The results were showed in Table 5.

Appraisement of resistance to NPV. By the summer in 2003, six selected materials had been selected for 16-18 generations, and the resistance to NPV and comprehensive economic characters had been almost genetically stable. When selecting the resistant system, we carried out the selection of hybrid combinations and resistance at the same time. And the results (Table 6) showed that the resistance of $(C_{03} \times B_2) \times (854B \times 874)$ to NPV (LD_{50}) is better than that of two commercial silkworm varieties, Qingsong × Haoyue (for spring rearing) and Liangguang NO.2 (for summer rearing), by 100- to 500-fold, and that economic characters of it are so similar to those of the two varieties that it can be a commercial silkworm variety. Showed in Table 6, 7, 8, 9.

Discussion

Compared with the currently extended silkworm varieties, Liangguang No. 2 and Dongting × Bibo for summer-autumn rearing, the variety is better in practicability which embodies in its robustness, strong resistance to NPV, high cocoon crop per 10000 larvae, high shell rate and so on.

Currently, silk quality of the new silkworm varieties bred by China has reached a high level. However, for varieties for summer-autumn rearing in China, robustness is what we should give the highest priority to. In order to breed a commercial variety having both good habitus and high silk yield, we attached importance to a balanced development of all economic characters in the whole breeding course, and laid emphasis on the complement of a single character when choosing hybrid combinations because Japanese varieties have the characters of high silk yield and long filament, while Chinese varieties have the characters of good resistance, high reelability, high neatness, strong resistance to NPV and so on.

According to the principle of complementarity in which characters of progenies of the crossing parents can be complemented through gene recombination, we selected a variety with good habitus and normal silk yield to cross with a variety with normal habitus and excellent silk quality. Alternate raising between controlled high temperature and natural high temperature and high humidity along with the selection of NPV resistance was adopted in order to improve its resistance. We selected cocoons by weighing them individually and reeling before the moth came out in order that the selected varieties could be improved in their comprehensive characters such as habitus, cocoon quality, silk quality, resistance and so on. Furthermore, on the basis of these, we laid emphasis on the improvement of silk quality in order to achieve a high balance between robustness and silk quality.

To breed a variety with high silk yield, we should eliminate the incompatibility among silk quality, habitus and fecundity, and the incompatibility has been successfully eliminated in all quarters by applying multiple-cross. Not only silk quality but also robustness should be taken into account, so we used stocks with big cocoon, good economic characters and excellent silk quality, which were tamed by the environment of our province, to cross with stocks with good robustness and adaptability, which were bred by ourselves. By doing so, we could obtain new hybrid combinations whose good characters could be complemented because of heterosis.

When setting up the breeding goal of commercial silkworm varieties, we should take into account the characters of the local check varieties, and attach importance to a balanced development of all characters and the passing of national appraisement. Specifically, they should have the following characters: high hatching rate, uniformity in development, high pupation rate, short duration of larva

Table 4. Shengming No.1 main achievement of what were bred out rearing in different area in 2003 and 2004

Appraisal Unit	Year	Hybrid	Duration of the fifth (d:h)	Duration of all instars (d:h)	Larva-pupa rate (%)	Survial rate of larvae (%)	Rate of dead worm cocoon (%)	Cocoon weight (g)	Cocoon shell weight (g)	Radio of cocoon shell (%)	Cocoon crop per 10000 four-inster silkworms (kg)	Cocoon shell weight per 10000 four-inster silkworms (kg)	Raw silk weight per 10000 four-inster silkworms (kg)	Raw silk rate (%)	Cocoon filament length (m)	Unwin-ding ratio (%)	Non-broken length of a bave (m)	Size (dtex)	Neatness (D)
Jiangsu	2003	Shengming No.1	7:23	24:06	97.26	98.64	1.4	1.79	0.428	23.91	19.31	4.62	3.40	17.63	1289	83.21	1073	2.8	96
		Liangguang No.2	7:08	24:15	96.62	98.59	2	1.71	0.389	22.75	16.94	3.85	2.88	17.01	1102	82.72	912	2.8	95
	2004	Shengming No.1	7:05	23:06	93.66	96.96	3.4	1.9	0.465	24.47	20.23	4.95	3.73	18.45	1305	86.21	1125	2.7	95
		Liangguang No.2	7:14	23:15	91.77	96.6	5	1.88	0.441	23.46	17.96	4.21	3.11	17.31	1218	86.96	1059	2.8	94
Henan	2003	Shengming No.1	7:09	24:12	97.22	98.9	1.7	1.91	0.457	23.93	20.56	4.92	3.88	18.86	1202	78.05	938	2.7	95
		Liangguang No.2	7:21	24:18	94.06	98.18	4.2	1.97	0.44	22.34	18.42	4.11	3.19	17.33	1091	73.02	797	3.0	93
	2004	Shengming No.1	6:21	24:06	92.86	96.13	3.4	1.98	0.478	24.14	20.84	5.03	3.60	17.26	1191	79.45	946	2.8	94
		Liangguang No.2	6:21	24:06	91.34	98.11	6.9	2.03	0.435	21.43	19.00	4.07	3.16	16.63	999	75.52	754	3.0	93
Shanxi	2003	Shengming No.1	6:18	25:21	90.54	93.53	3.2	1.834	0.428	23.34	18.53	4.32	3.39	18.32	1212	79.67	966	2.6	96
		Liangguang No.2	6:18	25:21	90.11	94.16	4.3	1.723	0.401	23.27	17.23	4.01	2.83	16.43	1196	76.01	909	2.8	95
	2004	Shengming No.1	6:06	24:12	93.13	97.11	4.1	1.828	0.452	24.73	18.66	4.61	3.34	17.89	1219	83.67	1020	2.8	95
		Liangguang No.2	6:06	24:12	90.55	95.72	5.4	1.731	0.407	23.51	17.91	4.21	2.97	16.59	1138	80.42	915	2.9	95
Anhui	2003	Shengming No.1	7:06	24:06	96.47	97.64	1.2	2.02	0.512	25.35	20.47	5.19	3.83	18.72	1213	81.49	988	2.6	97
		Liangguang No.2	7:18	24:06	93.25	96.23	3.1	1.92	0.478	24.90	19.06	4.75	3.47	18.20	1142	80	914	2.7	97
	2004	Shengming No.1	7:18	25:06	95.79	99.26	3.5	1.98	0.487	24.60	20.29	4.99	3.85	18.98	1261	82.26	1037	2.6	95
		Liangguang No.2	7:18	25:06	92.21	96.96	4.9	1.87	0.428	22.89	18.72	4.29	3.35	17.89	1159	79.01	916	2.6	93
Average	2003	Shengming No.1	7:10	24:17	95.36	97.18	1.88	1.89	0.46	24.13	19.72	4.76	3.63	18.38	1229	80.61	991	2.68	96
		Liangguang No.2	7:10	24:21	93.50	96.79	3.40	1.83	0.43	23.31	17.91	4.18	3.09	17.24	1132.75	77.94	883	2.83	95
	2004	Shengming No.1	7:01	24:08	93.86	97.37	3.60	1.92	0.47	24.48	20.01	4.90	3.63	18.15	1244.00	82.90	1032	2.73	95
		Liangguang No.2	7:03	24:10	91.47	96.85	5.55	1.88	0.43	22.82	18.40	4.20	3.15	17.11	1128.50	80.48	911	2.83	94

Table 5. Mail achievement rearing in rural areas

Appraisal Unit	Rearing type	Dration of the fifth (d:h)	Duration of all instars (d:h)	Larva-pupa rate (%)	Rate of dead worm cocoon (%)	Cocoon weight (g)	Cocoon shell weight (g)	Radio of cocoon shell (%)	Cocoon filament lenth (m)	Unwiding radio (%)	Non-broken lenth of a bave (m)	Size (D)	Neatness (D)
Anhui	Direct cross	8:15	27:18	98.98	0.8	2.01	0.511	25.42	1208	83.91	1014	2.93	94
	Reverse cross	8:21	28:06	97.32	1.5	2.09	0.514	24.59					
	Average	8:18	28:00	98.15	1.15	2.05	0.513	25.01					
Shanxi	Direct cross	8:09	27:12	97.23	2.0	2.12	0.504	23.77	1298	80.34	1043	2.87	94
	Reverse cross	8:21	27:18	96.98	2.8	2.14	0.521	24.35					
	Average	8:15	27:15	97.11	2.40	2.13	0.51	24.06					
Jiangsu	Direct cross	8:21	27:00	97.24	1.8	2.10	0.510	24.29	1301	81.21	1057	2.89	93
	Reverse cross	8:21	28:00	97.90	2.3	2.20	0.528	24.00					
	Average	8:21	27:12	97.57	2.05	2.15	0.519	24.14					
Henan	Direct cross	8:06	26:12	96.29	2.7	1.97	0.501	25.43	1208	79.03	955	2.78	94
	Reverse cross	8:12	27:00	96.02	3.2	2.09	0.518	24.78					
	Average	8:09	26:18	96.16	2.95	2.03	0.510	25.11					

Table 6. The table of contrastive results of the silkworm new strain with anti-hemolymph grasserie disease ability reared in countryside

Hybrid	Rearing type	Hat-ching rate (%)	Duration of all instars (d:h)	Duration of all instars (d:h)	Cocoon crop per case of silk-worm eggs (kg)	Amount of leaves used per case of eggs (kg)	Cocoon yield per-dan of mulberry leaces (kg)	Number of cocoon per-jin	Dried cocoon shell weight (g)	Radio of cocoon shell (%)	Rate of dead worm cocoon (%)	Dry discount of fresh cocoon	Percen-tage of reelable (%) cocoon	Cocoon filament lenth (m)	Non-broken lenth of a bave (m)	Unwid ing radio (%)	Size (D)	Weight of cocoon filament (g)	Clean ness	Neat-ness (D)	Raw silk percen-tage of fresh cocoon (%)
Shengmin-gyihao	Direct cross	98.2	7:18	27:21	42.34	566.85	3.734674	281	10.1	25.02	1.2	202	92.24	1209	970	80.23	2.67	0.315	98.5	95	17.89
	Reverse cross	96.4	8:00	28:00	45.34	573.22	3.954852	289	10.2	24.78	1.5	200									
	Average	97.3	7:21	27:23	43.84	570.035	3.844763	285	10.2	24.9	1.35	201									
Jingsong × Haoyue	Direct cross	96.1	7:21	27:21	40.21	555.33	3.62037	283	10.1	23.45	2.01	207	92.1	1102	827	74.28	2.74	0.304	98.2	84.4	15.96
	Reverse cross	96.2	7:21	28:00	39.08	564.12	3.463802	291	10.1	23.13	2.6	204									
	Average	96.15	7:21	27:23	39.645	559.725	3.542086	287	10.1	23.29	2.305	205.5									

Table 7. Appraisal results of inoculaion of silkworm larvae with NPV in the autumn of 2003

Hybrid	Rearing type	4.76 × 10^5 p/ml Number of silkworm/ Number of silkworm tested	4.76 × 10^5 p/ml Incidence of dissease (%)	4.76 × 10^6 p/ml Number of silkworm/ Number of silkworm tested	4.76 × 10^6 p/ml Incidence of dissease (%)	4.76 × 10^7 p/ml Number of silkworm/ Number of silkworm tested	4.76 × 10^7 p/ml Incidence of dissease (%)	4.76 × 10^8 p/ml Number of silkworm/ Number of silkworm tested	4.76 × 10^8 p/ml Incidence of dissease (%)	4.76 × 10^9 p/ml Number of silkworm/ Number of silkworm tested	4.76 × 10^9 p/ml Incidence of dissease (%)	log LD_{50}
Shengmin-gyihao	Direct Cross	0/30	0	1/30	3.33	10/30	33.33	16/30	53.33	27/30	90	
	Reverse Cross	0/30	0	0/30	0	11/30	36.67	18/30	60	25/30	83.33	
	Average		0.00		1.67		35.00		56.67		86.67	7.99
	Direct Cross	0/30	0	0/30	0	11/30	36.67	18/30	60	26/30	86.67	
	Reverse Cross	0/30	0	1/30	3.33	11/30	36.67	17/30	56.67	25/30	83.33	
	Average		0		1.67		36.67		58.335		85	8.06
	Overall Average				1.67		35.84		57.50		85.83	8.02
Jingsong × Haoyue	Direct Cross	8/30	26.67	19/30	63.33	28/30	93.33	30/30	100	30/30	100	
	Reverse Cross	9/30	30	18/30	60	26/30	86.67	30/30	100	30/30	100	
	Average		28.34		61.67		90.00		100.00		100.00	6.03
	Direct Cross	12/30	40	20/30	66.67	26/30	86.67	30/30	100	30/30	100	
	Reverse Cross	10/30	33.33	20/30	66.67	25/30	83.33	30/30	100	30/30	100	
	Average		36.665		66.67		85		100		100	6.23
	Overall Average		32.50		64.17		87.50		100.00		100.00	6.12

*NPV was fed to the newly exuviated silkworm larvae of the second instar for 24 hours. It was inoculated with 30 larvae for each density of NPV with 3 repeats. The number of succumbed larvae was collected after 6 days

Table 8. Results of inoculaion of silkworm larvae with NPV in the autumn of 2003

Hybrid	Rearing type	Duration of the fifth (d:h)	Duration of all instars (d:h)	Larva-pupa rate (%)	Rate of dead worm cocoon (%)	Cocoon weight (g)	Cocoon shell weight (g)	Radio of cocoon shell (%)	Percentage of common cocoon (%)	Radio of double cocoons (%)	Cocoon crop per 10000 four-inster silkworms (kg)	Cocoon shell weight per 10000 four-inster silkworms (kg)
Shengming No.1	Direct cross	7:12	24:15	98.32	1.2	2.12	0.521	24.58	98.4	1.3	20.32	4.64
	Reverse cross	7:18	24:21	95.22	2.2	2.15	0.528	24.56	96.87	1.72	21.56	4.98
	Average	7:15	24:18	96.77	1.7	2.14	0.525	24.57	97.635	1.51	20.94	4.81
Jingsong × Haoyue	Direct cross	7:09	25:12	93.24	2	1.99	0.438	22.05	96.32	1.86	17.35	4.10
	Reverse cross	7:18	24:21	89.23	7.2	1.92	0.461	23.97	95.54	2.24	17.86	3.56
	Direct cross	7:12	25:18	87.12	8.2	1.90	0.467	24.55	96.45	2.63	18.69	3.42
	Reverse cross	7:12	26:00	90.25	4.2	1.98	0.491	24.80	92.46	4.42	18.61	3.89
	Average	7:12	25:13	89.96	5.4	1.95	0.464	23.84	95.19	2.79	18.13	3.74

Table 9. Silk results of inoculaion of silkworm larvae with NPV in the autumn of 2003

Hybrid	Percentage of reelable cocoon (%)	Cocoon filament length (m)	Non-broken length of a bave (m)	Unwinding ratio (%)	Weight of cocoon filament (g)	Size (dtex)	Cleanness (fen)	Neatness (D)	Raw silk rate (%)
Shengming No.1	97.46	1256	1062	84.54	0.354	2.986	98	94.75	17.98
Jingsong × Haoyue	95.56	1201	990	82.41	0.332	2.888	98	92.75	16.65

instar, high cocoon crop per 10000 larvae, high raw silk rate, long filament, high reelability, high neatness, moderate filament size, little difference in filament size and no difficulty in propagating stocks. When setting up the breeding goal of silkworm varieties for special uses, we should give priority to the excellence of certain special characters on the basis of no defect in other characters. The breeding of forerunner varieties has a great significance to the improvement of silkworm varieties (Zhao *at al.*, 2001).

So far, the breeding methods of silkworm varieties adopted by sericulturists at home and abroad are routine cross breeding and system selection. Because conventional breeding techniques of silkworm are based on the selection of phenotype, they are poor in prediction, affected greatly by environment, and entail a long time, a great amount of work and rich experience in breeding. Moreover, it is difficult to break the inherent balance among characters because characters are linked, so the breeding cycle is very long, thus forming the bottleneck for breeding new varieties. Similar characters of varieties are caused by the lack of countries in the world engaging in silk production, weakness in research, and overuse of the limited germplasm resources. With the rapid development of biotechnology, a growing number of sericulturists realize that, only by years of hand work, observation and recording, it is more and more difficult to meet the demands of the current society which is reforming continuously and developing fast. The purpose of the breeding of commercial silkworm varieties is the accumulation and balance of excellent characters. In order to realize efficient accumulation, break the linkage among characters and achieve a higher level of balance, we must make the best of molecular methods for improvement of silkworm based on routine breeding methods, thus promoting the transformation from conventional breeding methods to modern breeding methods. Researches into the molecular methods for improvement of silkworm have been already launched, and focus on cloning of functional genes for important characters, molecular marker-assisted selection, transgenic technology and other biological breeding techniques. Molecular marker-assisted breeding and transgenic technology will be the main direction of breeding techniques of silkworm for some time to come.

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