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Review article

Research and implementation of good agricultural practice for traditional Chinese medicinal materials in Jilin Province, China

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ABSTRACT

Jilin Province is one of the principal production bases of traditional Chinese medicine (TCM) in China with its typical preponderance in TCM resources, research and development power, and industrialization capacity. The province has 2,790 species of TCM materials in total. Over 20% of the TCM materials in common use are from Jilin Province. The province has established 36 good agricultural practice bases for 22 typical TCMs. The overall situation, in terms of collection, processing, and preparation, and the implementation of good agricultural practice of TCM materials in Jilin Province are summarized.

1. Introduction

To strengthen the quality control of medicinal materials, the World Health Organization developed its guidelines for good agricultural and collection practices for medicinal plants in 2003, in which the quality standard of "quality, safety, and efficiency" was established [1]. In 1996, China worked out its plan for developing the modernization of traditional Chinese medicine (TCM) production based on standardization, internationalization, and technique updating with the policy of succession, innovation, and leap forward development [2]. Modernization of TCM production is an integrated development realized in the combination of the TCM knowledge with modern high technology. The key connotation of the modernization is assured efficiency, safety, and quality [3–5].

The patent Chinese medicine production takes the processing of medicinal materials as the first step in which material quality must be guaranteed. To standardize the production of TCM material, its quality is to be guaranteed, and facilitate the standardization of TCMs and realize "safe, efficient, stable and controllable" quality standards, China developed its guidelines of Good Agricultural Practice (GAP) for TCM materials in 2002 and put it into force on June 1st of the same year [6].

2. General background for GAP implementation of TCM in Jilin Province

In China, there was an urgent need to deal with the overexploitation of medicinal herbs. Due to the overexploitation, the reserves and output of wild medicinal plants were rapidly decreasing. According to world statistics, China received only a sales value of US$600 million, only 3% in the international market. The loss in herbal products sales value has been attributed to the improper efforts given on quality control and standardization. In China, there are no uniform standardizations and specifications in the cultivation of herbs to ensure the herbal quality. GAP emerged as the best ways to protect the medicinal plant resource for

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sustainable development during herbs growth. GAP is of fundamental importance for the modernization of TCM. With the GAP to be carrying out perfectly, herbal products sales value increased with the improvement of the quality of herbs. Meanwhile, good manufacturing practice (GMP), good laboratory practice of drug (GLP), good clinical practice (GCP) became more meaningful.

Jilin Province, the geometric center of northeast Asia, lies in the central part of northeast China, neighboring the far east of Russia and Korean peninsula to its east and southeast and with Japan on the other side of the Sea of Japan. The overall features of Jilin Province can be summarized in three statistics of approximately 2%: 187,400 km^2 of territory (1.95% of the nation); 27 million of population (2.08% of the nation); and 295.8 billion of gross domestic product (1.81% of the nation).

Jilin Province is the principal TCM base of China with its typical preponderance in TCM resources, research and development power, and industrialized capacity. By the end of 2004, the submission of patent TCM of Jilin Province reached 10% of the total value of the whole nation. Both the profit and taxation of patent TCM rank the province the first place in China [7,8]. The Changbai Mountain, designated by the United Nations as a "human and biosphere" natural preservation land, has long been known as "land of ginseng" and "land of Sika deer". This mountainous area is the gene pool of TCM in Northern China, and is abundant in organic and precious TCM materials. The volcanoes in this area erupted frequently in the past, and the dust and ashes from those eruptions fertilized the soil and nourished the forest coverage amounting 78% of the whole area. Tianchi (Paradise Lake) on top of its highest peak is the head of three famous rivers named Songhua, Tumen, and Yalu. The fine ecological environment has naturally endowed the area with abundant TCM materials. Here you can collect rare wild herbal medicinal materials such as ginseng (*Radix Ginseng*), gastrodia tubers (*Rhizoma Gastrodiabe*), Ganoderma (*Glossy Ganoderma*), and milk vetch roots (*Radix Astragali*), and can see living Sika, wood frogs, sables, and others, both domesticated and wild livestock.

Jilin Province has 2,790 species of TCM materials in total. In the key list from the national TCM resource investigation, there are 363 species among which 137 species are found in Jilin Province amounting to 37.7% [9]. More than 40 species of the TCM materials found in Jilin Province hold more than half of their natural storage of the whole nation. Over 20% of the TCM materials in common use are from Jilin Province. Ginseng, deer antler, and wood frog fat have long been sold to over 50 counties and regions for their superior quality, large quantity, and reputable origin (Table 1).

The GAP demonstrative areas for TCM were established in Jilin Province in 2000, and the technical supporting system and demonstrational system have been founded, resulting in the continuous development of GAP for TCM. The province has established 36 GAP bases for 22 typical TCM species, such as ginseng and magnolia vine fruits. The total demonstrative area reaches 16,000 ha, which accounts for 60% of the total area for TCM cultivation in the province. Six GAP bases for four species have been authenticated by the State Food and Drug Administration of China; it ranks Jilin Province in the first position in the GAP base for these species in China. The geographical distribution map of GAP bases is shown in Fig. 1.

3. Development of technical supporting system of GAP for TCM

The key idea of GAP for TCM is production guided by modern technologies. The rules and regulations concerning GAP were drafted in 2002 by the State Administration of Traditional Chinese Medicine of China, State Food and Drug Administration of China, and China National Group Corporation of Traditional and Herbal Medicine.

Table 1
Resources of traditional Chinese medicine (TCM) in Jilin province

Materials	Families	Species
Animals for TCM	264	822
Herbs for TCM	145	1,815
Fungi for TCM	34	153
Total	443	2,790

In recent years, the province has made considerable achievements in developments of techniques for environmental assessment of TCM cultivation area, variety selecting and breeding, pollution-free and standard cultivation, quality assurance system, and rational collecting and processing. This research and development work provided the GAP for TCM in the province with reliable technical supports. The GAP evaluation standards appeared strict and comprehensive, specialists in herbal medicine were whether they are suitable for China. The GAP evaluation standards contain 104 items for inspection, 19 of which are crucial; a single failure to reach the standard would mean disqualification of this batch of herbal products. But the other items of inspection, contents were vaguely defined and considered less important. Standards are obviously vague. It is further improved.

4. Suitable cultivation site selection and environmental assessment

4.1. Cultivation area delimiting

Scientifically delimiting a suitable cultivation area for TCM is very important. The quality of TCM is greatly related to its origin. In the nationwide delimiting of TCM cultivation area, Jilin Province is listed in the northeast mesothermal zone. According to the geographic condition and suitability for TCM cultivation, the province has been divided into three areas for TCM cultivation [10]. The mountainous area in the east part is mainly for cultivation and husbandry of ginseng (*Panax ginseng*), wild ginger (*Herba asari*), manyprickle acathopanax root (*Acanthopanacis senticosi*), magnolia vine fruits (*Schisandra chinensis*), and wood frog. The hill land area in the central part is mainly for cultivation and husbandry of north thorowax root (*Bupleurun chinense*), balloon flower root (*Radix Platycodi*), primrose (*Primula vulgaris*), etc. The prairie in the west part is mainly for cultivation and husbandry of licorice root (*Radix Glycyrrhiza*), fangfeng (*Radix Sileris*), polygala root (*Radix Polygalae*), common anemarrhena rhizome (*Rhizoma Anemarrhenae*), wolfberry fruit (*Fructus Lycii*), etc.

4.2. Environmental assessment

The environmental surveillance and assessment system has been established, and the monitoring and analyses on soil, atmosphere, and irrigating water have been done in the prime cultivation and husbandry area to keep the quality of the environment of those areas above grade 2 of the national standard. The monitoring and surveying work has covered over 100 cultivation bases in 32 counties or cities in the province.

5. Development of standard operating procedures

5.1. Variety selecting and breeding

A great deal of work has been done on variety selection and stock farm construction for more than 10 species, such as ginseng (*P. ginseng*), American ginseng (*Panax quinquefolius*), milk vetch

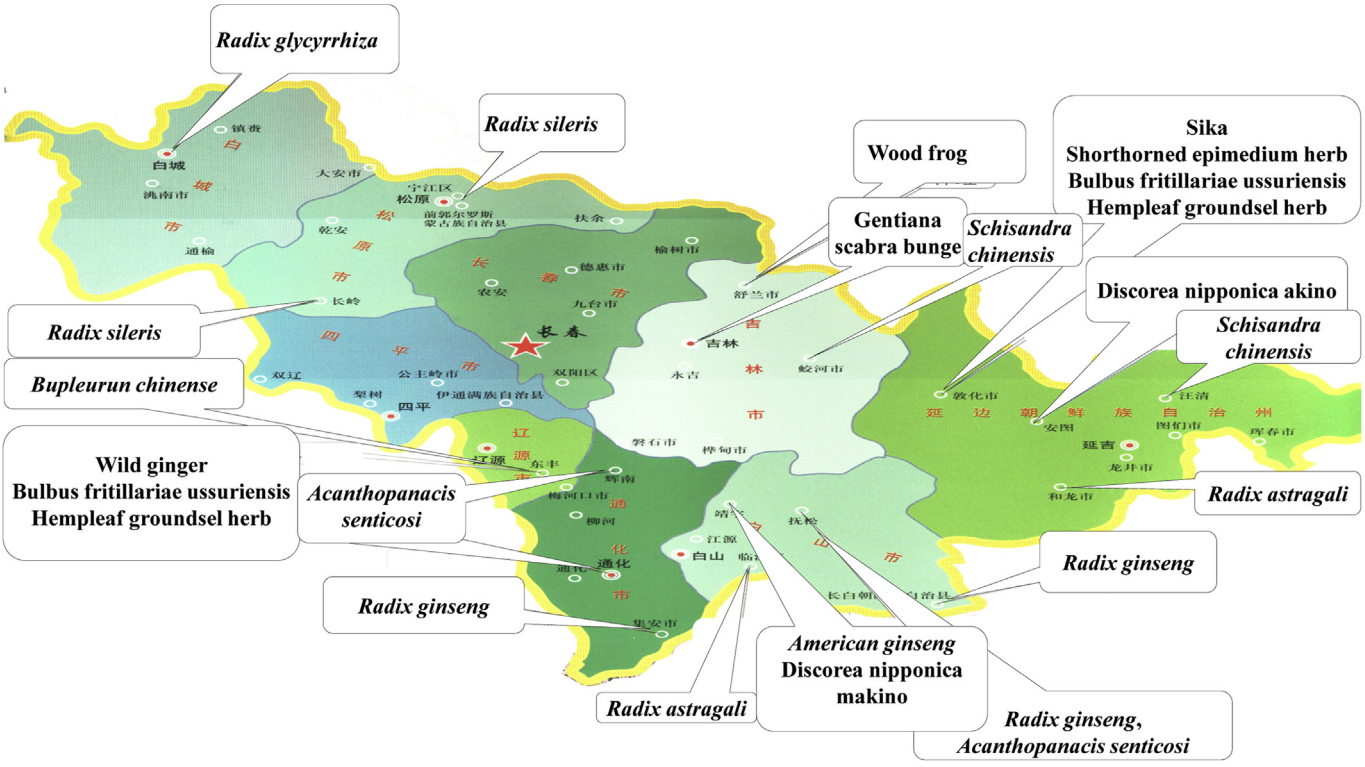

Fig. 1. The geographical distribution map of Good Agricultural Practice bases in Jilin Province.

(*Astragalus membranaceus*), and magnolia vine (*Schisandra chinensis*). The archive and bank of the germplasm of the above species have been established; their seeds have been purified and their suitable cultivating areas have been determined and delimited. The selected seeds with comprehensive or single superior performance have been summed up to 100 varieties, among which 20 super combinations have been formed, 40 super lines have been bred, 40 varieties have been put in controlled tests for herbal medicinal materials, and more than 10 varieties selected and tested [11]. The analysis of genetic polymorphisms has been done on the varieties of milk vetch, licorice, wild ginger, and thorowax from which the heritable differences among lines are identified, promoting the research on variety selection of medicinal herbs to the molecular level.

5.2. Research on the sustainable production model

To realize the protective development and sustainable use of the TCM resources, the province carried out research and development on nurturing wild TCM materials and regeneration of TCM material populations. The maximizing sustainable output model of the undergrowth resources in the forest ecological system has been established [11].

5.3. Development of chemical residue control technology

Research on the degradation of the three chemicals (mancozeb, phoxim, and carbendazim) in the soil and surface of TCM materials and kinetic response of the chemical residues have been carried out. According to the Recommended National Standards (GB/T, 2008), safe intervals for applying these chemicals have been determined.

5.4. Development of standard operating procedures

To assure that GAP is carried out successfully, standard operating procedures were laid down for different plants. A great deal of research work has been done on the photosynthetic physiology, hydrous physiology, and trophic physiology of TCM materials of 22 species such as ginseng. In combination with the research results with the productive practices in Jilin Province, the standard operating procedures for 32 species of TCM materials have been developed in the province.

6. Development of quality standard of TCM materials

6.1. Development of quality standards

The province has developed 10 quality standards for 10 species of TCM materials such as ginseng and American ginseng. Fingerprints of materials in common use are under development to ensure the TCM quality. High performance liquid chromatography (HPLC), gas chromatography–mass spectrometry (GC-MS), and near-infrared chromatography are used for the quality measuring and analysis to ensure the accuracy of quality assessment of TCM materials.

6.2. Research and application of fingerprints

The fingerprint authenticating standards for typical TCM materials have been developed based on the large amounts of data

collected from fingerprints of TCM materials. Based on analysis of features and signature of fingerprints, the authenticity and origin of TCM materials can be determined; based on the design of the area and proportions of characteristic peaks of fingerprints, the quality of TCM materials can be well controlled.

7. Research on collection, processing, and preparation of TCM materials

7.1. Rational collection

Collecting time is greatly related to the quality of TCM materials. The province has determined suitable harvesting time for 22 species of TCM materials in common use based on the research and analysis on accumulated dynamic state of their active ingredients [12,13].

7.2. Research on processing techniques

Microwave technology, freeze-drying technology, air-limited storage technology, and ultramicro grinding technology are applied in the processing of TCM materials, which leads to upgrading of traditional technique and developing new products. Macroporous resin technology, membrane separation process, supercritical extraction technology, and ultramicro grinding technology are applied into the extraction of active ingredients of TCM, which leads to high purity and top quality extraction [14,15].

7.3. Research on preparation of traditional Chinese medicine

Processing and preparation of TCM materials can lead to the positive results of purification, attenuation, potentiation, or even conversion of medicine properties. In recent years, Jilin Province has adopted the modern technologies and facilities such as HPLC, capillary electrophoresis chromatography, HPLC-MS and GC-MS in the research and analysis of the preparation of TCM materials. Stringent quality standard and standardized processing procedures have been developed for 16 TCM materials in common use.

8. Research on standardized processing of ginseng

8.1. Determination of an area suitable for ginseng cultivation

Cultivation of ginseng is mainly done in China, North Korea, South Korea, Japan, and Russia. Changbai Mountain area is the major producer of ginseng in the world. It holds 80% of the total output of ginseng in China and 60–70% of the world output. The best land for ginseng growing is the area in 40–48°N and 117–137°E [16]. To determine the best area for ginseng cultivation, the attaching function model is developed based on the fuzzy set theory with the five factors of annual precipitation, atmosphere relative humidity, sea level, maximum temperature and frostless period which is expressed by the equation:

$$\mu = \Sigma \mu j(x) Mj \quad (1)$$

(μ, comprehensive evaluation index; μj(x), membership function of climate factors; Mj, weight) [16]. The result shows that 12 counties in Jilin Province, including Changbai, Fusong, Jingyu, and Jian, are the optimum ginseng cultivation areas.

Table 2
Yield of four varieties of ginseng

Group	2-y-old plant		6-y-old plant	
	Unit yield (g/m^2)	Increment (%)	Unit yield (g/m^2)	Increment (%)
RS 03	1,890	24.4	2,861	37.3
RS 07	1,781	22.5	2,639	25.1
RS 14	1,623	12.6	2,427	−7.5
Control	1,026		1,849	−16.3

RS, ginseng

8.2. Variety selection of ginseng

Based on 30 years' hard work, Jilin Province has selected four variety groups of ginseng. The annual yield of ginseng and saponin content in ginseng are shown in Tables 2 and 3, respectively.

8.3. Illumination management of ginseng

Ginseng is a sciophilic (shade-loving) plant and illumination management is needed in its cultivation. The photosynthetic rate of ginseng is greatly related to illumination, temperature, humidity, variety, season, and plant age. In Jilin Province, illumination intensity is adjusted and controlled according to different growing seasons and plant ages and that improved the quality and increased the yield. Cultivation test of ginseng in a photic shed using films of different colors showed that vividescent and flavescent film (more red light pass through) increased ginseng yield by 39% in comparison with hyaline (colorless) film and by 11% in comparison with red film. Dark-colored films (red, green, blue, violet, and yellow), especially saturate-virent (dark green) film, affected the normal growth, had reduced-sized leaves and roots, and decreased the yield, and the dark blue film decreased saponin content in root [17], whereas the violet film and yellow film increased saponin content in root by 10–12% [17].

8.4. Fertilization of ginseng

Absorption, accumulation, and distribution of nitrogen, phosphorus, and potassium in ginseng plants increase with plant aging. Taking the accumulation of the three elements in a 6-y-old plant as 100%, 1–2-y-old plant only accumulate 3.5% of the total three elements, the 3–4-y-old plant period accumulate 37% of the total three elements, and 60% of the total are accumulated in the 5–6-y-old plant. Within each year, most of the absorption and accumulation are done in the periods of florescence and frutescence. Based on this regularity, the total fertilizer needed for ginseng growth is calculated by the equation [18]:

$$\text{fertilizer} = \text{designed yield} \times \text{nutrition needed for unit yield} \times \text{utilization rate} + \text{residual weight in soil.} \quad (2)$$

By this technique the increment of utilization rate reached 15–20%.

Table 3
Saponin content and essential oil content in four varieties of ginseng

Group	Total saponin (%)	Essential oil (%)
RS 03	3.40 ± 0.2	0.098 ± 0.027
RS 07	3.47 ± 0.3	0.127 ± 0.035
RS 14	3.26 ± 0.3	0.102 ± 0.023
Control	3.22 ± 0.4	0.095 ± 0.022

RS, ginseng

Table 4
Quality comparison (%)

Technique	Productive rate	Dehiscent root	White skin	Fresh core	Vinous (black–red)	Top quality rate
Digital control	35.4	2.5	3.6	3.1	4.2	86.4
Routine	33.2	7.4	7.2	5.3	15.9	64.2

Table 5
Comparison of active component contents (%)

Technique	Saponin	Essential oil	Total amino acid
Digital control	3.8	1.3	9.7
Routine	3.3	0.9	9.9
Korean ginseng	3.4	1.1	10.5

8.5. Control of ginseng rust with antagonistic bacteria

Rust is the most dangerous disease of ginseng. Jilin Province has developed biopreparation to efficiently control ginseng rust. A test of the antagonistic bacteria in rust control showed that the morbidity in the control area was 28.8%, but only 11.4% in the area treated with the biopreparation of antagonistic bacteria. The controlling efficiency reached 60.4% [19,20].

8.6. Digitalized processing of red ginseng

The relational models of red ginseng pressed quality with temperature, humidity, and pressure in processing have been developed for large, middle, and small capacities, respectively. A data collecting, transmitting, and processing system has been designed and developed; this realized the digital control of red ginseng processing. In comparison with routine (conventional) processing, the processed (via digital control) red ginseng has much better quality specifications in color, proportion of yellow skin, proportion of white core, and furrow depression. Essential oil content was increased considerably, but saponin content was increased slightly. It is shown in Tables 4 and 5 that the red ginseng processed with the digital controlled technique has a higher productive rate and lower proportions of dehiscent root, white skin, fresh core, and vinous body compared to those from routine lines. Both the saponin and essential oil contents of the red ginseng processed by digital control techniques were higher than those of the conventionally processed products [21].

9. Guiding and demonstrating by the government in implementation of GAP for TCM

"Guided by the government, sponsored by enterprises, and supported by science and technology" is the typical operating way in Jilin Province in implementation of GAP for TCM. The whole process is done by industrialization of TCM production centering the development of the market. In all the counties or cities where the GAP bases are located, the leading group for base construction headed by the dominative leader of the local government and technical leading group headed by chief experts in the related colleges and research institutions are organized. This forms the "administration (government) + technology (research institution)" operating model. An integrative leading organization consisting of both management system and technical supporting system is governed by the relevant provincial office. Nowadays, most of the model is led by the TCM company, the drug products were not sold very well or changed by the company. The drug materials became unsalable goods. So, an adjustment system should be built by a research institution among different GAP bases. In the new model, management department quickly responded to various situations. The following four aspects have received more attention in the implementation of GAP in Jilin Province.

9.1. Popularization of the knowledge of GAP

GAP is a new concept for most of the public. In order to implement it broadly and deeply, governmental and educational organizations should first make it understood by people in all related fields and make it receive enough attention. The provincial government has called some special conferences and held training courses to spread the knowledge about GAP for TCM, which enhanced the consciousness and desire of people to implement GAP in the province.

9.2. Protective and sustainable development of TCM resources

Adopting domestic nurture of the wild population of TCM resources (GAP for wildlife), carrying out research and development of the balance model for maximizing collecting wild TCM, and establishing demonstrative bases for domestication of TCM resources have made a great contribution to the protection of ecological environment and natural resources, improved quality of TCM, and reduced processing cost.

9.3. Emphasizing the construction of demonstration bases

Making full use of the demonstration bases to popularize GAP knowledge is an effective way in complementation of GAP for TCM. The province has delimited and equipped 16,000 ha of demonstration areas in the well-constructed GAP bases, which have directed standardized cultivation in an area of 8,000 ha in the vicinities of the bases that doubled the efficiency of the popularization work.

9.4. Emphasizing the centering position of enterprises

Enterprises are the centerpieces in the implementation of GAP for TCM. This is the model of "Operation Centering Enterprise" performed in Jilin Province. Eighty-five percent of GAP bases in the province are sponsored and run by TCM manufacturing enterprises, which greatly accelerated the upgrading of quality and increment of capacity in the implementation of GAP for TCM.

Our practice shows that the most important guarantee for implementation of GAP is the combination of science and administration (authority). The science and technology establishments of the government provide powerful support, guide, and demonstration, which might be considered as road paving and bridge building. The enterprises carry out standardized production according to the specifications of GAP, which is the task of driving. The drug administrating departments of the governments monitor and control the production activities in conformity with related provisions, that is the function of traffic control. This is our operating model in which the three operators including science and technology establishment, enterprises, and drug administrations interact in a benign circle just like a road builder, driver, and traffic policeman.

Conflicts of interest

All contributing authors declare no conflicts of interest.

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