

**Hand pollination of pears and its implications for biodiversity
conservation and environmental protection -- A case study from
Hanyuan County, Sichuan Province, China**

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Introduction

Rural reform in China, which was characterised by implementation of household responsibility systems, had caused revolutionary changes in rural areas in China since early 1980s. Agricultural production in the rural areas in China has been greatly improved. As a result, China could feed 22% of the world population with around only 7% of the world cropland. Despite increasing agricultural production a great challenge has been faced by governments, agricultural scientists and farmers that increase in farmers' income has been much slower than other sectors in China. The problem of increase in crop yield with income increase has recently been a focus of government and agricultural scientists. Rural areas, agriculture and farmers are the most concern of Chinese government. How to improve effectively rural income will be the focus of development in the future.

Many studies have revealed that food supply has no more a problem in most parts of China but increase in cash income has been tardy since about 10 years ago. The basic feature of agriculture in China is characterised by very big population and limited cropland. With economic development, more and more cropland is lost to urbanisation, housing construction, infrastructure development and natural hazards. As a result, the per capita cropland has been declining, from 0.18 ha in 1950, to 0.12 in 1970, and further to 0.08 in 1994 (Bi Yuyuan, 1995). With fast infrastructure development in the past decade and implementation of "stopping steep cropland to forested area" programme since 1999, the per capita cropland in the recent years is expected to decline to further less. With this background, how to effectively use the existing cropland to maximum benefits has been a focus of work for government institutions. In the past two decades, particularly in the past decade, great efforts have been made in development various models that can help absorb rural labour, improve land use efficiency and improve rural income. Among these models, cultivation of various fruit trees is one of the most important options for income generation, especially in the context of limited cultivated land. Pear is one of the important temperate fruit trees and cultivation of pears has been promoted in many places, especially mountainous and hilly areas of China.

China is a major pear producer in the world. According to the Ministry of Agriculture, People's Republic of China, the cultivation area and yield of pears in China in 2001 was 1,026,400 ha and 8,796,100 tons, respectively. In Sichuan, pears are cultivated commonly and widely in low mountainous and hilly areas but are cultivated on a large scale only in a number of counties, including Hanyuan, Jinchuan, Cangxi and Jianyang counties.

Most pear varieties are self-incompatible and cross-pollination by different varieties is required. Preliminary surveys in China indicated that most of the pear trees are pollinated by hand, which has important implications to an important but often neglected issue of natural pollinators and other biodiversity conservation issues.

Hanyuan County is the biggest pear producer in Sichuan and an important one in China. Interactions with people in the main pear cultivation areas in Sichuan in 2000 revealed that pear trees in Hanyuan and Cangxi were hand pollinated. Hand pollination is very common and every pear grower can do it very perfectly. In order to understand the issues of hand pollination, natural pollinators, and impacts of agricultural transformation on biodiversity conservation and environment, effect of insecticides on natural pollinators, a case study was designed and carried out at Hanyuan County and the results are presented in this paper.

Study area

Hanyuan is a typical mountainous county in southwestern part of Sichuan Province. It is 310 kilometres away from Chengdu, the provincial capital. Administratively it belongs to Ya'an Municipality (Prefecture). It is located in the east of the northern Hengduan Mountains and in the transitional area from Sichuan Basin to Tibet Plateau and between warm temperate and monsoon subtropics. It covers a land area of 2,388 square kilometres. Topographically it is characterised by high mountains and deeply dissected river valleys. The highest altitude is 4,021 m asl and the lowest 550 m asl. Separated by the Nibashan Mountain, the climate of Hanyuan is very different from that of its northern neighbour Yingjing County. The characteristic differences between these two counties include radiation, sunshine duration, annual rainfall, seasonal rainfall pattern, temperature and vegetation. The valleys in Hanyuan County belong to typical dry valleys, which are characterised by low rainfall, high evaporation, high temperature, a six-month long dry season and poorly developed natural vegetation. The climatic background favours development of different cropping systems and cultivation of some high quality fruits, especially some speciality varieties.

Pears are one of the four most important fruits produced in Hanyuan and pear yield accounts for over 70% of the total fruits yield of the county. Other main fruits include apples (10%), cherry (2%) and citrus (1%). Pears are planted mainly in the valley areas of the Liushahe River between 900-1,200 m asl.

Climate of the county is subtropical monsoon climate. The average annual temperature is 17.9°C. Rainfall is around 726 mm, with more than 70% falling during June to September (Table 1). It is characterized by high evaporation and low rainfall. The annual evaporation is over 2 times of the annual rainfall. Altitude of the main pear cultivation areas is higher than the county town and the climate of the pear cultivation is represented by the meteorological data collected at Jiuxiang Town (Table 2). A comparison of tables 1 and 2 indicates that the mean annual temperature and annual rainfall at the pear cultivation areas are 1.2°C lower and around 100 mm less than those at the county town, respectively.

Table 1. Monthly temperature (°C), rainfall (mm) and evaporation (mm) at Hanyuan county town (Altitude 798 m asl)

	1	2	3	4	5	6	7	8	9	10	11	12	Me an
Temperat ure	8.3	10. 3	15. 0	19. 3	22. 1	23. 6	25. 9	25. 6	22. 2	18. 3	14. 1	10. 1	17. 9
Rainfall	1.1	5.4	16. 0	45. 7	72. 1	106 .8	165 .4	145 .8	102 .7	48. 4	15. 1	1.6	726 .0
Evaporati on	79. 0	90. 0	147 .8	188 .8	172 .8	142 .9	170 .2	154 .9	115 .6	82. 2	75. 2	72. 1	149 9

Table 2. Monthly temperature (°C), rainfall (mm) and evaporation (mm) at Jiuxiang (Altitude 1055 m asl)

	1	2	3	4	5	6	7	8	9	10	11	12	Me an
Temperat ure	6.6	8.8	13. 4	18. 1	20. 6	22. 8	25. 1	24. 7	21. 3	17. 3	12. 8	8.4	16. 7
Rainfall	1.7	2.5	12. 3	35. 3	54. 8	85. 2	159 .6	135 .8	91. 9	38. 8	9.6	1.6	629 .1

Evaporati on	71	78.	126	139	140	120	149	157	97.	79.	61.	65	128
		7	.5	.3	.5	.6	.0	.1	2	2	4		6

Soils are alluvial soils that can be classified as paddy soil, purple soil and red soil. Most soils in the study area are neutral to slightly alkaline. Fertility is moderate to high.

As the case for all China, cropland in the county has been declining while population is increasing. Rural population increased from 171,350 in 1949 to 319,253 and cropland decreased from 416,440 mu² in 1949 to 316,738 in 2002. The ever increasing population and decreasing cropland have led to decreased per capita cropland, from 2.43 mu or 0.162 ha in 1949 to 0.99 mu or 0.066 ha in 2002, less than the provincial average of 1.20 mu (Zou Guangyan, 1999) and the national average of 1.59 mu (MLR, 2002). Cropland, rural population and per capita cropland in different years are presented in Table 3.

Table 3. Per capita cropland (mu/ha) of rural population in different times

Year	1949	1966	1976	1985	2002
Cropland (mu)	416440	372263	358379	367544	316738
Rural population	171350	201689	276125	286995	319253
Per capita cropland	2.43/0.162	1.85/0.123	1.30/0.087	1.28/0.085	0.99/0.066

Irrigation is well developed in this area. All the paddy land is irrigated and lots of dry land below the irrigation canals are irrigated as well. The well-developed irrigation facilities have helped greatly development of agricultural and horticultural sectors.

Agriculture is the main occupation of the local people. The pear cultivation area is famous for high yield of crops, especially the irrigated paddy rice field. In the past decades, agriculture is on the transformation from cereal crops-dominated systems to economic trees and cash crops-dominated systems. Role of cereal crops in household economy is declining. Improved nutrition of the rural population has led to reduced direct consumption of cereal grains. On the average, the monthly consumption of cereal grains per person is reduced by about 60% compared to early 1980s.

Methodology

Field visits were the main method to collect various information. Interviews were also designed before the field survey and were conducted during the field survey. Two types of interviews were conducted. The majority was conducted with pear growers with consideration of different management levels. Interactions with local government officials, village leaders and local technical professionals helped to classify the pear growers into three categories, good management, medium management and poor management. This classification was also assisted through some data from local people. The other type of interviews was conducted with key informants. They were village fruit technicians, governmental agricultural officials, government officials, and marketing agents.

² 15 mu = 1 hectare

Interviews were conducted with pre-designed and structured questionnaires. Interviews of local growers were intentionally conducted with three types of growers. Assisted by the local township leaders, visits were first made to village leaders in each administrative village. The village leaders were briefed with the objectives of the case study. Meetings were held with various growers to decide who should be interviewed. In each village, growers with good, moderate and poor management of pear orchards were interviewed. Before field surveys, interviewers were trained on how to talk to farmers and how to conduct structured questionnaires. In the field, the first three interviews were conducted collectively so as to make sure each interviewer understand clearly the procedures and make them familiar with the questionnaires. In order to get reliable information, the accompanied township officers were requested not to be present during the interview. Around half interviews were made while growers were pollinating pears so that the growers would not spend much time answering questions because the interviews were carried out during the pollination season. Half interviews were conducted in house.

Interviews were also conducted with farmer technicians and with officials of the county agricultural bureau, office for agricultural development and office for soil and water conservation.

Apart from field visits and interviews, secondary data regarding socio-economic development, agricultural development and environmental conservation are also collected from various sources, mainly from governmental reports and statistical data.

Results

Climate change and its impact on agriculture

It is getting hotter and hotter in the past 20 years. Many informants mentioned that temperature is increasing. A number of indicators were mentioned by some informants. A key informant mentioned that temperature in the past dropped at around 9.00pm but now it does not so until midnight. The maximum temperature was usually around 31⁰C in the past but now sometimes it goes up to 40⁰C. The increasing temperature leads to advanced maturity of fruits. Agriculture in China is very closely associated with so-called 24 solar terms. In the past, according to local pear growers, pears ripened only after autumn beginning but the same variety ripens some 10 days before autumn beginning.

Rainfall and its patterns have changed considerably. A general trend is that annual rainfall declines and frequency of big rains has increased. Snowing becomes very rare nowadays. It snows once every 3-4 years but the snowfall is very low. In the past decade, if there was snowing, it fell with rain. Hailstones become common. In 1950s it hailed extremely rarely in the county and almost did not hail in the river valley areas below 1,100 m. According to some aged people, the first hailstone in the valley areas was in early 1970s (1974) and becomes common since then. According to Wang Ming-Tian (2001), frequency of hailstones in Hanyuan County has been increasing since 1960s. The annual hailstone days were 0.5 for 1960s, 0.85 for 1970s, 1.78 for 1980s and 2.67 for 1990-1995. Usually it hailed two to several times a year, usually in mid- or late July, occasionally during February to March, which is always a serious damage to crops and fruit trees. If it hails in February or March, most flowers and young fruits will be lost. If it hails in July fruits near maturity will lost. To reduce damage of hailstones, the government has installed four cannons. Whenever there is dense cloud and possible hailstones, the cannons will fire to remove the cloud. They fire

around 20 times a year. Wind becomes common as well. It used to be windy in spring but now also in autumn, which usually blow down fruits.

Information about impact of climate on flower blooming is confusing. Different informants have quite different feelings and expressions about this. Some informants mentioned that due to climate change, sequence of flower blooming has changed. In the past, the pears in the valley bloomed first but now many flowers at higher elevation bloomed first. An informant mentioned that in the past Yali flowers bloomed usually about 5-7 days before the flowers of Jinhuali bloomed but the gap is narrowed down recently. It seems that they bloomed almost same time. According to our field investigation, the flowers of Yali bloomed around 3-4 days before Jinhuali in 2003. But all the informants mentioned the advanced maturity of pears.

Some of the informants mentioned indicators of climate that is getting warmer. One visible indicator is the flowering dates of the polliniser in the area. In addition, we were fortunate to interview an old farmer technician who was involved in development of various fruit trees in the study area. He has kept recording of many agriculture related events. According to his records, the blooming of an orchid, bigflower cymbidium (*Cymbidium hookerianum*), is getting earlier. Compared to about 10 years ago, the flowers bloom now about 10 days earlier. Rainfall in the region is getting less. One indicator is that water level in the irrigation canal is decreasing. Some people aged 35-40 years old mentioned that a bowl of water was frozen at night during winter when they were young but nowadays cannot be frozen at night in winter. However, according to most informants, the climate change does not have important effects on production of local crops and economic trees because there is a good irrigation system in the region.

Agricultural systems in the study area

Hanyuan is a typical agricultural county. Around 80% of the population are engaged in various land based activities. A number of crops are cultivated in the county and they are divided into food crops, cash crops, vegetables, fruit trees, dry fruit trees, and economic trees. Main food crops in the county include rice, maize, wheat, and sorghum. Cash crops include garlic, oil rapeseeds, peanuts, sugarcane, tobacco, medicinal plants, peas, broad beans, and sunflowers. Vegetables include Chinese cabbages, cabbages, Chinese onions, onions, potatoes, sweet potatoes, eggplants, tomatoes, cauliflower, chilly peppers, and other beans. Fruit trees are pears, apples, citrus, cherry, peaches, plums, and apricots. Dry fruit trees include mainly walnuts and chestnuts. Economic trees include huajiao (*Zanthoxylum bungeanum*), Chinese Tung oil tree, Chinese lacquer, and bamboos. In addition, livestock is also a very important and inseparable component of the agricultural system. Apart from the above, peas cultivated on dry land after harvesting of maize in the recent years has become an important cash crop as off-season vegetables.

The study area is located in so-called dry and hot river valleys and is on two sides the Liushahe river valley. The Liushahe River is a main tributary of an important tributary of the Upper Yangtze, the Dadu River. Very different from other dry and hot river valleys in the Hengduan Mountains region, this area is well irrigated. Good irrigation canals were built and water from the Liushahe is used.

Land holding in the region is very small. The per capita cropland in Jiuxiang and Datian townships is only 0.58 mu and 0.67 mu, or 0.038 or 0.044 ha, respectively, much lower than the county average of 1.07 mu, or 0.071 ha.

As in other parts of China, raising livestock in the study area has dual purposes. One is to produce meat products and the other is to produce organic manures. The main livestock include pigs, poultry, cattle, goats and fishes. Not every household keeps cattle, goats, poultry and fishes but nearly each household keeps pigs. One important consideration to keep pigs is to make organic manure. The number of pigs per household varies from 2 to 10 in different households. Raising pigs or raising cattle is found as an important activity for some households. They keep as many as up to 100 pigs and up to 50 cattle.

Yield of rice and wheat in the study area is among the highest in Sichuan. Average yield of rice and wheat is around 12 tons/ha and 11 tons/ha, respectively.

Cultivation of pears

Hanyuan is famous in Sichuan for pears, huajiao and cherry. Among them, pears are cultivated on the largest land area. Up to 2002, the pear cultivation area is around 200,000 mu or 13,330 ha (15 mu = 1 ha). It is cultivated in 37 of the 40 townships. However, annual yield is between 12,500 and 13,500 tons in two townships (Jiuxiang and Dayan), between 3,800 and 8,400 tons in five (Liyuan, Yidong, Datian, Fuzhuang, and Lianghe), between 1,900 and 2,700 tons in four townships (Fuchun, Tangjia, Fuxiang and Xixi). Yield of these 11 townships accounts for 92.5% of the pear yield of the county. Among the pear cultivation townships, Jiuxiang and surrounding areas in the valleys the Liushahe River produce around over 80% of the total yield of the county. Of various pear varieties, around 60% yield of the Jinhuali is produced from the Jiuxiang area alone. This area includes mainly three townships, namely Jiuxiang, Datian and Fuzhuang. Altitude varies from 900 to 1,200 m asl. Analysis of biophysical conditions revealed that this area is most suitable to pear cultivation. Compared to other parts of the county, most climatic elements in this area are between those at lower and higher altitude. Monthly temperature, rainfall and evaporation at Jiuxiang are presented in Table 2. Frost-free period is 281 days. It can be seen from Tables 1 and 2 that the evaporation in river valleys is two times of the annual rainfall. Seasonal distribution of rainfall is very uneven. The rainfall during June to August accounts for 60% of the total annual rainfall. Rainfall in the period from December to February is very low and accounts for only 1%.

Pear varieties

Hanyuan was rich in pear germplasms. According to Wang et al. (1985), as many as 177 cultivars or varieties belonging to five species were reported from Hanyuan before 1982, of which 149 were local varieties, 25 introduced and 3 wild. Pear varieties were estimated to be over 249 at that time. Since then many new improved varieties are introduced but some local varieties might have also disappeared. But the situation is unclear and an investigation about changes in pear germplasm might be interesting. The main varieties under large scale cultivation include Jinhuali, Hanyuan Baili, Yali, Fengshuili and Mingyueli. Statistical data indicate that around 50% of the pear yield in the county is Jinhuali. Before Jinhuali was planted on a large scale, the local Hanyuan Baili was the dominant variety. Two hundred eighty thousand pear trees were reported in 1982 (Wang et al., 1985), of which 224,000, or 80%, were Hanyuan Baili. The present study revealed that in Jiuxiang area around 85-90% of the pears are Jinhuali. Jinhuali was introduced from Jinchuan County of west Sichuan in 1965 but the mass cultivation of this variety did not start until 1983/4. Apart from these, some new varieties are introduced in recent years, including Huangjinli, Shuijingli, New Century, etc.

Model of pear cultivation

All pear trees of the local variety, Hanyuan Baili, were planted along land risers in the hillside areas and most were planted collectively during the communal system. Cropland was allotted when the Household Responsibility System was implemented in early 1980s, which has given farmers full freedom about land management. Trained by government agricultural technicians and encouraged by potential good income from pears, many farmers planted trees of Jinhuali on land risers of the paddy rice field. Rice and wheat had been cultivated in the paddy rice field as before. But many other farmers were still watching, wondering whether planting pear trees on the land risers or land boundary of their paddy rice field would affect yield of the main crops of rice and wheat due to obvious shading. The pear trees planted in 1983/4 brought very good cash income to growers though planting of pear trees on the land risers usually caused a 5-10% reduction in rice yield. Pear price at that time was about 4-5 times of rice price. Encouraged by good income from pears cultivated on land risers of the rice field, almost all the remaining farmers started planting pear trees on land risers in early 1990s. As a result, most pears are planted on the land risers of the terraced paddy rice field, because income from the pear trees planted on the land risers is much higher than the income of crops cultivated in the paddy fields. Some six years ago, wheat was replaced by garlic. Encouraged by high income from pear trees, farmers also planted pear trees in dry land. In addition, pears and other fruit trees are also planted in paddy rice field recently.

The field survey revealed that almost all the land risers or land boundaries in Jiuxiang area are planted with pear trees. Only a very few land risers are not yet planted with pear trees. Interactions with growers indicated that these lands are cultivated under a tenure system. The owners of these lands have not cultivated land for a long time. The cultivators, however, are not willing to plant pear trees on the land risers or land boundaries because of lack of ensured tenure and benefits.

Because pears need much less labour inputs than cultivation of food crops, some farmers who have been mainly engaged in off-farm business have planted pear trees all over their land. Under pear trees, no any food crops but only vegetables are planted sometimes.

Contribution of pears to household economy and marketing of pears

In the study area, pears and garlic are the two major sources of household income. According to the field survey, on the average, each household sell 5,000 kg of pears a year and the income for selling pears accounts for 50-80% of the household income. The pear price, however, has been declining in recent years. For 2001 and 2002, the unbagged pears were sold at around 0.8-1.0 yuan per kilogram and the bagged pears at 2.5-3.0 yuan per kilogram. The highest price was as high as 8 yuan per kilogram about 10 years ago.

Due to high yield, the pears consumed by household accounts for a very low percentage. Apart from unmarketable fruits, the amount of pears kept for household consumption ranged from 50 to 200 kilograms only. Farmers do not use any special method to store pears. Pears are simply piled in a corner of rooms or put in boxes.

Marketing of the pears is easy. Since this area has been well known in China for pears and garlic shoots, all the trade agents come to this area. There is a whole sale market for agricultural products in Jiuxiang Town. The price of agricultural products at this market is broadcasted daily on the agricultural channel of the China Central TV (CCTV-7). Growers

need only to pick pears and put in boxes according to different grades. Trucks are brought to as close to growers' household as possible. On the average, pears are carried out only about 500 metre to load on trucks.

Pears are sold throughout China but many to Yunnan. Pears were also sold to Southeast Asia, especially Thailand, Laos, Myanmar and Vietnam several years ago but are not so much recently.

Hand pollination of pears

Most pear varieties are self-incompatible and need cross pollination to set fruit. Natural pollination is usually done through insects and wind. However, the results of the field survey revealed that all the pears of 200,000 mu in Hanyuan County are pollinated by hand.

Origin of hand pollination in the county

Hanyuan is a main pear producing county in Sichuan and famous for production of pears. It is the number one in Sichuan in terms of cultivation area and yield of pears. Results of interaction with various agricultural technicians and aged farmers in the study area indicated clearly that not all the pears in the study area were pollinated by hand before mid-1980s. According to all the informants they knew that pear trees needed pollination by hand when they planted Jinhuali trees. Extensive pollination by hand started only from mid-1980s when the large-scale pear cultivation started.

It was known some 50 years ago in China that most pear varieties are self-incompatible and need cross-pollination. During the communal system, many people were not concerned about yield of pears though many pear trees bore few fruits.

According to agricultural officers of that time and the Hanyuan County Annals (1994, p721), flowering of many pear trees was normal but fruiting was not satisfactory. This situation was described as “pears having flowers but without fruits”. To solve this problem, professionals from the Fruit Tree Station and Fruit Company of the Hanyuan County tried introduction of two pear varieties from Hebei Province of Northern China. In 1977 they introduced 30,000 cions of Yali and 10,000 cions of Xuehuali. The introduced cions of two varieties were grafted on mature trees of the local Hanyuan Baili variety. It was found that the flowering time of the introduced pear varieties was nearly the same as that of the local Hanyuan Baili. All the grafted trees had satisfactory fruit setting and yield, indicating these two introduced varieties were compatible with the local Hanyuan Baili variety.

Encouraged by this, the professionals from the County Fruits Station tried grafting Yali on Jinhuali but it was found that the flowering time of the two introduced varieties was earlier than that of Jinhuali and that most pear trees did not have satisfactory fruiting and yield. Later, hand pollination was tried in earlier 1980s, which resulted in very satisfactory fruit setting and yield. Encouraged by this success, hand pollination was recommended to local communes through various training courses and commune meetings. When land was allotted to individual households, some local people tried hand pollination on pear trees but some did not, which led to very different fruiting rates. The different results helped local pear growers to understand necessity of hand pollination of Jinhuali, which had encouraged all the local farmers to adopt hand pollination. Interviews indicated clearly that almost all the pear growers knew that pears had to be pollinated by hand if satisfactory yield was expected. When most pear trees started bearing fruits in late 1980s and 1990s, all the growers had been

fully convinced by benefits of hand pollination. Many pear growers got to know that pears need hand pollination from their relatives or neighbours or by seeing hand pollination by some growers. Many farmers were told about this when they planted pears. However, it took about three years for many local farmers to learn how to pollinate pears by hand. In the first two years, many hand pollination did not result in good fruiting, mainly because many farmers did not really know how to prepare pollen for pollination and how and when to pollinate pears. They did not know either which flowers should be pollinated on the same tree. Through watching and asking experienced growers, most local farmers know how to pollinate flowers and how to stigmas in what flowers are receptive.

Results of the investigation indicated very clearly that 100% of the pears cultivated in the county are pollinated by hand. All the informants, including many informal interviewees, said pear trees would not bear fruits if no hand pollination was applied. Therefore, all the pear trees in the region are pollinated by hand.

Pollinisers

Though several varieties of pears can be used as pollinisers, flowering dates limit pollinisers to only 2 or 3 varieties in the region. An appropriate polliniser should produce large amount of flowers and pollen and its flowers should bloom at least two days before the blooming of the main variety because it takes at least one and half days to prepare pollen for pollination. Field survey indicated that in the study area almost 100% pollinisers are Yali variety, because its flowers bloom around 1 week prior to blooming of flowers of the main variety, Jinhuali. Another important reason to use Yali as the main polliniser is that Yali produces large amount of flowers and pollen. As it was mentioned earlier, two varieties, Yali and Xueli were proved good pollinisers. In the first several years of fast spread of hand pollination, many local people did not understand clearly that pollinisers should be different varieties. Some people pollinated flowers with pollen from the same variety or even the same tree. When it was widely known that Yali is the best polliniser, the number of pollinisers was not sufficient. Flowers of pollinisers were sold costly. Growers planted polliniser trees in pear orchards or in home garden or grafted pollinisers on Jinhuali. In addition, local Hanyuan Baili can also be used as polliniser to pollinate Jinhuali. Pollinated by this local variety, the Jinhuali can produce better-shaped and skinned fruit. The problem is that the flowers of Hanyuan Baili blooms usually about one week later than or same time with flowers of Jinhuali.

The pollinisers are usually planted within the orchards or in home garden. Occasionally they are planted separately on roadside. Many people planted the polliniser trees in home garden so that flowers will not be stolen and that it is convenient and time saving to collect flowers and to prepare pollen. In addition, it is also common that pollinisers are grafted on the main variety. Usually a polliniser tree of the same age as a main variety can produce flowers sufficient to pollinate 30-50 main variety trees. Survey results indicate that the average number of pear trees owned by each household is 80-100. To pollinate these trees, 3-5 polliniser trees are sufficient because a polliniser tree of around 8-10 years old can produce flowers to pollinate around 45-55 trees. Apart from individual trees of Yali, around 1-3% of Jinhuali trees have one branch grafted with Yali. Because polliniser trees are not evenly distributed among orchards and are not owned evenly among growers, during the pollination season, some growers sold also excessive polliniser flowers. Price varies according to timing of pollination and climate. In 2003 the price of polliniser flowers varied from 14-40 RMB³

³ 8.28 RMB yuan=US\$1

yuan (or US\$1.7-5) per kilogram. It is also common that relatives or neighbours get polliniser flowers free of charge. It was also reported that flowers of polliniser (Cangxi Xueli) trees in Cangxi County, another major pear cultivation county of Sichuan, were sold to Japan during March 2003. But flowers were sold at an extremely low price of 5 yuan per kilogram. A company purchased around 20,000 kg of fresh flowers in the spring of 2003.

Unlike Jinhuali, the polliniser variety, Yali, does not need cross-pollination. Field survey and interview indicated that around 80% of flowers of pollinisers were picked up. Without hand pollination, yield of polliniser trees is satisfactory. However, because market for Yali is not as good as Jinhuali and local variety Hanyuan Baili, many growers have recently grafted Jinhuali on the polliniser branches that were grafted on the main varieties earlier.

Except for one informant, all the other informants mentioned unanimously that pollination by the selected polliniser Yali can result in fruits of good economic traits, including shape, weight, skin, taste, and fruiting. Pollinated by other varieties did not produce satisfactory results.

Collection of flowers and preparation of stamens and pollen

Flowers of polliniser trees are collected in order to prepare pollen to pollinate flowers of the main variety. Time of flower collection is very important. Based on experiences of many informants, the best time is when the flowers are bell-shaped. Prior to this time, pollen is not fully mature. After this time, some anthers are open and some pollen spilled out. However, in practice, many fully bloomed and half-bloomed flowers are collected because flowers of a tree and different flowers of an inflorescence do not bloom simultaneously. In addition, weather also affect flowering duration of polliniser trees. When it is clear and hot, most flowers bloom within two to three days and have to be collected before pollen shed.

After flowers are collected, only stamens were brushed down by various methods. The most common one is to brush stamens down by toothbrush. Other methods include brushing two flowers each other. The remaining parts of flowers are not used. It is the whole stamens, including anthers and filaments, that are collected and processed for pollen preparation.

Drying of stamens and pollen

Immediately after stamens are collected, they are dried with a number of methods. The most common one in the region is to dry stamens in a cardboard box that are easily got from local shops or the cardboard box that farmers use for marketing pears. Stamens are spread evenly on a piece of white paper on a table. Usually the backside of a calendar is used. The white paper is covered by a cardboard box which is open on top and on bottom. The top, however, should be covered. A bulb of 25-60 W is used to dry the stamens and it usually takes 24 hours. Because it is usually quite cold at night, the top of the box is covered with clothes to keep warm. Very important for this method is that temperature should be maintained within 20-25⁰C. The temperature should be checked from time to time during the course of drying. Temperature should not be over 25⁰C, otherwise pollen will lose vitality. Stamens dried by such way will give best results of pollination. This method is used by some 80% of pear growers. If stamens are dried with temperature ranging from 25 to 30⁰C, pollination results will be very poor because it is believed vitality of pollen has lost due to high temperature.

The second method is putting stamens in a plastic bag and then the bag is put in pockets to use human body's constant temperature to dry stamens. The third method is to use electrical blanket. A piece of white paper is laid on electrical blanket. Stamens are spread on the white paper and covered first with a piece of paper, then with clothes or a blanket. The electrical blanket is put on at the low grade for 24-36 hours. The fourth one is to spread stamens on a piece of white paper on ground for 48 hours. In addition, some growers also used pot on fire to dry stamens in earlier days but this method gave very poor results. Few people use this method nowadays.

Drying stamens is the key step for a successful pollination. To get viable pollen, temperature is crucial. In the study area, unstable electricity voltage sometimes caused problems and burnt stamens that are dried with the first method mentioned above.

The prepared pollen is actually a mixture of pollen, filaments, anther wall, etc. Colour of the prepared pollen is usually brown or rarely yellow.

Pollination of pears

Different varieties need different methods of pollination and some newly introduced varieties do not need cross-pollination. The local variety Baili does not need pollination flower by flower. But each flower of Jinhuali, the main variety in the study area, needs pollination. Various methods can be used to pollinate pear flowers.

First method: the first method is used by most growers in the region. Usually after 24 hours of drying, stamens are dried and pollen shed from anthers. Mixture of pollen, anther wall and filaments is put in a small bottle. Each person will need a small bottle (pollen bottle). Apart from the pollen bottle, a tool is used to pollinate flowers. The tool is called pollination stick and is very simple. It consists of a thin stick, usually a small bamboo stick, and a "pollination brush" on the stick tip. The pollination brush on the stick tip varies in size and is made of different materials. Usually, cigarette filter and chicken feather are used to make the pollination brushes. Each person usually has two sticks, a shorter and a longer pollination sticks, in order to pollinate flowers at different positions.

Growers know clearly when to pollinate flowers. The time of pollination is important. Only when the stigma is receptive does the pollination work. Based on the experiences of the local people, a useful indicator to determine the receptivity of a stigma is colour of anthers of the main variety. After flower open, all anthers are pink and deeply brown. When the colour of the outermost whorl of anthers changes to brown, the stigma is receptive and can be pollinated. When all the anthers of a flower are red, the stigma is not yet receptive and pollination will not work even if pollination is conducted. Interestingly, changes in anther colour and receptivity of stigmas are closely linked with the degree of petals' openness. Associated with colour change in anthers and stigmas becoming receptive, the petals are widely open. Therefore, local people know from backside of a flower whether or not it should be pollinated. When the petals of a flower is not widely open, it means that the flower should not be pollinated. If petals of a flower are reflexed or fallen, it means that the flower does not need pollination any more.

A person hangs a pollen bottle and uses usually two pollination sticks to pollinate pear flowers. The pollination brush touching pollen from the pollen bottle once can be used to pollinate around 20-30 flowers. However, the smaller the brush, the fewer flowers are pollinated. According to most informants, a big pollination brush made of chicken features

can pollinate at least 50 inflorescences with one touch. Growers pollinate each pear flower. Flowers of pears are borne on an indeterminate inflorescence. The flowers of outermost whorl bloom first. The time gap between the first bloomed flowers and the last bloomed flowers varies with weather. Therefore, weather will determine how many times and how many days will be needed to complete pollination of a tree. When it is sunny, clear and hot, most flowers bloom within one to three days. Pollination has to be completed within this one to three days. In such cases, a pear tree needs pollination of two times. When it is cloudy and temperature is low, flower blooming of a tree can last for a week to 10 days. Every day there are some flowers blooming. Pollination has to be conducted up to 5-6 times in order to pollinate each flower.

Most pollination is carried out from 11:00am to 4:00pm. Pollination should be pended when it rains. It resumes only when flowers become dry but one couple mentioned they could pollinate their pears shortly after rain when flowers are not dry. Most pear trees are managed around 3-4 m tall. For those trees not very tall, pollination can be completed with the longer pollination stick. Various tools are used to reach flowers in the upper part of a tree. Stools and ladders are commonly used. Climbing trees is also very common in order to pollinate flowers of the upper part of a tree. Often wife and husband were seen pollinating trees in collaboration. Wife pollinated the lower parts of the trees while husband the upper parts of the trees.

Pollination can be carried out by women or men, the young or the old. However, it was mentioned that women could do this better than men. In the study area, children are very rarely seen pollinating trees. Interactions with farmers reveal that children are too busy with their school work to help pollinate pear trees. Almost all the children in the study area go to school.

Relative position of flower stigma and stamens is associated with selection of pollination. All the informants mentioned that it is due to the relative position of stigmas and anthers that Jinhuali needs cross-pollination. The styles of Jinhuali are longer than stamens and stigmas exceed anthers by about 3-5 mm. As a result, pollen from the same flowers cannot physically reach stigmas. Therefore, cross-pollination is needed to ensure fruit setting. On the contrary, the length of styles of Yali is similar to stamens and the stigmas and anthers are roughly at the same height. Pollen can be easily transported to stigmas. As a result, cross-pollination is not needed for Yali. Experiences with these two examples, however, might not be viable to apply to all the other varieties. For example, the flower structure and the relative position of the local Hanyuan Baili is very similar to those of Jinhuali but this variety does not need hand pollination flower by flower. Compatibility might not be always associated with the relative position of stigmas and anthers. Further studies are needed to clarify this.

Second method: Mixing pollen mixture with 2-4 times of French chalk (volume), use household sieves for 3-4 times to thoroughly mix pollen and French chalk. The well-mixed pollen mixture is put in two-layered gauze. The gauze is tied on a bamboo stick. Pollination is carried out through shaking the stick. But this method has not yet been widely used in the region because it use much more pollen; pollination is not 100% ensured and shaking trees will also lead to fall of flowers.

Third method: Collect polliniser branches with blooming flowers and put them into a bottle with water. The bottles are hanged on the target pear trees at different positions and directions. Pollination is carried out through wind. In order to use the polliniser flowers

efficiently, the polliniser branches are tied on a bamboo stick before putting into bottles. The polliniser branches on the bamboo sticks are shaken over pear crown to pollinate flowers.

Fourth method: Duster made of chicken feathers is common for household use. Some growers also use this to pollinate pears. The dusters are degreased with alcohol before tying on sticks. The dusters touch pollen mixture and then are shaken over the target pear trees for 1-3 times a day in order to ensure adequate pollination of pears.

Labour inputs in hand pollination

According to most informants usually a person can pollinate 30-40 trees a day. Some informants mentioned also that a person could pollinate only about 10-14 trees. It was found later that these households have fewer pear trees. Therefore, local growers usually do not hire labours from other areas to help. But when it is sunny and temperate is high, most flowers bloom within two to three days and wither very shortly. Then labours must be hired to help pollinate flowers. Usually hired labours are paid around 15-20 yuan a day in addition to two to three meals and cigarettes. But when it is very hot and pear flowers must be pollinated within one to two days, it costs over 30 yuan to hire a labour. Labours are usually hired from areas at higher altitude where pears are also planted because they know very clearly how to carry out hand pollination and flowers of the pear trees at high altitude bloom at different time. Untrained labours are very rarely hired. Some do not pay labour but exchange labour. Among labours, women are preferred because women do this better. Weather determines the total labour inputs. If weather is not favourable, more labour inputs are needed though no labours are hired because trees are pollinated over 3 times.

Based on the field surveys, each tree is pollinated 2-5 times. According to farmers, they also spend lots of time to thin out young fruit, indicating a problem of over pollination. We asked that if they reduced the pollination to one or two times they might not need to spend time to thin out fruit. Interestingly, most informants mentioned that one-time pollination could not ensure successful fruit setting. Therefore, all the growers always over pollinate flowers then spend time on thinning fruit, which ensure themselves sufficient fruit setting.

Beekeeping and honeybees

Beekeeping was common in the past in the county. According to the available data, number of honeybee colonies was increasing from 1,513 in 1949 to 3,739 colonies in 1985. During that time, all the honeybees were Chinese honeybees (*Apis cerana cerana*). At present there are only several beekeepers who keep either the western honeybee (*Apis mellifera*) or the Chinese honeybees. These beekeepers, however, do not place their bees in the pear cultivation areas. But most people mentioned that honeybees have not been seen since mid-1980s, which was in accordance with the large-scale cultivation of pears.

It was mentioned that a probable reason was that a large explosive of pear lice some years ago leading to over spray of insecticides, which might have killed most insects. Since then, pears have been sprayed often 12 times before harvesting of pears.

As mentioned already, the surveyed area has been well known in Sichuan for pears. Prior to adoption of “household responsibility system” in the early 1980s, no any hand pollination had been employed on the local pear variety. The reasons mentioned included two. The first one was that pear flowers were pollinated by insects, mainly honeybees. During that period, keeping one to three colonies of honeybees was common for some households. In addition, other wild pollinators were considered common in the region. Use of agricultural chemicals,

including chemical fertilisers, pesticides, insecticides and fungicides was very rare. The second reason was that few people were concerned about the yield of pears with a commune system.

Due to very concentrated and a large-scale cultivation of pears, there have been intensive sprays of many kinds of pesticides and insecticides. During the field survey, not any insects were seen on flowers of pears and other crops that are blooming simultaneously with pears. Informants also mentioned that beekeepers from the region relocated their honeybees out of this region when pear flowers start blooming. Apart from the local beekeepers, migratory beekeepers from other regions move to the valley areas in November and leave this region in late February when they see some pear flowers start to bloom. All the informants mentioned that it was pesticides/insecticides that have killed most insects if there were any insects and that have driven the honeybees out of the pear cultivation area. Use of insecticides is regarded as the sole reason for no insects pollinating pear flowers and for no beekeeping in the region.

However, in the pocket areas where there is no concentrated fruit tree cultivation, honeybees were seen pollinating fruit trees, especially cherry trees. In Qingxi Township at an altitude of 1,800 m asl, about 800 m higher than the pear cultivation area, cherry trees are the common fruit trees. All the informants mentioned that no hand pollination is needed for cherry trees because honeybees pollinate flowers. We also saw many Chinese honeybees pollinating cherry trees. Some households in the township keep honeybees in traditional way. Some migratory beekeepers were also seen in the region. In the pear cultivation area, local cherry variety is common and bears fruit successfully without hand pollination. The successful fruiting of local cherry might be owing to honeybees because cherry flowers bloom about 10-15 days prior to pear flowers and there are honeybees during that time. But a key informant mentioned that an introduced cherry variety that he planted did not set fruits in the pear cultivation area and he did not see any honeybees on the trees. He saw, however, honeybees pollinating the same variety in other places where sprays of pesticides or insecticides are not applied. According to informants, no sprays of pesticides or insecticides are applied to cherry trees. The above indicated that spray of insecticides/pesticides is the root cause for expelling of insects from the region.

When we asked why there were no honeybees or other insects pollinating pears, all the informants replied that it was because of spray of insecticides/pesticides. No beekeepers are willing to place their honeybees in the orchards even if they are paid for pollination. The survey results indicate that there were some beekeepers in the past but most of them stopped keeping bees. The remaining several beekeepers moved their bees up to mountains.

Dependence of pear cultivation on hand pollination

Though hand pollination of pears is reported labour consuming and boring, local growers have no choices. All of them mentioned that there would no pears or maximum 5-10% of pears if pear trees were not pollinated by hand. Not only yield is low, but economic traits are also not satisfactory either, especially shape of pears is not as good as that of pears pollinated by hand. The local pear cultivation, therefore, is 100% dependent on hand pollination.

Increasing requirements for alternatives

All the interviewees expressed strongly their requirements for alternatives that can replace or reduce dependence on hand pollination. However, none of them mentioned use of honeybees but asked for new tools or new facilities. Some tools or machines were tried in the region but results were not satisfactory. No adoption is seen. All of them said some kinds of sprayers

could be developed. Literature review indicated that various methods including modified sprayers have been developed to replace hand pollination but the results seem unsatisfactory because no such a method was used in the region.

Because many pear trees are tall and many people have to climb trees to pollination, some events have also happened, which led to injury of people and even loss of life. It was reported that in the past 15 years around 100 persons in the county were injured due to falling from trees, which also forces people to look for alternatives. Since practical alternatives to replace hand pollination seem not be available in the near future, planting of pear varieties that do not need cross-pollination is increasing in the study area.

Continuing agricultural transformation

Although the surveyed area has been well known in Sichuan for production of pears, most pears had been grown in hill side and very few on rice field before the rural reform. Encouraged by higher income, many farmers planted pear trees on land risers or land boundaries of paddy rice field at a distance of around 3-5 meters in 1984/5. These trees entered high yielding period in the early 1990s and brought high and visible income to growers, which stimulated second movement of pear tree planting in 1993/4. The field survey indicated that around 70% of the pear trees in the region were planted in 1993/4. In this area, only a few rice fields are not planted with pear trees. Interviewing local people indicated that these lands were managed by tenure system. The land “owners” were mainly engaged in off-farm activities. The growers were not willing to planted perennial pear trees on the land risers due to unsecured benefits.

Though this is a very productive area, rice cultivation area is decreasing. On the average, rice yield is around 800 kg/mu with common management practices. The yield, however, valued maximum 400 RMB yuan. Improved living standard needs less consumption of rice. On the contrary, income from cultivation of pear trees and other fruit trees is usually much higher than rice. As a result, many farmers have stopped rice cultivation but planted trees in rice fields. This region would become pure fruit producing area in the future if this trend continues. Transformation from mixed fruit trees and food crops to purely fruit trees would cause many environment and biodiversity conservation problems. A regular monitoring of this transformation might be of interest to many people.

Role of local government institutions

Local government played a key role in solving problems of unsatisfactory fruit setting with introduction of hand pollination and spreading of hand pollination in the pear cultivation area. Some government institutions have also played an important role in control of pests and insects on pear trees. Organisation of training courses for many selected farmers was the main method to spread hand pollination. However, visits of technical personnels to households have been reduced considerably in the past decade. Lack of funds has been regarded as a main reason that restrains agricultural technicians from going to field. The great demands of the local farmers are mainly two, namely new technologies that can help improve productivity and reduce pests and insects, and new varieties. Interviews indicated that many farmers received information about new varieties from the agricultural TV channel CCTV-7 and from private fruit agencies. The role of government in production of fruits in the region, similar throughout China, is declining. The role of market, on the contrary, is increasing rapidly.

Management of pear orchards

Management of pear orchards is essential in order to have a satisfactory harvest. It seems also to be true that management is very closely associated with adoption of hand pollination and disappearance of honeybees and other insects from the pear cultivation areas. The management of pear orchards in the study area includes mainly fertilising, pollination, sprays of pesticides/ insecticides, bagging of fruits, and pruning.

Fertilising

In order to have satisfactory yield, pear trees need to be sufficiently fertilised. It is known by many growers that the pear trees that are not received sufficient fertilisers will bear much fewer flowers. Usually, fertilisers are applied three times though two times or four times are also reported. The first time of fertiliser application is before blooming of flowers. The second time is when young fruit start expanding and the third time is after pear harvest. Farmyard manure (FYM) is the most important fertiliser and usually around 150 kilogram of FYM is applied to a tree each time. Some other fertilisers, such as N, P or K, are also often mixed with FYM each time. Since it was reported that soils in the region is poor in iron and symptoms of Fe insufficiency are also observed, FeSO_4 is also applied. Apart from this, some growers put iron nails into tree trunks, adding some vinegar into a hole with iron nails.

Spray of pesticides/insecticides

Pear trees in the region are often infested with pests or insects. The most serious ones include pear lice, plant louse, and red spider. Control of pests and insects has been carried out with mainly use of chemical insecticides and pesticides. A study in the region indicates that insecticides and fungicides account for 70% and 25% of the total sprays, respectively (Lu Xiu-Lan et al. 2001). Spray of pesticides/insecticides has become one of the most important management measures in pear production. Most informants mentioned there would not be good harvest if pear trees were not sprayed with pesticides/insecticides. In total, around 8-12 times sprays are employed during the course of pear production. The first time is conducted during winter. Each pear tree is sprayed with the mixture of lime and sulphur (1 part lime with 2 parts sulphur). The second spray is conducted prior to blooming of flowers. After pollination is completed and when all flowers wither and petals fall, pear trees are sprayed once each week to 10 days. The kinds of pesticides/ insecticides are recommended by the sale agents. But usually around 5-10 different kinds of pesticides/insecticides are used during the course of pear production. Some key informants mentioned that most of the pesticides are not necessary and they sprayed only 4-5 times. Interviews indicated that many growers do not know exactly when to spray and what to spray. Whenever they see insects of pests on pears they spray pesticides of insecticides so that they feel the risk of failure is reduced.

Thinning out of fruit

A common problem with hand pollination is that pear trees are always over-pollinated, resulting in over fruit setting. As a result, heavy thinning of fruit is essential to obtain good fruit size, to ensure annual cropping, and to avoid limb breakage. Results of interviews and surveys indicated that around 50-70% of the young pears are thinned out. All thinning is done by hand. Thinning out should be completed shortly after the fruit setting in order to give more nutrients for development of the remaining fruits but it can continue up to around one month before harvest.

Bagging of fruits

Fruit bagging is becoming common because bagged pears can be sold at higher price, usually double or even higher price than unbagged fruits. Compared with hand pollination, bagging can be done during a longer duration.

Harvest and maturity of fruit

Harvest season is generally late July through August. The best season is shortly after Chinese cropping season of beginning of autumn. Most growers determine harvest date by fruit colour and taste but more commonly by price in recent years.

Training and pruning of pear trees

Training is essential for pear trees to develop needed shapes. This is generally accomplished by heading the main limbs, leaving around 3 secondary limbs at the first branching and 4 limbs at the second branching. Annual pruning is important to keep pear trees productive. They are pruned in each winter. Pruning helps growth of branches. Field survey also found some trees that are not properly trained and pruned grew very tall and fruited poorly.

Discussion and suggestions

The rural reform in China has brought about great changes that produce sufficient food to feed increasing population. Application of improved technologies and improved crop varieties has improved greatly crop yield. As a result, food is no more a problem in China. However, sufficient food supply does not automatically mean improvement in livelihood. Demand for better life is increasing. China is making efforts to improve living standards of rural population and improving farmers' income is a great challenge. Planting of economic trees has been taken as an important option to improve farmers' income. However, a large-scale cultivation of similar economic trees in many parts of China would have also risks (TangYa, 2002). In addition, transformation from one system to another will also have many other impacts, which need to be considered carefully.

A transformation from nearly pure food crop based system to pear based agroforestry system completed about ten years ago and a transformation from pear based agroforestry system to pure fruit orchards in the pear cultivation areas in Hanyuan County of Sichuan Province is undergoing. Analysis indicates that seeking for maximal economic benefits is the driving force for these transformations. These transformations have had important impact on local environment and biodiversity conservation.

Advantages of hand pollination

A quick literature review indicates that hand pollination is applied extensively in the apple and pear cultivation areas in China. In addition, hand pollination is also used in ginkgo, kiwi fruit, etc. Apart from pears in the study area, hand pollination is also applied to other fruit trees, including peaches and plums. This situation has implied that hand pollination should have various advantages. According to analysis of field investigation results and interviews with local pear growers and technicians, the following advantages are listed.

- No need for cultivation of many pollinisers, giving more land for cultivation of the target pear varieties. For effective pollination, pollinisers should be planted evenly in pear orchards and account for around 20% of pear trees. Due to very limited land resources and available labours, pollinisers account for only 2-5% of pear trees and flowers of pollinisers are efficiently used. Fewer pollinisers will provide more space

for cultivation of the target variety. This is important for efficient use of land resources because the land holding is extremely small in the region.

- Ensured fruit setting. Hand pollination pollinates nearly every flower that ensures satisfactory fruit setting.
- Ensured pollination by managed/needed pollinisers.
- Solving the problem of temporal blooming gaps between pollinisers and target variety.
- Good marketing traits of the pears. Hand pollinated pears are larger and more uniformly shaped than fruit open pollinated because the latter have few seeds due to inadequate pollination.

Disadvantages of hand pollination

Despite all the above-listed advantages, hand pollination has also the following disadvantages:

- Labour intensive
- Often over-pollinated pears, which leading to increased fruiting and increased labour for thinning of fruit.
- Consecutive pollination of target pears by the same variety of pollinisers, leading to possible problems of biodiversity loss. This also reduces possibility of cross-pollination by other varieties.

Adoption of hand pollination

Most pear varieties are self-incompatible and only some varieties are self-compatible. The self-compatible varieties do not need cross pollination, such as Yali. But the self-incompatible variety, such as Jinhuali must be cross-pollinated. This relates to two issues. The first one is whether the variety is self-compatible and the second is whether a variety can be self-pollinated if it is self-compatible. For Yali, the stigmas are not higher than stamens. But for Jinhuali, the stigmas are higher than stamens. Pollen must be transferred to stigmas with help of external pollen transferring vectors.

Before adoption of hand pollination, fruit setting of pear trees was not ascertained, from very good to poor fruit setting. Convinced by higher and constant pear yield, all the pear growers have adopted hand pollination thought it took 3-4 years for local pear growers to adopt it. Owing to hand pollination, yield of pears has remained constant.

A very important reason to adopt hand pollination is because there are no insect pollinators. Intensive use of unselected pesticides and insecticides is the key factor for disappearance of insects in the pear cultivation areas. Field surveys and interviews of local people revealed that as many as 8-12 times pesticide/insecticide sprays are applied, many of which might be not necessary. There have been no studies about how many times are necessary. Some key informants mentioned that around 4-5 times are sufficient.

Beekeeping and hand pollination

Though pears are pollinated by hand in many parts of China, honeybees are hired to pollinate pears in Xinjiang and it seems that more and more people realise the importance of using honeybees to pollinate pears. Use of honeybees to pollinate pears and other fruit trees is recommended very often. It is recommended that a colony be placed in an area of 10 mu. But using honeybees to pollinate pears has been very rarely adopted, which is related mainly to

two things. One is the unwillingness of beekeepers due to spray of insecticides and the other is that few local farmers have tried this method.

Field survey and interviews with local people have revealed that there are nearly not any insects seeing on pear trees. Wild bees are also not seen in the region. The cause was thought by all the informants to be the use of insecticides because as high as 70% of the pesticides used in the region is insecticides. It was mentioned by all the informants that honeybees have not been seen in the past 12 years ago.

Tired of hand pollination, some growers have been trying different alternatives, of which hiring honeybees is one. Many growers have realised the role of honeybees in pollination but few of them think it to be possible due to excessive application of pesticides. Despite this, some local growers have contacted beekeepers to pay for pear pollination but beekeepers do not agree. The main reasons given are two. The first one is that sprays of pesticides/insecticides are not coordinated and some growers' sprays will definitely kill bees. Secondly, most pears do not secrete nectar. Bees cannot collect honey but pollen. Beekeepers must feed bees with sugar. What they are paid is not as much as they lose from honey.

With economic development in the region, labours will definitely become more costly. The present situation might continue for some time but some alternatives must be applied to replace hand pollination in the future. Use of honeybees might be most probable. Since each household is an individual production unit, a mechanism is lacking to coordinate control of pests and insects. Most of growers mentioned a strong need for such a mechanism. They have experienced problems of uncoordinated control of pests and insects. In the course of control of pear louses, it was required that all the growers should spray at the same time. But a few growers did not do so. Their pear trees became refuges for the pear louses. It was thought that the spray before flower blooming was not necessary at all. If this is acceptable to all the growers, placement of honeybees might be possible. Some experiments would be of great interest.

Need for new varieties

Almost all the informants mentioned that hand pollination is the most difficult and labour intensive among the needed tasks, including fertilising, pruning, bagging, spraying, hand pollination and fruit harvesting. Among these tasks, hand pollination is the only one that had time limitation. The year 2003 was mentioned as an abnormal year in terms of weather because it was not always sunny. Usually it was sunny and clear during the flowering period. In normal weather condition, flowers of pears have to be pollinated within two days.

Apart from this, pollination is also very much mind-concentrated, which always leads to easy fatigue. Eyes are also very easy to be tired due to concentration. As a result, many local growers are planting fruit trees and other pear varieties that do not need hand pollination.

Gaps for improvements

Needs for improvement in communication and sharing among growers

It was found, and many growers also mentioned, that a few local growers managed their orchards very well, much better than others. Interviewing some of them indicated that they did not use some pesticides commonly used in the region and the frequencies of pesticides spray were fewer than other growers. The yield of pears was higher than that of the others. But many of them are not willing to share their knowledge with others. A few growers have

spent much time in understanding life history of the most common pests and insects, which help considerably improve efficiency of pesticides and insecticides. A key informant also mentioned that he is using physical instead of sprays of insecticides to control pear louses with satisfactory results. This is knowledge property and need to be protected. How to improve this is an important issue in the region.

Optimisation of hand pollination

One very interesting results of the field investigation is the over pollination, which is not only more labour consuming but also leading to over fruit setting, which again needs more labour for thinning out of fruits. It was suggested that instead of 2-5 times pollination but one time pollination should be sufficient. But few farmers were brave enough to have this test. They are willing to over pollinate flowers because they know such over pollination will definitely result in good fruit setting. The degree of fruit thinning about 50-70% clearly explained that one time pollination should be sufficient. It would be very useful to carry out such a study about this, namely to find out what is the best pollination rate.

Use of pesticides

There is an increasing trend of not using some poisonous but to use low residual and less poisonous pesticides. Production of many highly poisonous pesticides has stopped. Growers have known that use of pesticides will affect the marketing traits of the products. They have strong requirement for new but effective pesticides. It is fortunate that most of the pesticides and insecticides are controlled by a semi-government agency, the Company of Agricultural Services and Materials. Around 80% of the locally sold pesticides and insecticides are controlled by this company.

Great need for integrated pest management

Food safety has become an important issue in China. More and more people have realised that intensive use of pesticides is harmful to people. Government of China has issued various regulations to limit use of pesticides. Production of so-called “green food” has received great attention and support. Demand for safe food is increasing. To produce safe food, use of pesticides must decrease to as least as possible. Integrated pest management should be a good option to achieve this. In the study area, the local growers also realised that pest-free fruits are sold at higher price because government has set up facilities to examine residual contents of pesticides.

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