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RESEARCH ARTICLE

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Threshold criteria for heavy metals in the soils of hazard-free dry fruit production regions of China

Abstract Determination of proper threshold criteria for heavy metals in soils is an important basis for hazard-free dry fruit production in China. Based on the detection of heavy metal contents in soils in this study, it is initially concluded that the soils for dry fruit production in China are suitable for hazard-free growing. Moreover, the soil safety qualification for dry fruit production is much better than that in some developed countries or regions, which might help our production have a competitive advantage on the international market. However, soil Cr contents in the country are slightly higher, so that it is necessary to take steps to control any contamination during the whole chain of production. The following threshold criteria for heavy metals in soils is suggested according to physical, ecological and economical considerations: Hg 0.15 mg/kg; As 20 mg/kg; Pb 50 mg/kg; Cd 0.30 mg/kg and Gr 200 mg/kg.

Keywords threshold criteria, hazard-free, dry fruit, soil, heavy metal

1 Introduction

Soil environmental quality in production regions is one of the primary factors that affect the safety of dry fruit (OuYang, 1999; Feng and Yan, 2002; Nie and Dong, 2002). Hazard-free dry fruit production requires that heavy metal contents in soils must be below a certain limit, so as to maintain ecological balance, human health and sustainable development of agricultural production. However, a great variation exists in chemical and biological effects of heavy metals in soils as well as in the interaction between those metals and environments due to the complexity of soil system. Therefore, the formulation of the threshold limit of contaminated substances in soils is not only more difficult but controversial in comparison with proposing the threshold criteria of polluted substances in both atmosphere and irrigation water. For this reason, there has not been any mandatory standard for limiting heavy metal contents in soils in most countries on the world so far (Meng et al., 2000).

In China, dry-fruit crops include both nuts and some kinds of fruits that can be processed as dry products such as Chinese date (*Zizyphus jujuba* Mill.) and Japanese persimmon (*Diospyros Kaki* L. F.). Those fruit species have been mainly grown in hilly, mountainous areas or parts of the plain areas where the soil property is generally favorable. However, soils in some orchards have become deteriorated in recent years due to a contamination from factory wastes (dust, polluted air and water) and improper application of agricultural chemicals, thus bringing a great threat to sustainable fruit production (Zhang, 2001; Zhong et al., 2001; Feng et al., 2002). The present study aims to propose a threshold criterion for heavy metals in soils used for hazard-free dry fruit production on the basis of extensive investigation and evaluation, so as to safeguard a smooth and healthy development of dry-fruit production in the future.

2 Materials and methods

Based on the commercial distribution of dry fruit crops in China, 10 representative orchards where the following fruits were grown, including walnut (*Juglans regia* L.), chestnut (*Castanea mollissima* Bl.), pistachio (*Pistacia vera* L.), Japanese persimmon, hickory (*Carya cathayensis* Sarg.) and Chinese date were selected from the Xinjiang Uygur Autonomous Region as well as Yunnan, Zhejiang, Hunan, Shaanxi, Shandong and Hebei provinces. At present, two types of growing models are being adopted in China, i.e. fruit-only

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orchards and intercropping ones. Among the orchards investigated, the walnut and pistachio orchards from the Xinjiang Uygur Autonomous Region, the chestnut orchard from Tai'an, the hickory orchard from Lin'an and the Chinese date orchard from Pingshan belong to fruit-only orchards with the rest being intercropping ones. Generally, the extent contaminated by heavy metals in soils is more severe in intercropping orchards than fruit-only ones as the result of frequent fertilizations and chemical applications on intercropped crops. Soil samples with depths of 40–60 cm were collected from the orchards and five locations were chosen along a diagonal line across each of the plots. A soil profile was made with a spade before a soil sample was collected with a bamboo spade to avoid any potential contamination.

The selection of hazardous heavy metals in soils is greatly based on the current requirements for evaluation on hazard-free food, which are usually regarded as more toxic and easy to be accumulated by plants. According to these principles, five kinds of soil heavy metals including Hg, As, Pb, Cd and Cr are chosen and assayed in this study.

The assay was conducted at Analytical and Testing Center of Hebei Province, situated at Hebei University of Science and Technology. Soil sample was prepared with wet nitrification. The dry soil sample was first ground and passed through a 2 mm nylon screen and then through a 100# screen, with later fully mixing with the soils for further measurement. A sample of 0.3 g weighed with a precision up to 0.000 2 g was put into a crucible pot containing tetrachlorethylene. Five mL of HNO_3 was added when the reaction liquid evaporated and left to 2 to 3 mL, and then 5 mL of HCl, 4 mL of HF and 2 mL of $HClO_4$ were added. Evaporation continued until the sample was almost dry, and HF could be added when necessary in order to achieve a complete release of all elements inside the silicon crystal lattice. When the color of sample in crucible pot turned gray-whitish, 1 mL of HNO_3 was added. Then, the sample was left cooled and transferred to a 25 mL volumetric flask and exactly filled with distilled water. Five kinds of soil heavy metals were quantified by means of relevant methods described in the following national standards: As (Silver diethyldithiocarbamate spectrophotometry, GB/T 17134), Hg (Cold atomic absorption spectrophotometry, GB/T 17136), Cd (Flame atomic absorption spectrophotometry, GB/T 17137), Pb and Cr (Graphite furnace atomic absorption spectrophotometry, GB/T 17141).

3 Results

3.1 Present status of soil heavy metal contents in dry-fruit orchards

The amounts of soil heavy metals are shown in Table 1. Based on the current national standards for soils of hazard-free fruit or green food production, none of the five metals exceeds the standards in all of the orchards (Table 2). In fact, in most of the orchards, the amounts are much lower than both standards. Moreover, the amounts of Hg or Cd in soils are tiny or negligible in some orchards.

3.2 Evaluation on the present situation

The results indicate that the amounts of soil heavy metals from ten orchards are lower than the standards for hazard-free fruit producing areas (GB18407.2-2001 issued by General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, 2001, or Called Standard I herein). If they are compared with the standard for the environment of green food production (NY/T 391-2000 issued by Ministry of Agriculture of the People's Republic of China, 2001, or called Standard II herein), the concentration

Table 1 Heavy metal contents in soils of different dry-fruit orchards in China (mg/kg, pH 6.9–8.1)

Location	Species	Hg	As	Pb	Cd	Cr
Akesu, Xinjiang	Walnut	0.020 0	11.030	0.840	0.056	99.16
Kashi, Xinjiang	Pistachio	0.005 0	27.890	8.360	0.098	93.70
Kunming, Yunnan	Walnut	0.007 8	20.420	13.470	0.076	122.50
Taian, Shandong	Chestnut	0.003 9	0.473	4.910	0.080	159.07
Taian, Shandong	Walnut	0.010 2	8.027	4.390	8.7×10^{-5}	128.00
Feicheng, Shandong	Walnut	0	5.497	9.745	1.3×10^{-4}	171.00
Yangling, Shaanxi	Persimmon	0	7.511	7.050	4.15×10^{-5}	193.00
Zhuzhou, Hunan	Chestnut	0.004 2	12.500	2.100	1.004×10^{-4}	103.00
Linan, Zhejiang	Hickory	0	15.600	3.450	8.4×10^{-5}	93.00
Pingshan, Hebei	Chinese date	0	17.620	35.740	0	123.00

Table 2 Comparison of heavy metal contents with relevant standards (mg/kg, pH 6.5–7.5)

Item	Hg	As	Pb	Cd	Cr
Environmental requirements for the origin of pollution-free fruit[a)]	0.50	30	300	0.30	200
Green food technical conditions for environments of producing areas[b)]	0.30	20	50	0.30	120
Range of tested values	0–0.02	0.473–27.89	0.84–35.74	0–0.098	93.0–159.07

Note: [a)]General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, 2001;
[b)]Ministry of Agriculture of the People's Republic of China, 2001.

Table 3 Comparison of heavy metal contents with soil element background values (mg/kg, pH 6.5–7.5)

Item	Hg	As	Pb	Cd	Cr
Background values in China*	0.065	11.2	26	0.097	61
Average of seven provinces*	0.05	12.64	26.1	0.12	62.74
Two-fold Sd. of background values	0.07	6.87	14.54	0.1	14.52
Range of tested values	0–0.02	0.473–27.89	0.84–35.74	0–0.098	93.0–159.07

*:Liu, 1991.

of each element can meet the requirement of heavy metal limits except a slightly higher total Cr amount from the six orchards. It is noted that the total Hg amount in dry-fruit orchards is much lower, with the maximal value being 14-fold less than Standard II and 24-fold than Standard I. Moreover, the total As amount in all of the orchards, except in Kashi and Kunming, is lower than Standard II. In addition, the total Pb content is 2.7 times lower than Standard II and 13.8 times lower than Standard I in all of the orchards except in Pingshan. Finally, the total Cd amount is two times lower than both standards. For these reasons, we can formulate stricter threshold criteria for dry fruit production than domestic fruit crops or foreign nut species for the sake of raising the competitiveness of dry fruit produce on different markets (Zhang and Wang, 1997).

In a comparison between soil element background and our tested values, the total Hg, Pb and Cd amounts obtained in this study are significantly lower than the natural background values plus 2-fold standard deviations, but the total Cr amount is higher than either of the values. The total As amount in all of the orchards except in Kashi and Kunming is also lower than element background values plus 2-fold standard deviations (Table 3). These results suggest that element background values representing the area concerned is not consistent with a particular dry fruit orchard. This may contribute to the deeper root system distribution and variations in localities, resulting in lower heavy metal contents than the average level of the seven provinces (except for Cr). Therefore, we cannot rely on the natural element background values completely when determining the threshold criteria for soil heavy metals. Appropriate adjustments should be made for a reasonable determination on the basis of extensive investigation.

As compared with some developed countries or regions where the maximum allowance of heavy metals in soils is apparently higher, the Chinese dry-fruit orchards have much lower concentrations as far as four kinds of heavy metals are concerned (Table 4, Liu, 1991; Meng et al., 2000). For instance, the total content of Hg is 265, and that of Cd 34 times lower in China than in the United States of America, which might be used as a technical barrier in the international trade.

3.3 Determination of proper threshold criteria

Based on the comprehensive analysis in this study, the threshold criteria for soil heavy metal contents are suggested with a full consideration of native soil background values, the need for hazard-free dry fruit production, as well as the demand of future market competition (Table 5). Among these indices, the total Hg amount is determined by natural element background value plus 2-fold standard deviations; the total amounts of As, Pb and Cd depend largely upon a compromise between natural element background and tested values, and the total Cr amount is determined by combining our tested values with the requirements of relevant standards. During the determination of maximal limit of each of the heavy metals, we have made a full of consideration to meet both local conditions and the requirements for hazard-free dry fruit production in China.

Table 4 Maximum allowable concentrations of soil heavy metals in some countries or regions (mg/kg)

Country or region	Hg	As	Pb	Cd	Cr
European Union	1–1.5	–	50–300	1–3	–
USA	5.34	36.6	–	3.56	–
France	1	–	100	2	–
Germany	2	20	100	3	100
Italy	2	–	100	3	–
Scotland	0.4	12	90	1.6	–
England	1	4.5	550	3.5	–
Canada	0.5	14	63	1.6	120
Russia	2.1	15	Background value + 20	5	100

Table 5 Threshold criteria for heavy metal contents in soils of dry-fruit orchards in China (mg/kg, pH 6.5–7.5)

Heavy metal	Hg	As	Pb	Cd	Cr
Threshold value	0.15	20	50	0.30	200

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References

Feng M X, Wang P S, Wang J Q, Jiang R D (2002). Study on contamination of heavy metals and agricultural chemicals in soils of Qingdao suburbs orchards. China Fruits, (1): 24–26 (in Chinese)

Feng Z H., Yan H J (2002). Environmental and technical requirements for green food production. Shanxi Fruits, (4): 29–30 (in Chinese)

General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (2001). Safety of Agricultural Produce: Environmental Requirements for Origin of Non-environmental Pollution Fruit. GB 18407. 2-2001, Beijing: Standard Press of China (in Chinese)

Liu F Z (1991). Handbook of Agricultural Environment Monitoring. Beijing: Standard Press of China (in Chinese)

Meng F Q, Shi Y J, Wu W L (2000). Determination on soil environmental quality criteria of hazard-free produces and advance in researches in China. Agro-environmental Protection, 19(6): 356–359 (in Chinese)

Ministry of Agriculture of the People's Republic of China (2001). Green Food-technical Conditions for Environments of Producing Area. NY/T 391-2000, Beijing: Standard Press of China (in Chinese)

Nie J Y, Dong Y F (2002). Impact and control of heavy metal contamination in orchards. China Fruits, (1): 44–47 (in Chinese)

OuYang X H (1999). Discussion on monitoring and evaluation on environmental quality for green food production. Agro-environmental Protection, 18(6): 281–282 (in Chinese)

Zhang G L, Wang K R (1997). Present status and trend of studies on Cd contamination in both domestic and foreign agriculture. Agro-environmental Protection, 16(3): 114–117 (in Chinese)

Zhang Y (2001). Evaluation on the present status of soil and produce contamination with heavy metals in Shenyang suburbs. Chinese Journal of Soil Science, 32(4): 182–186 (in Chinese)

Zhong W K, Fan Y B, Wang M J (2001). Contamination and preventive strategy of soil heavy metals in agricultural crops in China. Agro-environmental Protection, 20(4): 270–272 (in Chinese)