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Focus on Economic Benefits and the Most Appropriate Strategy of Sericulture in *Yuexi* Area of Guangdong, China

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Abstract: The research team investigated and analyzed the data of *Yuexi* silkworm rearing area in Guangdong province. Recently, the silkworm rearing farmers averagely got products from mulberry fields by 3547.65kg cocoons per hectare; the incomes rose to ¥73,363.8 (RMB) every hectare per year; for individual, the average income rose to ¥118,02.2 every year. In the five counties of *Yuexi* silkworm rearing area, the farmers in *Huazhou* input the least investment so that got higher silkworm diseases but they gained the best ratio of output and input as 365~376%; whereas that in *Luoding*, *Yun'an* and *Suixi* county, the number was 289.1~395%, 231.1~263% and 206.2~255.8%, respectively. However, in *Gaozhou* county, the farmers invested much more than the other counties which resulted in the lowest lost by silkworm diseases, unfortunately their ratio of output and input was low to 151~164%. Accompanied by the cost rising of agricultural materials and investments, silkworm rearing total cost increased by 16.54% and it cost ¥1,855 every household. The average productive cost account for 46.4% of income. The paper analyzed the situation in *Yuexi* silkworm rearing area faced, and proposed technical devices to further improve economic effectiveness with low ratio of productive cost which aims to promote quick and stable development of sericultural production.

Keywords: Sericultural Industry, Economy, Investigation Analysis, Strategy, Guangdong

1. Introduction

Sericulture is a traditional production in China with a long history which is more than five thousand years. Mulberry planting and silkworm rearing long lasted along every dynasty and had been an important index of agricultural and economic development; therefore, it built up and passed down skillful technologies, also including the character of labor-intensive industry. So far, sericulture in Guangdong province carried over no less than two thousand years and became one of the four largest silkworms rearing areas of China in 1990s. It is still one of the characteristic and traditional agricultural industry in Guangdong and form special features of tropic and subtropics in production pattern, industry model and technological level [1]. With the lapse of time, the original cocoon production in delta region along *Zhujiang River* faded out and the other region in the western and northern of Guangdong (*Yuexi* and *Yuebei*) gradually grew up. In 1992, the new cocoon production areas provided the yield of 46,057 tons [2]. *Huazhou* county in *Yuexi* mounted 200 tons and kept high yield for more than 10 years. In 2007, it accounts for 10% of provincial total 85,000 tons [3]. In 2010, Guangdong province planted 38,800 hectares' mulberry and produce 79,080 tons of fresh cocoon with ¥30.62 per kilogram and sold out 1,168,566.4 boxes of silkworm eggs [4]. In 2015, the mulberry field shrink to 28,000 hectares. 800,000 boxes of silkworm eggs were delivered to the farmers which produced 57,100 tons of fresh cocoons (unpublished data).

From 2000 to 2013, 73.46% of silk production in the world trade market came from China, while that of 21.2% exported from Indian, 1.6% from the countries in the Commonwealth of Independent States (CIS), 0.9% from Brazil, 0.14% from Japan and 2.7% from the other countries (Figure 1).

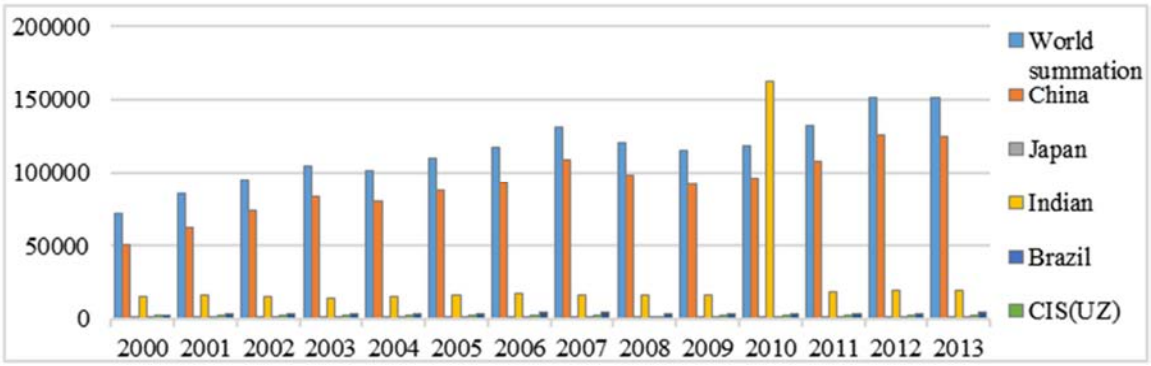

Figure 1. *Mulberry silk production statistics in the world and China.*

Data sources: silk year book of China on Internet of World Silk [5]. Mulberry silk production exported from China occupied the largest part in the world from 2000 to 2013.

In 2014, Guangdong exported silk commodities total value around $34.4 million dollars, which account for 9.8% of summit number of whole country; in 2015, it rose to $60.46 million dollars and up to 19.7% of all exported commodities of China; however, in the prior eleven months in 2016, the number continuously increased to $77.9 million dollars and the percentage was 29.41% [6]. At present, silkworms rearing region mainly distributed in the northern and western area in Guangdong, named *Yuebei* and *Yuexi*, respectively, is mountainous, rainy and fertilized hill land.

Yuuexi is a generic term of five silkworms rearing counties in the western Guangdong province including *Huazhou*, *Gaozhou*, *Suixi*, *Luoding* and *Yun'an (*official data, unpublished data). They are main cocoon production areas beside *Xijiang River* which account for 30% of the province and yield 20,000 tons each year [7~11]. However, along with the development of modern industry, the contradictions are emerging and sharping such as low value of workforce, eruption of every kinds of mulberry and silkworm diseases, and directly cause of unideal economic benefits.

2. Economics Benefits Focus

The mulberry fields in the *Yuexi* were constantly kept in steady hectares recent years. The farmers produced 3,547.86kg fresh cocoons per hectare which brought an income of ¥73,363.8 every year. However, the average of workforce per year maintained the low level only ¥11,802.2. On the other side, the producer gods unfortunately spiraled inexorably on which increased the farmers' investment. The data showed that the amount of increase was 16.54% in three years including input of eggs production, fertilizer, insecticides and chemical drugs for silkworm rearing. The average consumed cost accounts for 46.4% of incomes (Table 1).

Table 1. *Economic benefits of the randomly investigated farmers in Yuexi.*

County	Time	Mulberry field (hm^2)	Fresh cocoon production (kg/hm^2)	Incomes (¥)	Individual income (¥)	input-output ratio (%)	Total production cost * (¥)
Huazhou	The 1st year	5.71	3,018.45	335,500.0	9,319.4	365	91,910.0
	The 2nd year	5.71	3,127.95	388,600.0	10,794.4	376.4	103,250.0
Gaozhou	The 1st year	7.96	5,910.00	1,031,300.0	18,416.1	151.0	682,904.0
	The 2nd year	7.96	5,635.50	1,157,900.0	20,676.8	164.6	703,425.0
Suixi	The 1st year	11.77	1,738.15	414,323.6	9,207.2	206.2	200,965.0
	The 2nd year	12.19	1,809.00	590,123.9	13,113.9	255.8	230,668.0
Luodiing	The 1st year	7.6	3,557.25	425,488.0	8,683.4	395.0	107,747.0
	The 2nd year	7.67	3,774.90	636,252.0	12,984.7	289.1	220,088.0
Yunan	The 1st year	4.08	3,380.25	217,288.5	6,602.7	231.1	94,297.5
	The 2nd year	4.4	3,505.50	302,952.2	9,180.4	263.0	119,175.4
Average		7.5	3,545.70	550,032.7	11,897.9	269.7	255,443.0

*Note: Total production cost exclusive workforce just including the producer gods. Data source: base counties in *Yuexi*. Statistical analysis showed that F>F0.01, P<0.01, so there are obvious differences between the two groups of samples.

The sericultural development magnificently depends on the silkworm rearing technologies of the farmers but what kinds of crops being to plan based on policies of the local government. The silkworm rearing areas expanded at the different time so that different skill extent of the households. The data in the table obviously suggested that the farmers in *Gaozhou* achieved the advanced indexes in every aspect of fresh cocoon productions, incomes, and average individual incomes. The highest individual income presented in *Gaozhou* which run up to more than ¥20,000 a year, whereas in *Yun'an*, lower to only ¥6,600. From the view of investment, however, the lowest record presented at total amounts of ¥90,000 in

Huazhou and the highest record in *Gaozhou*, up to around ¥700,000 that showed the differences between 7~8 times. The puzzling data was comparative analysis of the counties that the lowest ration of output and input presented in *Gaozhou* where we recorded the highest investments, incomes, and the least losses of silkworm diseases. This phenomenon might due to silkworm rearing technologies cause of skillful workforce in *Huazhou*, a mature region of sericuturual development. To further explore and address the question, we explored the silkworm rearing process including management of mulberry planting and harvesting, silkworm rearing and cocoon collection.

3. Analysis Methodology

Randomly, 20 households who engaged in silkworm rearing each county were asked to fulfill the forms of investigation. The contents of forms involved in economic benefits, management of mulberry field, pests and diseases of mulberry trees, fertilizer and harvesting forms of mulberry, cooperative young silkworm rearing, silkworm eggs production, and cocoon production. Collected data were separately classified into sorts. Comparisons between two groups were tested by One - Way analysis of variance (ANOVA). Further， comparative studies on the data of mulberry and silkworm diseases were performed among base counties.

4. Results and Discussion

4.1. The Management of Mulberry Fields

Mulberry is the base of silkworms rearing which directly related with incomes of the year. Therefore, lots of silkworms rearing households realized the importance of the issue. The skillful farmers might use organic fertilizer, poultry manure such as chicken and pig manure, and silkworm droppings mixed with straw, mulberry branch powder to improve the nature of the mulberry fields in the Winter. Compound fertilizer, phosphorus, potassium, and carbamide fertilizer are used in the Spring and Summer to help leaves grow. The investigation data showed that 6.5 tons of organic fertilizer were applied and output 4.29 tons of fresh cocoons per hectare. Averagely, every 50kg of mulberry leaves produced 3.06 kg of fresh cocoons. Fertilizer is the biggest investment of sericultural production which account for the most input of the households (Table 2). It cost ¥597.63 each hectare.

Table 2. *The amounts of cocoon production from mulberry garden.*

County	Amounts of households	Amounts of organic fertilizer per hectare (tons)	Amounts of cocoon production (kg)	Amounts of cocoon production per 100 kg mulberry (kg)	Mulberry leaves production per hectare (kg)	Harvesting form
Luoding	15	6.68	3786.75	6.5	58,257.7	branches
Yun'an	15	12.85	4795.65	5.7	83,840.0	branches

Data source: base counties in *Yuexi*.

4.2. Harvesting Forms of Mulberry Trees

The forms of mulberry harvesting are studied thoroughly under the tropic and subtropic temperature zone in silkworms rearing region including branches cut-off and leaves picking. Nowadays, cooperative young silkworms rearing and commercial young silkworms rearing are popularized in the eggs production and cocoon production process. The households purchase silkworms at the 3rd or 4th instar, and directly feed them on the ground in the south of China. For labor saving, the most of farmers might choose cutting off branches and put it on rearing bed. Our data showed that 90% of households adapted cutting off branches all the year which decreased by 30% of workforce than that of leaves picking. However, considering to harvest equal weight of leaves, the farmers had to increase the same percent of mulberry field. Although work efficiency increased, but the amounts of leaves weight decreased that finally makes no obvious differences between branches harvesting and leaves picking method [12]. Practically, if the farmer managed reasonable ratio of two method, they might get a good production effects. In fact, some mature developed regions still follow the traditional method of harvesting that picking leaves all the spring and summer, and cut off the branches in the next half year. The forms of harvesting might influence on the amounts of mulberry production per hectare and indirectly affect the economic benefits of silkworm rearing. It should be varied with climate condition, fertilizer management and physiological condition of the mulberry trees that year.

4.3. Investigation of Pests and Pathogens of Mulberry

The most households considered that neglect management and less investment of mulberry garden resulted in pests and pathogens break off in a certain period. The data showed that *Pseudomonas solanacerum* Dowson, a disaster bacterial pathogen which destroyed almost all mulberry trees in 1970s, disappeared at present for planting *Kangqing* No.10 in the large areas of silkworm rearing. However, another two fungi pathogen, *Aecidium mori* (Barclay) and *Bemisia myricae* Kuwana, became uncontrollable diseases (Table 3), especially in later autumn. For fruit usage mulberry, a fungus disease of mulberry *Ciboriashiraiana* P. Henn, *Mitrulashiraiana* (P. Henn) Itoetlmai or *Ciboriacarunculoides* Siegleret Jankins which caused production of mulberry fruit sharp declined in recent year that greatly influenced on production of mulberry fruit juice and wine.

Table 3. *The situation of pests and pathogens in Yuexi*[*].

Pests and pathogens \ County	*Huazhou*	*Gaozhou*	*Suixi*	*Luoding*	*Yun'an*	Average
Aecidium mori (Barclay)	14	48.2	2	14.5	3.4	16.4
Mycoplasma-like organism	3.5				4.9	1.7
Pseudomonas solanacerum Dowson	7		14.3		26.2	9.5
Meloidogyne incognita Chitwood	10.4		14.3	13	4.9	8.5
Bemisia myricae Kuwana	16.5	50	16.3	15.2	26.2	24.8
Pseudcden drothrips mori Niwa	15.6		6.1		9.8	6.3
Phthonandria atrilineata Butler	7.8		8.2		13.8	6
Porthesia xanthocampa Dyer	10.4		14.3	13.5		7.7
The others pests and pathogens	14.8	1.8	24.5	30	24.6	19.1

*Notes: The number in the table referred to the ratio of the pests or diseases which account for all hazards to mulberry trees. The others pests and pathogens in *Huazhou* and *Yun'an* indicated *Apriona germari* (Hope), while in *Suixi* and *Luoding* it referred to *Contarinia* sp. and *Gibberella baccata* or *Fusarium lateritum*. Data source: base counties in *Yuexi*.

4.4. Technologies of Silkworm Rearing and Operating Management

Up to now, eggs production is self-sufficient in *Yuexi*. *Gaozhou*, *Huazhou* and *Luoding* seized of their own farmer to provide condition of parent silkworm rearing and complete the process of eggs production. Our investigation showed that households averagely reared 38.3 boxes of silkworm eggs per year in *Gaozhou* and 14 boxes in *Yun'an*. Some households in *Huazhou* fed more than 26 batches and averagely fed 18.6 batches a year, while the least rearing farmer just fed 8 batches.

Cooperative young silkworms rearing is a model that the newly-hatched silkworms are collected and reared by skillful technicians to avoid pathogens infection and keep ants strong and fast grow. When silkworms grow into 3rd or 4th instar, the young silkworms are delivered to the households. The model first applied in a few farmers like union peasants and then it fast developed to commercial company and specific households. The technology promotes majority, large scale, and industrialization of silkworms rearing. It is benefits to elongation of eggs production which reflects commercialize and marker of the young silkworms rearing. It is also an effective technological device for the farmers to control the risks of silkworm rearing. The measure was learnt from Japan and popularized in 1970s. The model is developed and branched into many forms today that nearly leading the management of silkworms rearing for commercial and industrial applications [13]. Face to market needs, sericultural industry made a state-widely used standard that require the numbers of healthy young silkworms must touch more than 99% and the numbers of silkworms around 30,000 per box. One cooperative young silkworms rearing famer could bring up 10,000 boxes every year. The delivered young silkworms reared in the household harvest about 40~45kg per box. Overall, the technology greatly improved the regional level of silkworms rearing.

Big silkworms rearing requires more labor strength and workforce than young. After 4th instar, the silkworms grow very fast in size and weight, and exhaust almost 70~80% of total times and labor. Therefore, application and popularization of labor-saving methods are proposed.

The most important device to study is ground bed feeding. The households purchased back 3rd or 4th instar silkworms from the center of cooperative young silkworms and directly spread them on the previously disinfected room ground and fed them with mulberry branch leaves. It greatly decreases labor strength and workforce by 30~50% and improve the process efficiency. However, some researcher reported that leaves picking method whole the year could produce 26.12~33.63% more of the amounts per hectare than that of branches cutting[12]. Investigators further suggested that branches on the ground provide a comfortable bed for silkworms that make air flow under the branches and benefit to silkworm crawl and ingesting food. The ecological environment for silkworms living is better than that of leaves feeding.

Secondly, some simple and practical facilities for labor saving were gradually developed in the rural. The mulberry-giving vehicle is a typical simplified equipment which widely applied in *Guangxi* saving more than 50% of labor, especially at the 5th instar.

Thirdly, as I concerned that the silkworms always fed three times a day, but the feeding frequency might decrease to one time with comfortable humidity in the southern region of China. Some researchers argued that less feeding times might cause weak and unhealthy silkworms and results in diseases, unnormal shaped cocoon and decreasing of cocoon shell. In my view, it is valuable project to further explore in lab.

4.5. Control of Silkworm Diseases

In the southern region of China, the most time in a year under high temperature and high humidity. It becomes low temperature and high humidity in the spring, but it changes to high temperature and low humidity in the autumn. The undesirable climate makes silkworm rearing become difficulty due to pathogens are easy to propagate under the conditions. The data showed that Nuclear Polyhedral Virus (NPV) was very serious in all silkworm rearing zone which averagely account for 24% of the diseases. To avoid lost, some farmers choose ceasing silkworms rearing in the summer. In the earlier spring of south China, the climate is favorable for fungus propagation, the other serious pathogen to parent silkworms and pupae was white muscardine, caused by fungus *Beauveria bassiana* which lost 15% of income (Table 4). Only a few households with high skill can keep 1~2% of diseases lost. Bacterial diseases are common at the later stage of the 5th instar.

If the silkworms were infected by virus at the 4th instar, thereafter the silkworms would be weak and easy to infected with bacteria which resulted in diseases break out at the later of the 5th instar or spinning stage. This might cause 20% of lose.

Table 4. *The situation of silkworm pathogens in Yuexi*[*].

Pathogens \ County	*Huazhou*	*Gaozhou*	*Suixi*	*Luoding*	*Yun'an*	Average
Nuclear Polyhedral Virus (NPV)	34	24	34	16	21	24
Cytoplasmic Polyhedral Virus (CPV)	11	/	15	16	22	13
Flacherie virus (FV)	10	/	13	1	18	8
Densovirus (DNV)	6	/	2	16	/	5
Bacillus thuringiensis (Bt.)	4	21	4	/	3	6
Metarhizium anisopliae	1	24	6	3	11	9
Beauveria bassiana	14	19	8	16	16	15
fly maggot	5	/	6	16	/	5
Chemical insecticides poisoning	5	12	6	2	3	6
The others pathogens	20	/	6	14	6	9.2

*Notes: The number in the table indicated the percentage of the diseases which accounted for all silkworm pathogens. The others pathogens in *Huazhou* and *Luoding* indicated *Bacillus bombysepticus*, while in *Suixi* and *Yun'an* it referred to *pebrine*. "/" represent not find the kind of pathogen. Data source: base counties in *Yuexi*.

Unfortunately, 90% of investigated households in *Huazhou*, who spent less investments on agent disinfectants lost more than 20% of their harvesting in the estimated duration, while the lowest ratio of output and input in *Gaozhou*, 73.1% of the farmers who purchased relatively expensive disinfectants to prevent diseases and pests only lost lower than 5% of incomes. The comparative study showed that it is important to disinfect their rearing environments and rooms before feeding. The measure is not closely related with silkworms rearing technologies but take precautions against silkworm pathogens and synthetic devices in the procedures of rearing.

Table 5. *The lost distribution of the farmers.*

Lost percentage \ County	*Huazhou*	*Gaozhou*	*Suixi*	*Luoding*	*Yun'an*	Average
Lower than 5%	5	73.1	6.3	/	/	17
5~10%	5	19.2	37.5	20	93.3	35
Higher than 20%	90	7.7	56.2	80	6.7	48

Data source: base counties in *Yuexi*.

Another sound argument on the problem is the disordered silkworm disinfectants markets. There were more than 100 kinds of chemical agents on drugs cabinet in the store. The products came from all over the country, some of them are not registered and illegally inpoured to the tremendous sericultural marketplace. The Factory Manager concern about disinfectant for silkworm rearing rooms, tools and environments as well as silkworm nutrients, agent for trying to cure virus diseases. Generally, the disinfectants and agents are crucial to silkworm rearing, but some questions remained to be addressed. For example, some households replenished their disinfectants stocks in an agricultural business season for a long time which led to effective components overdue; in the high humidity season, the disinfectants brought about wet environments that is not favor to silkworm rearing; the farmers couldn't completely disinfectant their rearing environments, tools and rooms; too density batches to get enough places for silkworm rearing which resulted in young and big silkworms were reared in the same place; and finally, the farmers had no scientific ideal to deal with silkworm droppings and directly fertilized back their mulberry fields resulted in silkworm pathogens scattered around the countryside and brought back to the silkworm rearing rooms by flood, wind and poultries.

4.6. Scientific Programming and Promoting Stable Development of Sericulture in Yuexi

Sericltural industry is not a simple production line but complicated procedures which involved in mulberry planting, silkworm rearing, silk reeling, and even to weaving and clothing. It covered agriculture and industry. Looking inside agriculture operations, we also found it branches into plant and animal science. Its development requires more and more advanced technologies, not only planting and rearing but modern industry measures, such as scale criterion and standard, mechanization, and automation.

General trend of sericultural development sounds stable in *Yuexi*. In our review, the farmer passionate enthusiasm on the mulberry planting and silkworm rearing due to that economic benefit is better than rice, maize, and sugar cane, although it is poor than that of livestock and fish farming.

To address the problems, the sericultrual industry greatly depend on planning of agricultural operation. Firstly, the local government play important role in scientific programming of mulberry land and formulating encouragement policies, for example, large scale planting of mulberry trees, favorable prices of mulberry seeds and silkworm eggs production, decrease cost of sericultural operation, and insecticides or

disinfectants subsidy. On the other hand, the households should plan to order silkworm eggs production depend on growth of mulberry trees and rearing rooms, and avoid too density batches of rearing times. Secondly, sericultural in *Yuexi* still need the guidance of technology teams. The methods were popularized in the prior period of sericultural great prosperity in 1990s and significantly promoted the sericltural development. Nowadays, the farmers in the countryside who engage in sericulture are those women, teenage and the aged parents or grandparents cause of main labors migrated into cities. Shorting of strong workforce and educated skillful technician, sericultural regions faced universal demands. The practical ways to amend the condition is technical training. Thirdly, the conundrum of economic benefit of sericulture request continuously input and strengthen scientific researches. We found record of Nuclear Polyhedral Virus (NPV) of silkworm long times ago which puzzled the pioneers in AD. 1149 and last to nowadays. The "agricultural book (*Nongshu*)" written by Fu Chen [14] described the symptom of NPV as "high segments" and "foot swollen"; thereafter in AD 1639, "Complete Treatise on Agriculture (*Nongzheng Quanshu*) "described as "wandering and not fitting on mounting"[15]. They suggested that NPV is infectious disease of silkworms but still a problem in perplexity which cannot be cure even up today. Another obfuscation is pebrine, *Nosema bombycis* which destroyed sericulture in France and Italy in the 19th century. Pasteur, who discovered the pathogen was parasitic pebrine and transmitted generation by generation through mother moth and saved sericulture in 1835-1865, was worldwide famous France pioneer scientist. His creative method of microscopic check of mother moth by random group selection continuous effectively used all over the world today with no more further innovation but machinery. The two kinds of pathogens existed around silkworm rearing environments, cross infected with the other insects and varied accompanied with the history of sericulture which seriously damaged traditional sericultural industry. Finally, to stabilize and improve the quality and quantity of fresh cocoons, technological integration will be the most important and effective measure. In any event, fractionized profession depends on technology itself in part, but generally it's a close connected agricultural system engineering. It needs advanced industry technologies in mechanization and automation to save labor and improve the efficiency of workforce.

5. Conclusion

Economic benefit in *Yuexi* silkworm rearing region is relatively little better than that of the other crops and agricultural operations; however, the ratio of output and input exist great differences among the base counties. Some skillful households invested few on materials and encountered serious diseases and lost large part of their incomes, but they success finally in higher benefits. For the purposes of stabilizing and improving the quantity and quality of fresh cocoons, advanced scientific planning and programing of management of mulberry fields, silkworm rearing technologies, large scale criterion, mechanization and automation are required to fit the current situations and improve the efficiency of the workforce.

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