

Continuous Cropping Problems in Ginseng *Panax ginseng* C.A. Meyer: An update

S.A. Zhang, M.L. Yu, Y. Shen¹, M.M. Ma⁴, L.K. Fan³, L.M. Shan¹,
Z.Q. Zhang*, K.M. Zhang^{1,2*} and Y.Y. Wang
Binzhou Vocational College, Binzhou 256603, China
Email: wyy6677@126.com, zhangzhuqidragon@163.com

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ABSTRACT

This paper summarizes the updated research on continuous cropping problem of *Panax ginseng* C.A. Meyer. (i). Current status of ginseng cultivation, (ii). Development of continuous cropping problem, (iii). Methods to alleviate the continuous cropping problems and (iv). Suggested future research to prevent development of continuous cropping problem in ginseng.

Key words: Allelochemicals, autotoxicity, continuous cropping problem, medicinal plant, *Panax ginseng*, soil diseases.

1. INTRODUCTION

Ginseng (*Panax ginseng* C.A. Meyer) (Family Araliaceae, Genus *Panax*) is one of the most famous medicinal plant with numerous medicinal and health care uses (17). Its products are used not only in Asian countries (China, South Korea, Japan and North Korea, etc.), but also in western countries (USA, European Union etc.). In China, it is herbal medicine with several uses (Improve human immunity, enhance cardiac function, regulate neurasthenia and physical weakness, etc.). It also has some other special functions (Diuresis, enhancing excitement, delaying ageing and inhibit tumors, etc.), hence, it is known as "King of all medicinal herbs" (35,71).

*Correspondence author, Z.Q. Zhang and K.M. Zhang, ¹Co-Innovation Center for Sustainable Forestry in Southern China, College of Biology and the Environment, Nanjing Forestry University, Nanjing 210037, China, ² Department of Botany, National Museum of Nature and Science, 4-1-1 Amakubo, Tsukuba-shi, Ibaraki, Japan, ³Qianjiang Management Office, West Lake Scenic Area, Hangzhou 310000, China, ⁴Binzhou Agricultural and Rural Bureau, Binzhou 256603, China.

Ginseng is perennial plant, adversely affected by the continuous cropping problem. It cannot be planted again in the same land cultivated with ginseng in past 10-20 years, otherwise, there will be multiple diseases "rotten roots/burning whiskers, weak growth, low yield" and other continuous cropping related problems (58). Its continuous cropping problem directly affects the growth and product quality of ginseng, which causes huge economic losses to ginseng farmers, ginseng industry and sustainable use of cultivated land (27). Therefore, it is of immense significance to study the development mechanisms of continuous cropping problem and methods to control it (Figure 1 and 2).



Figure 1. Ginseng plant in normal soil at Dunhua, Jilin Province, China.



Figure 2. Ginseng plant with disease spots in continuous cropping soil at Dunhua, Jilin Province, China.

Continuous cropping problem refers to the phenomenon of poor growth, weak plants, low yield and quality and increase in diseases and insect pests (especially soil diseases). It occurs even under normal cultivation and management conditions, if ginseng or related plants are continuously cropped on the same land (51). It is a global problem, which often occurs in some crops. Its intensity is closely related to crop species, varieties and cultivation method. It is less problem in grain crops (Corn, millet, wheat, etc.) but serious in horticultural crops.

2. CURRENT STATUS OF GINSENG CULTIVATION

Ginsengs like the humid, shade and cool climate conditions and have strong cold endurance. It used to grow in deciduous broad-leaved forest or coniferous broad-leaved mixed forests, (40°-45° North latitude and 117.5°-134° East longitude) (23,70). It is of two types: Wild ginsengs (commonly called Mountain ginsengs) and cultivated ginseng (called Garden ginsengs). Due to the decrease of forest resources and the changes in ecological environment, the wild ginsengs are getting rarer and rarer (69). Presently, the ginsengs sold in the market is mostly cultivated ginsengs. It is cultivated in China, South Korea, Russia, North Korea and Japan, among these China is the largest producer (61 % of world's total output production). Ginseng cultivation in China has long history of > 1700 years (28). Now the ginseng cultivation in China is largely concentrated in Changbai Mountain of Jilin Province, Huanren of Liaoning Province, Daxing'anling and Xiaoxing'anling of Heilongjiang Province. In recent years, Hebei, Shanxi, Shandong and other provinces have also started its cultivation (62). Jilin Province is the main ginseng producing area in China, mainly concentrated in Fusong, Jingyu, Ji'an, Changbai and other cities and counties. It is planted in about 4600 ha, with total output of 25000 t, accounting for 80 % of the national total output and 61 % of the world's total output. It can be said that Jilin Province is the cultivation center of ginseng in China (67).

Ginseng is a perennial medicinal plant, susceptible to continuous cropping problem. It cannot be planted again in the same land within 10-20 years, and the restoration of old ginseng land is very slow and difficult (50,58). Therefore in past, farmers mainly adopted the model "Deforestation for planting ginseng" to grow ginseng, but it caused serious damage to forest resources and ecological environment in the main ginseng planting areas in China. In recent years, China has formulated policies to strictly prohibit the reclamation of new forest land for ginseng planting. Hence replanting ginseng in old ginseng fields have become the main cultivation method in China. Continuous cropping problem of ginseng has become the bottleneck of ginseng industry development (41). Presently, the important tasks for ginseng research are: (i). to study the mechanism of formation of continuous cropping problems of ginseng, (ii). how to prevent development of this problem, (iii). explore the methods to overcome the ginseng continuous cropping problems, (iv). development of technology for replanting ginseng in old ginseng fields for sustainable and healthy development of ginseng industry.

3. HARMFUL EFFECTS OF CONTINUOUS CROPPING PROBLEM

If ginseng is continuously planted in the same land, there will be many problems (Rotten roots, burned whiskers, weak growth, decreased yield, poor quality, frequent diseases, etc.), called "continuous cropping problem of ginseng" (48,74). The main harmful effects of ginseng continuous cropping problem are: (i). Poor growth, (ii). Less yield and poor quality, (iii). Increase of autotoxicity and decline in roots activity, (iv). Deterioration of soil physico-chemical properties, nutrients deficiency or imbalance in soil, (v). Change in soil microflora, (vi). Promotion of harmful microorganisms and (vii) Aggravation of soil diseases and insect pests (20,24). Wang *et al.* (49) summarized the symptoms of ginseng continuous cropping problem in old ginseng fields as "burning beard, root rot, more diseases, low yield and poor quality" (49). The decrease in fibrous roots of ginseng adversely affects the absorption of nutrients and water, and thereby, adversely affects the photosynthesis and plant growth. The root growth becomes slow, root activity decreased and disease resistance reduced, hence, ginseng is easily infected with various root diseases (9). Besides, the continuous cropping of ginseng also causes: (i). Fibrous root abscission, (ii). Root epidermis become reddish brown with disease scars and (iii). Frequent diseases. These seriously affected the yield and quality of ginseng (47). Jin *et al.* (22) reported that in second year, the survival rate of ginseng seedlings was only 30 % in old ginseng field, the fibrous roots of most of ginseng seedlings fell off, root epidermis rotted, turned red and covered with disease scars and all such seedlings died in some plots. Even if ginseng was planted in the new forest land, the growth, yield, quality and disease resistance were reduced in later growth period (22,43).

4. DEVELOPMENT OF CONTINUOUS CROPPING PROBLEM

Development of ginseng continuous cropping problem mainly includes undesirable changes in soil physico-chemical properties, soil micro-ecological environment and autotoxicity of ginseng, etc.

(i). Diseases

Continuous cropping of ginseng leads to the occurrence of infectious diseases one after another, even simultaneous occurrence of several diseases. The soil diseases are also epidemic in the whole ginseng Garden (52). Jian *et al.* (19) found that the ginseng planted in the old field (under ginseng cultivation for 2-3 years), its seedlings began to rot and then gradually died. Only about 30 % ginseng seedlings were healthy, the roots of 70 % plants were covered with disease scars, root epidermis rotted and turned red, and the fibrous roots fell off (19). The physiological diseases of ginseng are mainly red skin disease, becoming more and more serious in ginseng cultivation (68). Burning whisker disease is a transitional form, from the physiological disease to infectious disease. In ginseng continuous cropping problem, the root infectious diseases are more serious. Cho *et al.* (8) reported that ginseng rust was a major infectious disease of ginseng, which occurs from seedling stage to harvest stage. It mainly harmed the roots, underground stems and overwintering buds of ginseng and may even cause crop failure. Its incidence was 30-40 % in China. In 3-years old

seedlings, with bacterial infectious diseases in old ginseng land was upto 90 %. The incidence in 2-year old seedlings with bacteria in old ginseng land was 95.8 % in Korea and the inhibition of lateral root growth was 37.3 % (8). The ginseng rust rot is the soil borne disease caused by *Cylindrocarpon destructans* (Zinss) Scholten after ginseng continuous cropping. It was one of the most serious diseases and also the most difficult to control in ginseng cultivation, which seriously affected the yield and quality of ginseng (29). Secondly, *Sclerotinia sclerotiorum* serious infectious disease of ginseng spreads by soil transmission, mainly harmed the roots and stem base of over 3-years old ginseng (45). The rust rot and *Sclerotinia sclerotiorum* were major soil borne diseases in continuous cropped ginseng with high occurrence frequency and seriously affected the yield and quality of ginseng. Besides, some other frequent soil borne diseases in ginseng continuous cropping problems are: *Fusarium solani*, *Pythium debaryanum*, *Rhizoctonia solani*, *Alternaria panax*, *Sclerotinia ginseng*, *Phytophthora actorum* and bacterial soft rot etc. (72).

(ii). Imbalance of soil microflora

Ginseng continuous cropping deteriorates the soil ecological environment, which prevents the growth of beneficial bacteria and actinomycetes, but help in spread of pathogenic fungi and nematodes, thus, the soil borne pathogens spread and the root diseases occurred frequently (65). Li *et al.* (32) studied the effects of continuous cropping of ginseng on the species and quantity of fungi in the soil. The results showed that the number of bacteria and actinomycetes in the ginseng rhizosphere soil decreased year by year, while the number of fungi increased year by year (32). Based on the study of genetic diversity of microbial population in continuous cropping soil, Li *et al.* (31) believed that the ginseng root exudates promotes some soil microorganisms, causing the changes in microbial population structure in continuous cropped soil (31). The number of fungi in continuous cropping soil was positively correlated with the ginseng plants age (that is, older the ginseng plants, the more fungi in soil), and the number and species of harmful fungi increased significantly (11). After soil improvement, the number and activity of all beneficial microorganisms were increased significantly in old ginseng land. In addition, the number of actinomycetes, trichoderma and VA mycorrhizal all increased and soil nematodes decreased significantly (66).

Soil contained a large number of beneficial bacteria and actinomycetes, which played an important role in degradation of plant residues and allelochemicals and maintains the balance of soil ecosystem. However, the species and quantity of beneficial bacteria and actinomycetes decreased significantly in the continuously cropped soil of ginseng, while, the quantity of pathogenic fungi increased significantly (12). The total number of fungi in ginseng rhizosphere soil under continuous cropping for 15-years was 1.82 times higher than for 2 years cropped land. Other studies showed that the main microorganisms in ginseng rhizosphere soil were *Penicillium* and *Aspergillus*, while the main ones were fungi on ginseng root surface (59). In summary, the continuous cropping of ginseng changes the soil micro ecological environments and soil microbial population. Thus, the imbalance of microbial community in the soil of old ginseng land is one of the main causes of ginseng

root disease.

(iii). Nematodes and mites

There were > 20 species of parasitic nematodes in continuous ginseng cropping soil, among which the most common were *Meloidogyne hapla* and *M. changbaiensis*. The main mites were *Hisriostoma feroniarum*, *H. sapronyzarum*, *Rizoglyphus echiplus* and *R. robin*, etc. Nematodes and mites not only cause ginseng root disease, but also made wounds on ginseng root epidermis, which became the targets of pathogen infection. At the same time, they are also the vectors of pathogen transmission. The root rot and seedling death in continuous cropping of ginseng are caused by multiple pathogens, which decrease the ginseng yield and quality. The root disease must be controlled for replanting of ginseng in old ginseng field (75).

(iv). Autotoxicity

In recent years, with the advances in allelopathy and chemical ecology, researchers began to explore the development mechanism of continuous cropping problem and achieved satisfactory results (7). In ginseng cultivation, some secondary metabolites from the plants and microbes are released into the soil, these gradually accumulate in the soil with the duration of cultivation years. When they accumulate to a certain concentration, they inhibit the seed germination and growth of ginseng, which is called "autotoxicity" (33,65). The extracts from old ginseng soil are significantly inhibitory to ginseng roots growth and with increase in extracts concentration, the inhibitory effects increased (50). The extracts from ginseng rhizosphere soil inhibit the accumulation of ginsenoside in ginseng roots and the seedlings growth of ginseng, and the inhibitory effects followed the Order: Continuous cropping rhizosphere soil > Old ginseng soil > New forest soil (30). Chen *et al.* (5) reported that the extracts from ginseng rhizosphere soil had inhibitory effects on root activity of ginseng seedlings, and 100 g/L concentration significantly reduced the dehydrogenase activity of ginseng seedling roots by 42 % than control. Ginseng is a perennial plant, whose roots continuously secrete various secondary metabolites into the soil during its growth. Many of the secondary metabolites are autotoxic that inhibit the growth of ginseng and also promote the pathogens. Huang *et al.* (18) found the high-content of autotoxic substances in the soil of old ginseng land and were: Fatty acids, alcohols and alkanes, aniline, phenolic acids and their derivatives. They also found that these allelochemicals could promote the formation of starch granules in the cells of meristematic zone of ginseng seedlings root tip, leading to the occurrence of "empty bubble" phenomenon, which causes the disintegration and disappearance of nuclear membrane and nucleolus, and cells lose the normal life activities. Chen *et al.* (6) extracted the active components from ginseng rhizosphere soil by methanol extraction, isolated and identified them. There were many autotoxic substances that promoted the soil borne diseases and inhibited the growth of ginseng roots in the soil of old ginseng field. There were 5-phenolic acid allelochemicals (salicylic acid, benzoic acid, gallic acid, 3-phenylpropionic acid and cinnamic acid) in ginseng rhizosphere soil of continuous cropping for 6-years. These phenolic acids drastically inhibited the seed germination and seedling growth of ginseng (38).

Root exudates: Ginseng is a perennial plant, whose roots continuously secrete various secondary metabolites into the soil during its growth. Many of the secondary metabolites are autotoxic that inhibit the growth of ginseng and also promote the pathogens. Garbeva *et al.* (12) found a variety of allelopathic active components in ginseng root exudates, these inhibited the seeds germination of ginseng. Carney *et al.* (4) found that the soil extracts and the root exudates from ginseng had similar chemical composition and contained a variety of allelochemicals with the same chemical structure. These allelochemicals had significant effects on the activities of defense enzymes in ginseng cells. Huang (18) collected root exudates from ginseng by hydroponics and identified the main compounds by GC-MS. The results showed that a variety of compounds from ginseng root exudates promotes the reproduction and growth of pathogenic bacteria in soil (18). Therefore, the autotoxicity of ginseng is also important factor causing continuous cropping problem.

(v). Deterioration of soil Physico-chemical properties

The soil Physico-chemical properties decreases with the increase of ginseng cultivation years.

(A). Soil physical properties: The bulk density and specific weight of soil increased, total porosity decreased and clay increased, which leads to soil hardening, decreases soil aeration and water retention. Yu *et al.* (61) studied the physico-chemical properties of ginseng farmland soil, new forest soil and old ginseng land soil. He found that the ratio of solid/ liquid/ gas, bulk density, porosity and water content were significantly changed, and the change trend followed the order : New forest soil > Ginseng farmland soil > Old ginseng land soil. Many growth indexes of ginseng (Root weight, root diameter, leaf area, etc.) were positively correlated with soil permeability and porosity (34). The soil became sticky and the soil structure was destroyed with the increase of ginseng cultivation years, which led to the soil hardening, poor aeration and less water permeability in old ginseng field (15).

(B). Soil chemical properties: Soil acidification increased, which adversely affected the growth and development of ginseng. Jia *et al* (21) studied the soil acidification of old ginseng field. The soil pH decreased gradually with the increase of ginseng cultivation years. In third year of ginseng cultivation, the soil pH decreased to 5.0-5.5 (21). In acidic soil, microorganisms and pathogens multiply, which makes the soil environment non-conducive to the growth of ginseng. During the ginseng cultivation, the content of exchangeable bases in soil decreased, while the content of exchangeable hydrogen increased (22).

(C). Soil nutrients: The organic and mineral nutrients in the soil were greatly reduced and the nutrient elements were unbalanced, especially the trace elements were deficient. In continuous ginseng cropped soil the contents of organic matter, total nitrogen and C/N ratio all decreased (10), while the contents of active Fe, Al and Mn in rhizosphere soil increased, but the content of effective Si decreased. With the extension of ginseng

cultivation years, the soil cation exchange capacity decreased, and the content of acid cations (e.g. H^+ , Al^{3+}) increased, which decreased the base saturation (10). Yu *et al* (60) determined the trace elements in the soil of old ginseng field and new forest land. The results showed that the contents of available B, Cu, Zn, Fe, Mn and other trace elements decreased in the old ginseng soil and were only 3.8 % that of new forest soil (60). The deficiency of trace elements may lead to weakening of disease resistance, metabolic disorders and poor growth and development, and eventually caused physiological diseases of ginseng.

5. HOW TO CONTROL CONTINUOUS CROPPING PROBLEM

To solve the continuous cropping problem of ginseng, in recent years researchers have developed some prevention and control methods, viz., diversified planting, soil improvement, soil disinfection, biological control etc.

(i). Diversified cultivation

Diversified cultivation methods (Rotation, intercropping, interplanting and mixed cropping, etc.) could improve the soil structure, soil nutrients status, microecological environment of rhizosphere soil, control the population of pathogenic microorganisms and reduce the harmful effects of continuous cropping problem (54,64). At present, the control measures for continuous cropping problems of ginseng used are mainly cultivation systems (Ginseng rotation with crops, ginseng intercropping with trees and ginseng rotation with green manure crops, etc.). These methods reduces the harmful effects of continuous cropping on ginseng to a certain extent, and showed that ginseng can be replanted in old ginseng field (57). Some crop rotations (Ginseng with *Medicago sativa* L., *Asarum sieboldii* Miq. and *Amorpha fruticosa* L, etc.) could shorten the replanting period of ginseng to 6-10 years in old ginseng field (44,56). In Japan ginseng rotation with grain crops (Wheat, corn, rice, etc.) could shorten the replanting period of ginseng to 13-19 years (56). In South Korea, ginseng rotation with upland rice could shorten the ginseng replanting period in old ginseng fields to 3-7 years (56). It can be seen that the diversified cultivation models greatly shortened the ginseng replanting period in old ginseng field, and improved the yield, quality and land use ratio of ginseng. Besides the ginseng-medicinal plants rotation (*Gastrodia elata* Bl., *Amorpha fruticosa* L. and *Lespedeza abiolor* Turcz, etc.) could increase the number of bacteria, actinomycetes, fibre degrading bacteria and nitrogen fixing bacteria in old ginseng field soil and reduces the number of pathogenic fungi. The number of beneficial bacteria (Nitrifying bacteria, sulfur bacteria, phosphorus bacteria and ammoniated bacteria, etc.) were increased, while, the number of anaerobic nitrogen fixing bacteria were significantly decreased (55). Tan (44) reported that ginseng- *Asarum sieboldii* rotation reduced the root rot of ginseng in the old ginseng field, and the phenomenon of burning beard and root rot was also greatly reduced. Further studies showed that the root exudates from *Asarum sieboldii* had inhibitory and killing effects on the harmful microorganisms in the soil. In addition, the new cultivation methods such as intercropping had good effects to alleviate the continuous cropping problem of ginseng. Thus the diversified planting methods increases the root exudates, improves the micro-ecological environments of crop rhizosphere soil,

increases the diversity of rhizosphere microbial community, limits the pathogenic microorganisms and reduces the occurrence of soil diseases. Therefore, it is an effective strategy to overcome the continuous cropping problem of ginseng soil to develop scientific cultivation system by crop rotation and intercropping etc.

(ii). Soil improvement

Scientific fertilization and increased use of organic fertilizers can effectively increase the soil nutrients content, improve physico-chemical properties of continuous cropped ginseng soil and create good soil environmental conditions for the growth of ginseng in continuous cropped soil. The application of bio-organic fertilizer significantly increased the soil pH, content of organic matter, and number and activity of beneficial microorganisms in the soil of old ginseng land (13). Likewise, the application of decomposed organic fertilizer (Pig manure, deer manure, oilseed cake etc.) before replanting ginseng in old ginseng field increased the content of organic matter, increased the soil fertility, improved permeability and water retention in continuous cropped soil (20). The applied fermented corn straw significantly increased, the content of organic matter, the available nitrogen, phosphorus, potassium and other mineral nutrients in the soil, which effectively promoted the growth of ginseng (40). The addition of organic materials (Corn straw powder, bean stalk powder, bean cake, etc.) improves the soil physico-chemical properties, increases the activity of soil enzymes and promotes the growth of ginseng (16). The applied trace elements (Boron, manganese, iron, zinc, copper, etc.) in the soil of old ginseng field, increased the yield and disease resistance (20).

The applied biomass plays an important role in improving the soil physico-chemical properties and fertility in continuous cropping soil (26). The biochar rapidly increases the organic carbon content in soil, improves soil structure, and promotes the reproduction and growth of beneficial microorganisms in soil (76). Biochar prepared from crop straw or forest waste has good physical properties, hence, good soil conditioner and is rich in nutrients (38). As a soil conditioner, biochar can be used to alleviate continuous cropping problems and restore soil productivity.

(iii). Soil disinfection

The continuous cropping of ginseng increases the pathogenic bacteria and soil borne diseases in the soil, year by year. Soil borne diseases of ginseng were mainly caused through infected ginseng roots and stems by pathogenic fungi, bacteria, viruses and nematodes. Soil disinfection could kill pathogenic bacteria and nematodes in soil and effectively reduces the harmful effects of soil borne diseases (1). The main methods of soil disinfection are : chemical, physical and biological methods.

(A). Chemical methods : Some chemical agents (Chloropicrin, temik, methyl bromide, 1,3-dichloropropene, methyl iodide, methyl isothiocyanate, allyl isothiocyanate, propylene oxide, sulfur dioxide, sodium azide, sulfuryl fluoride, lime nitrogen, etc.) are added into the soil for its sterilization and disinfection. Some chemical disinfectants (Dazomet, carbendazim and chlorothalonil, etc.) greatly reduces the incidence of ginseng rust rot (36). Zhao (73) reported that the fenaminosulf controls the

phytophthora blight of ginseng. Chemical disinfection, is most commonly used to alleviate continuous cropping problems in ginseng production because of its low cost, good effect and convenient operation. However, these chemicals pollutes the ecological environment (25,73).

(B). Physical methods: The soil is disinfected by sun exposure and steam fumigation. The ridges are made in summer in ginseng field and covered with mulch film. This effectively kills the root rot pathogens and eggs of worms upto 10 cm deep soil layer. There is no pollution, good effect, but heavy work and high cost.

(C). Biological methods: This method developed recently replaces the chemical sterilization. It causes pollution and recommended for soil disinfection and sterilization (42). At the beginning of last century, Japanese scholars put forward "Strong reduction soil sterilization (RSD)", also known as biological soil sterilization. In this method a large quantity of organic materials are added into soil, then filled with water and covered by mulch film, hence, limited air entry in the soil to create a strong reduction state in soil in a short time to kill soil borne pathogens (2). This method not only controls the soil borne pathogens (e.g. fungi, bacteria and nematodes), but also improves the soil physico-chemical properties and increase soil organic matter (37). RSD is environment-friendly soil disinfection method, hence, very popular. However, in the practical application, it is limited by some factors (cost, practicability and stability), hence, some problems are needed to be solved. This method was used to control soil diseases in Japan, Netherlands and United States (77).

(iv). Biological control

In recent years, a great progress has been made in controlling the continuous cropping problems of ginseng by using soil microbial antagonism. Wang *et al* (46) reported that the UV irradiated *Trichoderma* strain (ECT-01-2) inhibited the ginseng rust rot fungi (83.68 %), and its fermentation broth also inhibited the spores germination and hyphae growth of ginseng rust rot fungi. Besides the ECT-01-2 antagonized the ginseng rust rot fungi through competition, parasitism and bacteriolysis, etc. (46). The *Trichoderma viride* effectively controlled the ginseng rust rot and increased the yield of ginseng by 1.77 times (53). Two strains of *Trichoderma viride* controlled ginseng rust rot fungi upto 75 % (39). In addition to the researches on biocontrol fungi, the researches on biocontrol of bacteria and biocontrol actinomycetes had also achieved satisfactory results in controlling soil borne diseases of ginseng (63). In recent years, some progress has also been made in alleviating continuous cropping problems of ginseng using mutualistic symbionts established by mycorrhizal and host crop roots. Ginseng is a mycorrhizal plant and Arbuscular mycorrhizae (AM) can form symbionts with ginseng roots and participate in its physiological activities (Promote rooting, increase transplanting survival rate, promote nutrients absorption, etc.) to enhance the resistance of ginseng to adverse environment and reduce the occurrence of soil borne diseases (14). Studies on the application of mycorrhizal technology in controlling the continuous cropping problem of ginseng and other medicinal plants has just started, but

satisfactory results have been achieved. This technology has a great potential in controlling continuous cropping problems of ginseng.

6. FUTURE AREAS OF RESEARCH

The future research should be strengthened in following areas:

- (i). Extraction and identification of allelochemicals from ginseng field.
- (ii). Allelopathic effects of root exudates and decomposed substances from ginseng on soil microbial flora, its activity and autotoxicity to ginseng growth.
- (iii). Effects of diversified cultivation methods (Ginseng rotation with trees, ginseng intercropping with crops and medicinal plants, etc.) to overcome the continuous cropping problem of ginseng and improve the growth of ginseng,
- (iv). Effects of adding rotten crop straw on activity of soil microflora, growth and development of ginseng,
- (v). Application effects of ginseng soil-less culture (organic form soilless culture, hydroponics, etc.).
- (vi). Antagonistic effects between the beneficial and pathogenic microorganism in ginseng continuous cropping soil and the effective measures to maintain the balance between the beneficial and pathogenic microorganism to alleviate continuous problems of ginseng.

7. CONCLUSIONS

Ginseng continuous cropping problem is caused by many factors and their interactions, and the causes are very complex. For many years, extensive and in-depth researches have been done on continuous cropping problems of ginseng from many aspects (Soil structure, soil physicochemical properties, soil nutrients and soil microorganisms, etc.). These studies showed that the continuous cropping problem of ginseng was mainly related to physico-chemical properties of soil, soil microbial flora, soil borne pathogenic bacteria, autotoxicity, etc. The development mechanism of continuous cropping problems of ginseng is still not very clear, it is very complex and results from the multi-factors interactions and its control measures are very limited. Allelochemicals from ginseng may be one of the important factors leading to problem of ginseng. Much researches have been done on the causes of continuous cropping problem of ginseng, and suggested many measures to overcome it.

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DECLARATION

We declare that all authors of this Ms. have made substantial contributions. We did not exclude any author who substantially contributed to this Ms. We have followed our ethical norms established by our respective institutions.

CONFLICT OF INTEREST

The authors announce that they have no conflict of interest.

ETHICAL APPROVAL

The authors declare that the study was carried out following scientific ethics and conduct. However, this study did not involve any use of animals, hence no ethical approval has been obtained from the concerned committee.

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