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Studies on the Genesis of Ginseng Rust Spots

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Abstract : In order to explain the connection between ginseng rust spot and soil ecological conditions, the bed soils and ginseng roots were sampled at different microrelief units and the reducing substances of the bed soils and iron froms of the ginseng root epi dermises were determined. The results showed that the occurrence of the rust spot was connected with the ecological conditions of the soils and the metabolism of the plant which was caused by the excessive Fe^{2+} in the soil solution. Ginseng rust spot was the enrichment of iron which was mainly composed of organic complex irons. including active ferrous active ferric and non active ferric forms and they were transformed into each other following the change of soil moisture and temperature regimes. According to the regularity of growth and decline of reducing substances in soil and rust index of ginseng roots as well as the difference of adaptability to excessive Fe^{2+} in soil among different year-old seedings, a new comprehensive measure based on the connection of ameliorating soil and improving cultivation system was recommended to prevent the occurrence of ginseng rust spot.

Key words : *Panax ginseng*, ginseng rust spot, albic soil.

Introduction

Ginseng rust spot is one of physiological disorder, whose characteristic is that the epidermises of the roots become rusty. At the begining the rust spot was on some parts of main or lateral roots. Whith the increase of root age. the major part of main roots or the whole roots might become rusty, only the ends of the fibrous roots appeared as a white color.

The ginseng which had rust spot was mainly distributed on the lava platform in Jilin province, were the soil type is albic soil with a fine clay and non-permeable layer. The yield of ginseng did not drop down significantly when the rust spot took place, but the rust epidermises of roots must be peeled off by hand thus the quality of ginseng would drop 2-3 grades.

Moreover, the roots should be processed to shine-dry ginseng (white ginseng), so the ginseng farms would suffer from heavy economic losses.

Studies on ginseng rust spot were carried out on quite early in our country. In the early sixties. Wang[1)] first reported that the occurrence of ginseng rust spots was the result of the precipitation of Fe and Mn on the surface of its root epidermises when ginseng grew in aquic soils. Such spot belonged to a physiological disorder.

In the middle of sixties, research work was stopped, so no progress had been made in this area. In the early eighties, Zhang *et al.*[2)] summarized the experiences about how to prevent rust spot on the farms of Fusong and Jinyu counties and pointed out that the genesis of rust spot was connected with the high content of orgainc matter which was not fully decomposed as well as soil water. They recommended the following prevention method: using the soil turned up the previous year, mixing the yellow subsurface layer with low organic matter, processing higher beds and tilling the soil early and so on. Due to the lack of theoretical studies, those measures could not be applied by ginseng farms. Meanwhile, a few research works persisted in stating that rust spots were produced by some orange red bacteria[3], but there was no success in artificial infection of the red bacteria. In the late eighties, Wu[4] determined the contents of 11 inorganic elements in the epidermises of rust roots and gave a regression between them. He conculded that besides Zinc (Zn), the rust spot was significantly postively correlated with Al, Fe, Mn, Ba, Ca, Sr P, Cu and Mg, but such a correlation should be studied furthey. In the early nineties. according to the formation theory of albic soil, Gao and Jin[5] declared that rust spot was resulted from the accumulation of Fe and Mn on the surface of epidermises of ginseng roots with the alternate occurence of oxidation and reduction in the soils. He claimed that the high water content of bed soil was the principal cause of the rust spot, so in order to control the rust disease thoroughly, the farms should possess underground drain system. Obviously, during the past thirty years or more, there was some progress made in this area, but the research work was still insufficient. Most of the research work was limited in theoretical explanation, and few experiments were done. Moreover, the major experiments perfomed were over the simple com parison of healthy roots with diseased ones or the comparison of soils in the same manner. The major works done lacked any connection with soil ecological conditions and let alone the studies on adaptability of ginseng for the unfavorable circumstances.

In order to explain the relationship between the rust spot and the soil ecological conditions, we sampled bed soil and ginseng roots at different microreliefs : mount, level and depression. Then we determined the reducing substances in soil solution and the iron forms of the epidermises of ginseng roots, made a linear regression for revealing the interactions among the soil reducing substances, the epidermis iron forms and rust index of ginseng roots. Meanwhile, we carried out the annual dynamic observation for three years and made the seasonal observations on 4-6 year old plant at growing stages. Besides these, we also determined the iron forms, humic composition, porosity regimes in soil, and carried out the field trials for preventing the occurrence of gnseng rust spot. All results above mentioned became the basic for reviewing the cause of the genesis of ginseng rust spot and producing prevention measures against ginseng rust spot. Thus the completed research work has an important significance for enriching and developing research of ginseng rust spot in China.

Materials and Methods

1. Collection of samples

The bed soils and the ginseng roots were sampled at three micro-relief : mount, level and depression. The area sampled was 1~1.5 cm^2 and had 50-80 roots, which were different from the root age.

In the areas sampled, buck density was frist determined, then the original-liking soils were collected, sealed closely and sent into the laboratory as soon as possible. The fresh samples were used to determine the reducing materials while the weathering-dry ones were used to determine humic composition, iron forms and others.

When the roots were taken out from the area sampled, the granule (< 5 mm) adhered to the fibrous roots were collected, the weathering-dry samples were used to determine the available nutrients (N, P, K, Fe, Mn, B, Zn and others).

Then the roots were sent into the laboratory. After the roots had been washed the rusty area of every root was observed. The epidermises of main roots were peeled off, which were used to determine Fe, Mn, iron forms and others.

In order to observe the influence of the exessive Fe^{2+} in soil solution on the metabolic process of ployphenol oxidation, according to the rust spot class (0, 10~20, 40~50%) the roots were selected repectively from the area sampled on mount or level (its upper slope). In this case the fibrous roots might keep white and parts of them were used to determine the polyphenol.

2. Methods of determination

The methods of determination reducing materials in soil solution, total Fe, Mn and iron forms in epidermises, iron forms in-soil, humic composition, buck density, available nutrients and others were carried out according to reference 6~9. Besides, the polyphenol in roots and the vigourity of roots were determined according to reference 12 and 13, respectively.

3. Calcluation of rust index

All roots collected from an area sampled were taken as a mixed sample. Estimating the rust spot area on every root, formula : calculated the rust index as the following

$$\text{Rust index} = \frac{\Sigma\ (\text{every class number of rusty roots} \times \text{every class representative value})}{\text{total root mumber observed} \times \text{the representative value of the highest class}}$$

Among them, 0-class denoting non rust spot, 1-class denoting the rust spot area<10%, 2-class denoting that 10~25%, 3-class denoting that 25~50%, 4-class denothing that>50%.

Results and Discussion

1. The influence of reducing substances in bed soil and their interaction with the ginseng rust spot

The irons contained in the epidesmises of ginseng were attributed to the enrichment of iron in soil. Iron is a changeable element in its valence. Its chemical behaviour is connected with the oxidation-reduction regime in soil. A characterisic of the bed soil to be tested is that it is too porous to measure Eh value in the field, so we collected fresh soil samples and determined the total reducing substances, active reducing substances, Fe^{2+}, active organic matter and Mn^{2+} in soil soution. The results showed that the reducing substances in bed soil varied with the change of the relief units : the concentration of reducing substances of the mount was low while that of the depression was high, and the concentration of reducing substances of the ground level was between them (Fig. 1). Thus it could be seen that in the lava platform regions, ginseng rust spot was seen not only within the depression, but also within the mount. Within the mount the degree of the rust was more slight than that within the depression.

Table 1 denoted that reducing substances had a relationship with the rust index. The relationship coefficient of the total reducing substances was lower than that of the active reducing substance (r=0.896**, 0.984**, n=8), which meant that in the occurrence of ginseng rust spot the active reducing substances could play an important part while the non active reducing substances were of secondary significance. The active reducing substances were composed of Fe^{2+} and active organic matter. Compared with rust index, Fe^{2+}'s coefficient was lower than that of active organic matter (r=0.682, 0.966**, n=8). There was a better re-

Micro-relief	Mount	Level	Depression
soil type	Common albic soil	Perchic ablic soil	Pachic meadow soil
Ratio of relative height	2.5	1.2~1.5	1
Moisture regime	Lateral infilteration	Lateral infilreration	Periodicly wate-sturaled
Active reducing substances (cmol(+)/kg)	0.199	0.168~0.269	0.273
Characteristic of rust	Slightily, solwly	Heavily, fast	Most heavily, very fast
Rust index	0.282	0.256~0.994	1.000

Fig. 1. The relationship between the relief-soil ecological conditions and ginseng rust spot.

Table 1. Correlation matrix of reducing substances in soil and rust index of ginseng roots

Item	Total reducing substance	Active reducing substance	Fe^{2+}	Active O.M.	Mn^{2+}	Rust index
Total reducingn substance	1	0.825**	0.616	0.796*	-0.761*	0.896**
Active reducing substance		1	0.707*	0.981**	0.601	0.984
Fe^{2+}			1	0.570	0.522	0.682
Active O.M.				1	0.583	0.966**
Mn^{2+}					1	-0.614
Rust index						1

Total samples were 8, among them numer 3, 4 from mount and depression respectively, the other number 1-2, 5-8, from ground level. OM : Organic matter.

$p<0.05$, sufficient level (*), $p<0.01$, very sufficient level (**), n=8.

Table 2. Correlation matrix for humic acid and Fe_0/Fe_d in soil, epidermis active ferrous form and rust index of ginseng roots[1]

Item[2]	O.M.	HA+FA	HA	FA	Active O.M.	Active ferrous from	Fe_0/Fe_d	Rust index
O.M.	1	0.906**	0.849**	0.600	0.509	0.522	0.784*	0.578
HA+FA		1	0.909**	0.885**	0.697	0.652	0.841**	0.724*
HA			1	0.611	0.542	0.839*	0.764*	0.693
FA				1	0.716*	0.562	0.738*	0.655
Active O.M.					1	0.951**	0.725*	0.966**
Active ferrous form						1	0.646	0.990**
Fe_0/Fe_d								0.728
Rust index								1

[1] $p<0.05$ sufficient level (*), $p<0.01$, very sufficient level (**), n=8.

[2] O.M. : organic matter, HA : humic acid, FA : fulvic acid, Fe_0/Fe_d : ratio of amorphous iron to free iron.

lationship between Fe^{2+} and the active organic matter (r=0.570, n=8), but their relationship coefficient could not reach a sufficient level. The cause might be the looseness of the bed soil and Fe^{2+} was apt to be oxidized, so that the concentration was varied markedly and the relationship coefficient between. Fe^{2+} and the active organic matter could not reach a sufficient level.

The bed soil had high active organic matter (0.10 ~0.15 cmol kg^{-1}), which was sufficiently related to the ratio of Fe_o/Fe_d of bed soil (r=0.725*, n=8), and was very sufficiently related to the rust index or the active ferrous in epidermises of the ginseng roots (r=0.966**, 0.951**, n=8) (Table 1, 2). The soil type to be tested was a weakly reduced soil, and the field Eh was 300 mv more or less. The active organic matter existed in marked amounts and played the most important roles, not only causing ferric forms to be reduced to the ferrous forms, but also keeping the concentration of ferrous ions in soil solution to a critical level, and preventing the Eh in soil solution from suddenly dropping down.

The result indicated that as the lapse of the ginseng age increased, the organic matter of bed soil was decreased and the concentration of reducing substances was also reduced[10]. Because the beds were just processed and transplanted, the bed soil was too loose to measure the initial concentration of the active reducing substance. But according to their annual average decreasing amount, the concentration of the active reducing substance within the level ground was 0.020 mg kg^{-1} and the depression was 0.022 mg kg^{-1}, whose amounts were verg close. Thus, we found that the initial concentration of the active reducing substance was 2.3~3.6 times higher than the critical concentration (0.05 mg kg^{-1}).[10]

Because of the limitation of testing conditions, it was not clear what the composition of the active organic matter was. But there existed a better relationship between the active organic matter and the other three variables (HA+FA, HA, FA) (Table 2). It was suggested that the active organic matter might contain FA and HA with low molecular weight, which had the capacity of solution complexity and reduction.

Fe^{2+} was the inorganic part of the active reducing substances. The statistical data showed that Fe^{2+} was positively related to rust index ($r=0.682$, $n=8$), i. e., the formation of rust spot was closely connected with the amount of Fe^{2+}. The other statistical data denoted that there was no relationship between the total iron of soil and the rust index but there was a sufficient relationship beteween the Fe_o/Fe_d in bed soil and the rust index (Table 2). Meanwhile, the relationship coefficient between active organic matter and Fe_o/Fe_d was relatively highy sufficient (Table 2). These implied that the Fe^{2+} in soil solution was related to the transformation of amorphous iron.

The field trial showed that the concentration of the reducing substances in bed soils varied with the lapse of ginseng growing stages and there was a seasonal regularity[10] with regard to the concentration of reducing substance in soil solution. At the beginning of leaf-unfolding, the concentration of reducing substances increased gradually. The concentration was the highest on the first of August when it was the very season of high temperature and sufficient precipitation, then it dropped down gradually and finally varied smoothly. At the begining of the upfolding-leaf, the rust index of the ginseng root increased gradually and reached the maximum value, then it varied smoothyl. The result had important significance for recognizing the regularity of the genesis of ginseng rust spot.

2. Epidemis iron forms of ginseng root and their transformations into each other

Total iron was the characteristic index of ginseng rust spot, but in could not explain the existance of iron forms and the periodic change of iron enrichment. In order to explain the iron forms of ginseng root epidermises, first, we extracted the fresh sample with cold water in the field condition. We, however, did not discover the red reaction when the extract reacted with O-phenanthroline. Hence, there was no Fe^{2+} in the epidermises of ginseng root[10], but when 6M HCl was used to extract fresh samples, the red reaction appeared as the extract was treated with O-phenanthroline. After the extract was treated with hydroxylamane hypohloride, Fe^{2+} increased in the solution, which showed that the solution contained Fe^{3+}. The auther might name the iron extracted by 6M HCl as active iron, including the active ferrous and ferric forms, and name the difference between total iron minus active iron as non active iron. Besides, when the fresh samples were treated with 2, 2-bipyridyl, the solution appeared as a red colour, which proved that the active ferrous form was a complex compound with a small complex contant. The ferrous forms could be transformed into a ferric form through oxidation and the latter could be transformed into non active irons through dehydration.[10]

Table 3 showed that there was a high relationship between the four iron forms and the rust index. They all reached the sufficient or very sufficient level ($r=0.946^{**}$, 0.831^{*}, 0.844^{**}, 0.990^{*}, $n=8$). Among them, total iron and active ferrous form had the greatest coefficient with the rust, and they could be considered as the characteristic indexes. As the four iron forms were sufficiently correlated with active organic matter, it was considered indirectly that the epidermis irons were mainly composed of the organic complexing iron. Moreover, the epidermis ferrous forms were certainly correlated with the Fe^{2+} in soil solution, although they did not reach a sufficient level. This fact could be used to identify the Fe^{2+} in soil solution to play the important role in the formation of ginseng rust spot.

Active ferrous forms were the starting point of enrichement for iron in soil toward the ginseng root epidermises. The contents of the active ferrous forms of rusty ginseng were higher than that of the active ferric forms, and still higher than that of healthy ginseng. For example,

Table 3. Correlation matric for epidemis iron froms, soil reducing substances and rust index

Item	Fe_t	Nonactive Fe	Active ferric	Active ferrous	Mn_t	Fe^{2+}	Active O.M.	rust index
Fe_t	1	0.962**	0.694	0.924**	-0.691	0.684	0.931**	0.946**
Nonactive Fe		1	0.512	0.793*	0.536	0.622	0.828*	0.831*
Active ferric			1	0.891	0.574	0.480	0.751*	0.844**
Active ferrous				1	0.783*	0.637	0.951**	0.990**
Mn^t					1	-0.691	-0.771*	-0.796*
Fe^{2+}						1	0.570	0.682
Active O.M.							1	0.966**
Rust index								1

$p<0.05$, sufficient level (*), $p<0.01$, very sufficient level (**), n=8, O. M. : organic matter.

both were the same with 6-year-old plant and the contents of active ferrous forms of rusty ginseng were 72~218 mg kg^{-1}, while that of healthy ginseng only 40 mg kg-1. With the increase of ginseng age, the ratio of the active ferric form to ferrous form gradually increased, but the ratio of active ferric forms to non active form decreased, which reflected the tendency of transformation among the different iron forms[10]. The observations of fixed position in the ginsgeng farm indicated that from the seedling stage to the yielding stage the three iron forms previously mentioned were varied with the periodicchanges of soil moistures and temperature regimes.

Statistical results (Table 2) also showed that the active ferrous forms were correlated with HA+FA (r=0.652. n=8), or very sufficiently related to active organic matter (r=0.951**, n=8). These facts might imply that the formation of rust spot could certainly be related with active humus acid, and that there might exist certain properties of natural humus matter in the composition of gineseng rust spot.

3. The antagonism of Fe^{2+} to Mn^{2+} in soil solution

It was the common view that the rust spot of ginseng root epidermises resulted from the coprecipitation of Fe and Mn. But as it might be shown in Table 1, Fe^{2+} in soil solution was positively related to rust index (r=0.682, n=8), while Mn^{2+} in soil solution was negatively related to rust index (r=-0.633, n=8). Besides, Fe^{2+} was negatively correlated with Mn^{2+} in soil solution, although they had not reached the sufficient level (r=-0.552, n=8). These implied that Fe^{2+} and Mn^{2+} in soil solution existed in antagonism with each other. The cause was that under the acid condition, the E_0 of Mn^{2+}-Mn^{4+} system is higher than that of Fe^{2+}-Fe^{3+} system and Fe^{2+} was ahead oxidized, while Mn^{2+} existed stably in soil solution. During the growth period of ginseng, although iron and manganese were enriched at the same time on the epidermis of ginseng roots, the contents of the total iron were markedly higher than that of the total manganese. For example, for 6-year-old ginseng, the contents of total iron of the rust root were 858~1068 mg kg^{-1}, while the contents of total manganese were only 50~82 mg kg^{-1}. As was shown in Table 3, ginseng root epidermis iron was sufficiently postively correlated with rust index (r=0.946**, n=8), while the ginseng root epidermis manganese was negatively related to rust index to sufficient level (r=0.79*, n=8). Meanwhile, the epidermis iron was certainly negatively correlated with the epidermis manganese (r=-0.691, n=8). Apparently, it was the reflection of antagonism of Fe^{2+} to Mn^{2-} in the soil solution through the rust spot. Thus, we considered that the rust spot was minaly the enrichment of iron in soil, and was not the result of coprecipitation of Fe and Mn.

The result obtained from the rhzosphere soil samples showed that the genesis of ginseng rust spot was certainly correlated with the lack of the effective B in soil and their negative coefficient was sufficient (r=-0.770*, n=8). This implied that the effective B in soil might play the role in restraining the genesis of ginseng rust spot. The

Table 4. The change of soil porosity regime

Age	Soil characterisitic	Date					
		June, 8	June, 30	July, 16	Aug, 2	Aug, 17	Sep, 1
4	Bulk density (gcm^{-3})	0.481	0.495	0.488	0.470	0.643	0.460
	Porosity (%)	80.6	81.5	80.2	81.0	81.3	82.0
	Water-holding pore (%)	29.5	33.4	33.5	38.3	35.7	34.7
	Air-filled pore (%)	51.1	48.1	46.7	42.7	45.6	47.3
6	Bulk density (gcm^{-3})	0.574	0.579	0.563	0.573	0.575	0.591
	Porosity (%)	76.9	74.8	77.2	76.9	76.8	76.2
	Water-holding pore (%)	34.2	36.8	36.7	39.0	37.9	37.2
	Air-filled pore (%)	42.7	38.0	40.5	37.9	38.9	39.0

effective B was low in albic soil and was apt to be exhausted by ginseng, so the application of B fertilizer might be an effective measure for the prevention of ginseng rust spot.

The result determined from the neutron activated method denoted that Fe, Al, Eu, Sc and La *et al* inorganic elements of ginseng root epidermisis were positively correlated with rust index, whose coefficient reached the sufficient or very sufficient level ($r=0.554^*$, 0.689^{**}, 0.541^*, 0.608^*, 0.529^*, $n=14$) and Mn, Mg and K *et al* inorganic elements of ginseng root epidermises were negatively related to rust index, whose correlation coefficient reached the very sufficient or sufficient revel or neared to the sufficient level ($r=-0.689^{**}$, -0.593^*, -0.490, $n=14$). The epidermis Fe was very sufficiently correlated wit Al, Eu, Sc, and La, which indicated that there existed cooperation effect among these elements. For example, the essence of the cooperation effect of Fe and Al might be connected with Al^{3+} in soil solution, which could supply H^+ that was necessary for Fe^{3+} transformed into Fe^{2+} or for the formation of complex-Fe. Sc, La and Eu are the higher valence elements in the pericdic table, and La and Eu are the elements of the lanthanide series at the same time whose concentration were very diluted in soil. Perhaps, these elements might possess the catalytic reaction in the oxidation or reduction process, but the essence of their interaction should be researched further. As for the antagonism of B, Mg and K to the rust spot, whether they might control the equilibrium of phenolquinone oxidation-reduction system was a question which required further verification.

4. The characteristic of soil pore space and its role in the formation of ginseng rust spot

Table 4 showed the characteristics of soil pore space. It was obvious from the table that the bed soil possessed the important characteristic of both high capicity in water-holding pores and air-filled pores which created the necessary condition for carring out the necessary condition for carring out the oxidation process as well as the reduction process in soil. The air-filled pores were a necessary arena for the oxidation process, thus the iorn oxides on the surface of soil particle would be reduced into Fe^{2+} through the superficial complexing reduced reaction. The water-holding pores were a necessary arena for reduction process, thus Fe^{3+} in the soil solution would be reduced into Fe^{2+} through the anaerobic process. Both common effects were that the concentration of Fe^{2+} in the weakly reduced soil could be kept at a certain level so that the Eh of soil solution could not be dropped down suddenly, which was a necessary condition for the formation of ginseng rust spot. Beacuse the two processes carried on at the same time, when the content of soil water reached the top of the whole year in the first days of August, the active ferric forms as well as the active ferrous forms were increased at the same time, which could not be explained by traditionl theory, that is, the oxidation process and the reduction process could carry on alternately. It was obvious that it was not necessary to emphasize drainage for prevention ginseng rust spot.

Stastical data showed that the air-filled pores were positively correlated with the ratio of active ferric forms to active ferrous forms, the relationship coefficient reached the very sufficient level ($r=0.850^{**}$, $n=8$) and the water-holding pores were negatively correlated with the ratio of active ferric forms to non active ferric forms, but their relationship coefficcient had not reached the sufficient level ($r=-0.661$, $n=8$). These denoted that the soil water was an importent condtion for transformation of three iron forms into each other.

5. The connection of ginseng rust spot with the metabolic process of ginseng plants

Field observation showed that the plants existed normally and were not retarded obviously in spite of the higher concentration of Fe^{2+} in soil (as in depression). This implied that ginseng had the ability of being adapted to the high concentration of Fe^{2+} in soil. There existed the stable brown colour on the surface of ginseng roots, meaning the formation of rust spot connected with the brown reaction. This fact implied that quinone might exist in the composition of rust spots. As same as the other plant, there was the phenol-quinone oxidation-reduction system in ginseng and H^+ or activated O_2 could be secreted from the system.[11] According to these acquaintances already mentioned, we determined the amount of polyphenol compounds in ginseng roots with the Folin method.[12] As shown in Table 5, the amount of polyphenols in ginseng roots had correlative tendency to that of ginseng rust spot but the tendency of synchronism was different form the age of ginseng, so the amount of polyphenol varied with the lapse of ginseng age. From 4-year-old to 5-year-old, the plant photosynthesis was strengthened gradually, thus the amount of polyphenol was increased with the age of ginseng; but photosynthetic ability of 6 year-old ginseng was decreased and the roots vigour also declined, so the amount of polyphenols in ginseng root's was decreased. Just as the 4-5-year-old plant, the amount of polyphenol of the 6-year-old still kept the same thendency from light to heavy. The reason seemed to be that when the Fe^{2+} in soil solution was increased, the potentality of root oxidation was strengthened and the polyphenol was promoted to oxidize into quinone so that the latter was markedly secreted to the rhizosphere, where the quinone was not stable and apt to be reduced into phenol by the promoting enzyme reaction. The phenol was complexed reaction. The phenol was complexed with Fe^{2+} in soil solution, thereby eliminating the damage to ginseng caused by the excessive Fe^{2+} in soil solution. This result provides a primary suggestion for further study on the cause of adaptability of ginseng for the unfavorable circumstances.

Table 5. The concents polyphenols in ginseng root

Age	Main root with no rust spot ($mg\ kg^{-1}$)	Main root with slightly rust spot ($mg\ kg^{-1}$)	Main root with markedly rust spot ($mg\ kg^{-1}$)
4	568	608	–
5	600	640	680
6	–	504	608

6. The comprehensive measures for the prevention of ginseng rust spot

According to the regularity of growth and decline of active reducing substances in bed soil and the difference in the adaptation of different year-old ginseng to excessive Fe^{2+} in soil, we adopted the comprehensive measures with soil and cultivation system amelioration as the basic meaures. The soil and cultivation system ameliorations were the two circles not departing from each other. The first year of ginseng transplant, the amount of active reducing substances was much more in soil solution so that the addition of loess (e. g., the subsurface layer with less organic matter) was necessary for diluting the concentration of reducing substances. However, its amount should be suitable and in additon, its effect of prevention could be seen only in the first or second year. This implied that the addition of loess could not be always effective. Under this tested condition, it was better that when the soil contained organic matter 8~10% and the amount of loess added was 10~20% (volume%) and when the 3-year-old seedlings were transplanted the roots of 5-year-old plant should be taken out from the bed soil. In comparison with the 3-year-old seedlings, the 1-or 2-year-old seedlings were smaller in their main root, less in their fibrous roots, weaker in their transpiration and faster in the renewal of their epidermises. All of these already mentioned factors had important significance for alleviating the incidence of rust spot. As far as the vigour of the seedling roots, there existed the difference with the following order: 1 year-old > 2 year-old > 3 year-old. This order reflected the difference in the rhizosphere oxiding circumstance. Thus the combination of soil and cultivation system ameliorations was a more effective model for the combination of transformaing the circumstance with adapting to the circumstnce, so we set up a new way to prevent the ginseng rust spot. When the rust index was > 90%, the effect of prevention was more than 300%. As to considering the economic effect. We recommended the 2~3 system, i.e. the 2-year-old seedlings were transplanted and the roots of 5-year-old plant were harvested from the bed soil, so that the higher yield could be kept.

Summary

1. Ginseng rust spot was the products of specific soil ecological factors and also its feedback form adapting the excessive Fe^{2+} in soil. The active organic matter was the main factor causing the genesis of ginseng rust spot.

2. Ginseng rust spot was the enrichment of iron, and mainly composed of organic complex irons, including active ferrous, ferric and non active ferric forms. The ratio of Fe^{2+} to Fe^{3+} forms and the ratio of active iron to non active iron regularly varied with the soil moistures and temperature regimes.

3. Transferring the amount of active reducing substances in bed soil, changing the 3:3 into 2:3 cultivaton system, and controlling the equilibratory direction of phenol-quinone oxidation-reduction system, all of these previously mentioned should be the basic way to prevent ginseng rust spot, which should be summed up and improved in practies.

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