***Pak. J. Bot.*, 55(4): 1313-1320, 2023.** **DOI: http://dx.doi.org/10.30848/PJB2023-4(13)**

EFFECT OF DIFFERENT SELENIUM FERTILIZER CONCENTRATIONS ON PEAR YIELD AND QUALITY

LEI WANG[1,2Θ], LIANG JIN[1Θ], JIAJUN WU[2], YAN LI[1], ZHIZHUANG AN[1], LINNA SUO[1], JIANLI DING[1], YEHUI HAN[3], CHAO ZHOU[3], JIANZHI XIE[2*] AND DAN WEI[1*]

[1]Institute of Plant Nutrition, Resources and Environment,
Beijing Academy of Agricultural and Forestry Sciences, Beijing 100097, China
[2]College of Resources and Environmental Sciences, Agricultural University of Hebei, Baoding, Hebei 071000, China
[3]Qiqihar Branch of Heilongjiang Academy of Agricultural Sciences, Qiqihar, Heilongjiang 161000, China
[Θ]Authors contributed equally
[*]Corresponding author's email: xjianzhi@126.com; wd2087@163.com.

Abstract

Excessive and deficit foliar fertilization adversely affects pear fruit yield and its qualitative characteristics. In the present study, we investigated the impact of higher to a lower foliar spray of amino acid selenium fertilizer concentrations on the Huangtukan pear variety. Foliar fertilizer treatments were 50.0 mg plant^{-1}, 60.0 mg plant^{-1}, 75.0 mg plant^{-1}, 100 mg plant$^{-1,}$ 150.0 mg plant^{-1}and 0.0 mg plant^{-1}(Control check, CK), which were sprayed on the interval of every 15 days since the full-bloom period (8 times in total) and stopped before the maturity stage. The results demonstrated that the pear's yield, quality, and absorption of nutrient elements first increased and then decreased with the increase of the selenium fertilizer concentration. In contrast, the absorption of the selenium was constantly increasing. When the mass concentration of the selenium fertilizer was 75 mg plant^{-1}, the pear yield, the soluble solids, and the vitamin-C content increased by 19.07%, 21.69%, and 85.2%, respectively, and titratable acid content decreased by 52.45%; content of major elements such as phosphorus and potassium increased by 42.48% and 89.18% respectively; sodium, magnesium, and sulfur increased by 191.53%, 78.68%, and 157.84% respectively; trace elements including selenium, boron, manganese, zinc, iron, and copper increased by 52.39%, 179.02%, 72.11%, 26.8%, 100.33%, and 55.94% respectively. Thus, based on the comprehensive analysis of different yield and quality attributes, it is concluded that the optimum foliar spraying mass concentration of the selenium fertilizer for the Huangtukan pear is 75 mg plant^{-1}.

Key words: Huangtukan pear; Selenium; Yield; Quality; Nutrient absorption.

Introduction

Selenium is an essential trace element for the human body, closely related to human health, immunity, and other aspects (Shi *et al*., 2009; Radomska *et al*., 2021; Wang *et al*., 2022). An adequate amount of selenium supplementation can prevent cancer and help identify and treat human cell mutations (Molnár *et al*., 2013; Kipp *et al*., 2015; Xu *et al*., 2021). Selenium can remove free radicals, reduce blood lipids, delay aging and enhance disease resistance (Agarwal & Behari, 2007; Fang & Xia, 2022). According to the recommendation of the Chinese Nutrition Society, the daily selenium intake of healthy adults' ranges from 50 to 200μg (Zeng *et al*., 2003). However, the human body cannot synthesize selenium. Diet is the safest and most effective way for the human body to supplement selenium (Chen *et al*., 2002). An estimated 72% of China's land area is a selenium-deficient zone (Longchamp *et al*., 2015), and soil is plants' main source of selenium absorption. Lack of selenium in the soil will lead to low selenium content in local agricultural products. To ensure the selenium content standard of agricultural products, the method of "selenium-rich soil + biological selenium transfer technology" is mainly used in production to ensure that selenium in selenium-rich soil is effectively utilized by plants and transformed into selenium forms easily absorbed by the human body (Yin *et al*., 2018).

Selenium-rich fruits, as functional fruits, are available at high prices in the market. Most of the exogenous selenium fertilizers in production are inorganic selenium fertilizers. The main components are quick-acting fertilizers such as sodium selenite, sodium selenite, and selenium mineral powder which are conducive to the absorption of plants and can permanently solve the problem of selenium deficiency (Wang *et al*., 2022). However, inorganic selenium is highly toxic, and the selenium-rich fruits produced by direct spraying have great potential safety hazards and easily pollute the environment. Hence, the application has limitations (Li *et al*., 2022). Most selenium compounds in soil are insoluble selenium salts, which have very low bioavailability and cannot be effectively used by plants.

Pear is one of the three major fruits in China. It has a long history of cultivation and a wide range of cultivation areas (Wang, 2017). The Huangtukan pear is rich in polysaccharides, vitamins, and minerals. Both traditional and modern experts believe that pear has the effects of lowering blood pressure, clearing away heat and calming (Wang *et al*., 2018; Hailisi *et al*., 2021), and it has high medicinal value. It also has the characteristics of high yield, high quality, storage resistance, wide adaptability, and good economic benefits.

Plant-derived organic selenium is safe, green, and efficient, which is the most beneficial way for humans and animals to ingest selenium. Selenium-rich fertilizer improves selenium in plants and has proved to be a reliable, low-cost, efficient, and convenient means of enrichment in fruits (Xue *et al*., 2016). The quality of pear fruit is significantly enhanced with the application of selenium fertilizer, reducing stone cells and improving leaves' growth conditions (Wang *et al*., 2012). Organic selenium fertilizer spray on the crisp pear 3 times could result in selenium content in the pear can reach at standard levels (Peng *et al*., 2015). In previous studies, the positive effects of selenium fertilization on cereals have been noticed as well. The application of sodium selenite on millet leaves and rice roots significantly increased the grain selenium content of millet (Zhang *et al*., 2010) and rice (Wang *et al*., 2009). Cheng *et al*., (2017) studied the 6-year-old late autumn yellow pear and found that amino acid selenium leaf fertilizer can significantly increase the selenium content in pear fruit.

Currently, the studies mainly focus on the effect of selenium fertilizer on yield of Yali pear. At the same time, there are few studies on the effect of selenium fertilizer on yield of other important pear varieties and their nutrient absorption. In the present study, we applied different concentrations of selenium fertilizer on Huangtukan pear as the research object to explore the effects of foliar spraying of amino acid selenium fertilizer on pear yield, quality, and absorption of large, medium, and trace elements and to provide a theoretical basis for the high-quality production and rational fertilization of Huangtukan pear.

Materials and Methods

Study area: The experimental site Zhuanshanzi village in Miyun district of Beijing is located at 40°30′N, 116°52′E. The planting area of the pear tree was approximately 666.67m^2 with a row spacing of 3m × 2m. The local climate belongs to the warm temperate and semi-humid monsoon conditions. The average temperature is 7~9℃, and the non-frozen period lasts for 172 days. The average annual rainfall is 600 mm, and about 60–70% occurs between June and August.

The soil of the study site is the cinnamon type with a pH of 5.8, total nitrogen content of 0.098%, available phosphorus of 75.374 mg kg^{-1}, exchangeable potassium of 145.41 mg kg$^{-1,}$ and organic matter of 17.742 g kg^{-1}.

Experimental design: The experiment was conducted from March to October 2020. The experiment was conducted in 2020 on fruit yield and qualitative characteristics of the famous pear variety Huangtukan under the effect of different amino acid selenium fertilizer concentrations. Amino acid selenium fertilizer was developed by the Research Institute of Pomology of the Chinese Academy of Agricultural Sciences (CAAS). In formulation, the Na_2SeO_3 was added to the amino acid mother liquor, which reacted at 70-80℃ under pH 6.5 for 2 hours. Its main ingredient was amino acid selenium, and the selenium content of the liquid fertilizer was 3%.

The foliar spray of amino acid selenium fertilizer was performed at 6 concentrations, including 50.0 mg plant^{-1}, 60.0 mg plant^{-1}, 75.0 mg plant^{-1}, 100 mg plant$^{-1,}$ 150.0 mg plant$^{-1,}$ and 0.0 mg plant^{-1}(CK). The liquid fertilizer at each concentration with water as the solvent was sprayed 3 times, covering 10 trees each time. The hand-held sprayer was used to spray 1500mL fertilizer on each tree. Liquid fertilizer was sprayed 8 times on tree at an interval of every 15 days from the full-bloom stage and stopped before the ripening stage.

The pear samples were picked through the five-point sampling method during the fruit maturation period. 20 fruits were taken from the crown periphery and inner chamber. They were rinsed with the detergent, flushed with pure water three times, and then left to dry in the air.

Observations and measurements: During the fruit ripening period, 10 representative pears with consistent growth were selected randomly for each treatment to measure the average single fruit weight. The fruit setting rate was counted to calculate the yield. The hand-held refractometer and 2, 6-dichlorophenol indophenol titration were used to measure the soluble solid and vitamin-C contents (Bao, 2000). The titratable acid content (i.e. the malic acid) was measured according to GB/T12293-1990 (China Standards Press, 2017).

The selenium content was determined using hydride atomic fluorescence spectrometry under GB 5009.93-2017 in the National Food Safety Standards of the People's Republic of China (Bao, 2000); the P content was determined by the molybdenum antimony resistance colorimetry method (Bao, 2000); the content of K and Mg was determined using flame photometer method (Bao, 2000); the contents of Iron, copper, manganese, sulfur, zinc, and boron were determined using flame atomic absorption spectrophotometric method (FAAS) (Bao, 2000).

Statistical analysis: The statistical analysis was performed using SPSS software. Duncan method was applied to determine the significant difference in single fruit weight of pear, yield, soluble solid, vitamin-C and titratable acid under low, medium, and higher foliar spray of amino acid selenium fertilizer concentrations at $p<0.05$. Origin 2018 and SigmaPlot 10.0 software were used to visualize the data graphically (Brian, 2017).

Results

Effect of selenium fertilizer at different concentrations on pear yield and quality: The selenium fertilizer at different concentrations remarkably affected pear yield and quality (Table 1). Compared with CK, the pear yield increased by 6.38%, 14.31%, 19.07%, 10.96%, and 6.97% under selenium fertilizer application of 50 mg plant^{-1}, 60 mg plant^{-1}, 75 mg plant^{-1}, 100 mg plant^{-1}, and 150 mg plant$^{-1,}$ respectively, among which the pear yield under 75 mg plant^{-1} was substantially higher than other treatments. The results demonstrated that with the increased application concentration of selenium fertilizer, the soluble solid of the pear first increased and then decreased. The soluble solid content of the pear under 100 mg plant^{-1} was the highest, which significantly increased by 26.35% compared with C.K. The vitamin-C content under 75 mg plant^{-1} was the highest, which significantly increased by 85.2% compared with C.K. With the increase of the concentration of selenium fertilizer, the pear's titratable acid content first decreased and then increased; the titratable acid under 75 mg plant^{-1} was the lowest, which significantly decreased by 52.45% compared with the control treatment.

Table 1. Effect of different concentrations of selenium fertilizer on pear yield and quality.

Selenium fertilizer ($mg\ plant^{-1}$)	Fruit weight (g)	Yield (kg)	Soluble solids (%)	Vitamin-C ($mg \cdot kg^{-1}$)	Titratable acid ($mg \cdot kg^{-1}$)
0 mg（CK）	112.23e	89.79e	9.45d	1.97e	4.08a
50 mg	119.40d	95.52d	10.70c	2.28d	2.90d
60 mg	128.30b	102.64b	11.31b	3.12b	3.18c
75 mg	133.63a	106.91a	11.50b	3.65a	1.94e
100 mg	124.53c	99.63c	11.94a	3.14b	3.62b
150 mg	120.07d	96.05d	10.69c	2.85c	3.83b

Note: Different letters in the same column indicate a remarkable difference at $p<0.05$

Effect of selenium fertilizer at different concentrations on major elements of pear: Figure 1 shows that the selenium fertilizer at different concentrations significantly affected on absorption of phosphorus and potassium. The selenium fertilizer at different degrees, increased the absorption of phosphorus in pear, which first increased and then decreased with the increase of the selenium concentration. Phosphorus content of pear under 50 mg $plant^{-1}$, 60 mg $plant^{-1}$, and 75 mg $plant^{-1}$ was the highest and significantly increased by 29.44%, 42.48%, and 36.19%, respectively, compared with CK. When the mass concentration of the selenium fertilizer was less than 75 mg $plant^{-1}$, the phosphorus content significantly improved. Conversely, when it exceeded 75 mg $plant^{-1}$, the phosphorus content highly decreased. Compared with CK, the phosphorus content decreased by 2.6% under the application of selenium fertilizer at 100 mg $plant^{-1}$. The correlation equation between the mass concentration of the selenium fertilizer and the phosphorus content is $y = -0.0003x^2 + 0.5741x + 306.59$, $R^2 = 0.6424$. Similar to phosphorus nutrient, the potassium content first increased and then decreased with the increase of the selenium fertilizer concentration. The potassium content increased by 18.19%, 71.35%, 89.18%, 69.37%, and 26.67% under all treatments, including 50 mg $plant^{-1}$, 60 mg $plant^{-1}$, 75 mg $plant^{-1}$, 100 mg $plant^{-1,}$ and 150 mg $plant^{-1}$, respectively compared with CK. The correlation equation between the mass concentration of the selenium fertilizer and the potassium content was $y = -0.3057x^2 + 51.196x + 2587.4$, $R^2 = 0.7686$. Thus, results demonstrated that the impact of selenium fertilizer on absorption of major nutrient elements in pear was potassium>phosphorus, and its negative effects on potassium/phosphorus absorption were significant. The extremely high concentration of selenium fertilizer could inhibit the absorption of phosphorus.

Effect of selenium fertilizer at different concentrations on medium elements of pear: In pear, the magnesium content was 4.4 times that of sulfur and 3.2 times that of sodium. The impact of selenium fertilizer on absorption of magnesium, sodium, and sulfur in pear was basically the same. The content of these three medium elements first increased and then decreased with the concentration of selenium fertilizer. A mass concentration of selenium fertilizer less than 75 mg $plant^{-1}$ increased the absorption efficiency of pear for magnesium and sodium, and greater than 75 mg $plant^{-1}$ decreased its absorption efficiency for both nutrients. Compared with CK, the magnesium content increased by 50.25%, 78.68%, and 68.14%, respectively, under fertilizer treatments of 50, 60, and 75 mg $plant^{-1}$. The correlation equation between the mass concentration of selenium fertilizer and the magnesium content was $y = -0.0191x^2 + 3.2853x + 194.03$, $R^2 = 0.8611$. Compared with CK, the sodium content under fertilizer concentrations of 50, 60, and 75 mg $plant^{-1}$ significantly increased by 42.37%, 191.53%, and 96.61%, respectively. The correlation equation between the mass concentration of the selenium fertilizer and the sodium content was y = 2E-05x4 - 0.0063x3 + 0.6054x2 - 17.198x + 59.23, $R^2 = 0.8897$. Furthermore, results showed that the selenium fertilizer mass concentration was less than 100 mg $plant^{-1}$ could improve the absorption efficiency of pear for the sulfur. Compared with CK, the sulfur content significantly increased by 90.20%, 157.84%, and 236.27% under fertilizer treatments of 50, 60, and 75 mg $plant^{-1}$. The selenium fertilizer dose of over 100 mg $plant^{-1}$ could decrease sulfur content. The correlation equation between the mass concentration of the selenium fertilizer and sulfur content was $y = -0.0005x^3 + 0.0869x^2 - 2.8725x + 50.69$, $R^2 = 0.9964$. Notably, the effect sequence of the selenium fertilizer on medium element absorption in the pear was sulfur > sodium > magnesium (Fig. 2).

Effect of different concentrations of selenium fertilizer on absorption of trace elements of pear: The selenium fertilizer could significantly increase the selenium content in pear. Compared with control treatment, selenium content increased by 35.42%, 46.42%, 52.39%, 57.86%, and 62% under fertilizer application of 50 mg $plant^{-1}$, 60 mg $plant^{-1}$, 75 mg $plant^{-1}$, 100 mg $plant^{-1}$, and 150 mg $plant^{-1}$, respectively. When the mass concentration of selenium fertilizer exceeded 75 mg $plant^{-1}$, the content of selenium reached its peak and remained unchanged. The correlation equation between mass concentration of the selenium fertilizer and the selenium content was $y = -0.0115x^2 + 0.1198x - 0.089$, $R^2 = 0.9585$ (Fig. 3).

The selenium fertilizer significantly promoted the absorption of boron and manganese. The boron content increased by 45.31%, 49.78%, 179.02%, 141.07%, and 48.44%, and the manganese content increased by 116.33%, 189.12%, 72.11%, 82.31%, and 106.12% under selenium fertilizer application of 50 mg $plant^{-1}$, 60 mg $plant^{-1}$, 75 mg $plant^{-1}$, 100 mg $plant^{-1}$, and 150 mg $plant^{-1}$, respectively, compared with CK. Moreover, selenium fertilizer promoted the absorption of zinc, iron, and copper. Nonetheless, when its mass concentration exceeded 75 mg $plant^{-1}$, the increase in the absorption rate of zinc, iron, and copper was not significant. Compared with CK, the zinc content under fertilizer rates of 50, 60, and 75 mg $plant^{-1}$, increased by 15.27%, 16.62%, and

26.80%, respectively; the iron content increased by 1.86%, 61.49%, and 100.33%, respectively; the copper content increased by 7.69%, 17.83%. And 55.94%, respectively. The order of trace element content in pear was iron > zinc > boron > manganese > copper > selenium, whereas the promoting effects of selenium fertilizer on absorption of trace elements were manganese > boron > selenium > iron > copper > zinc (Figs. 4 and 5).

Correlation analysis of nutrient absorption of pear: As indicated by the correlation analysis of nutrient absorption of pear in Figure 6, there was a remarkable positive correlation between copper and iron + potassium + magnesium + sodium; between potassium and magnesium + manganese + phosphorus + zinc; between magnesium and manganese + phosphorus + sulfur + zinc + boron; between manganese and selenium; between sodium and zinc; between phosphorus and sulfur + boron; between sulfur and boron, indicating that the trace elements of selenium, manganese, copper, iron and zinc could mutually promote their absorption. Moreover, the selenium fertilizer could enhance the selenium content; its absorption could promote manganese content.

The correlation between the selenium concentration and the absorption of nutrient elements of pear shows that when the selenium fertilizer mass concentration was smaller than or equal to 75 mg plant^{-1}, it was positively associated with the absorption of major, medium, and trace elements excluding sodium and boron; when it exceeded 75 mg plant^{-1}, it was negatively associated with the absorption of copper, potassium, magnesium, manganese, sodium, phosphorus, sulfur, zinc, and boron; when it was 0-100 mg plant^{-1}, it was always positively correlated with the absorption of pear on iron, selenium, and other elements (Table 2).

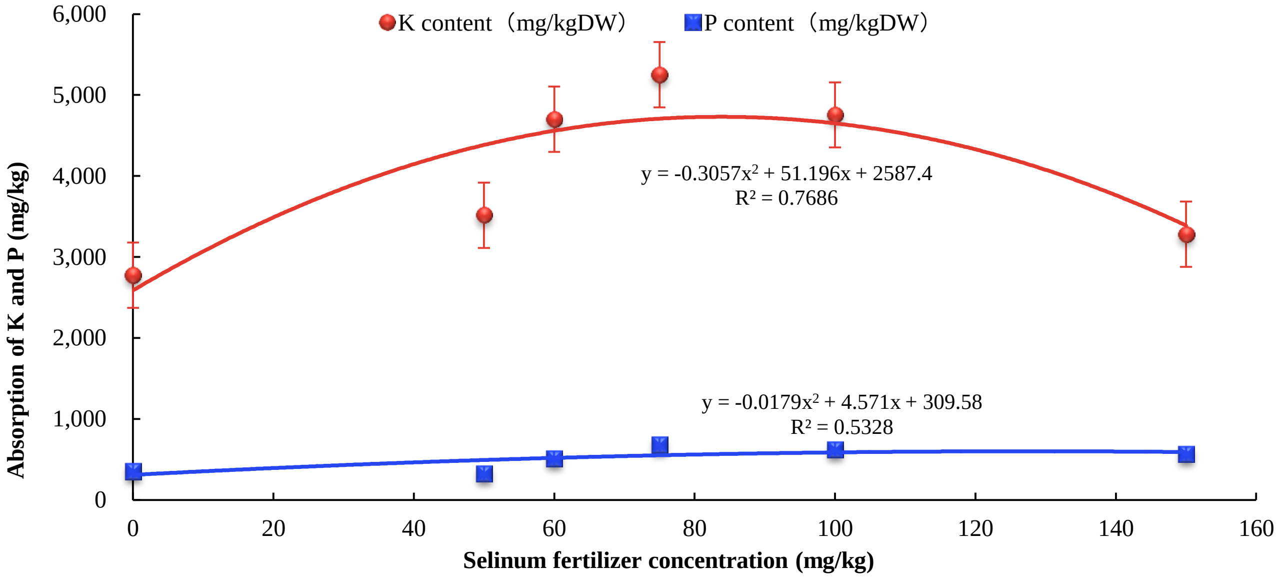


Fig. 1. Effect of different concentrations of selenium fertilizer on absorption of P and K of pear.

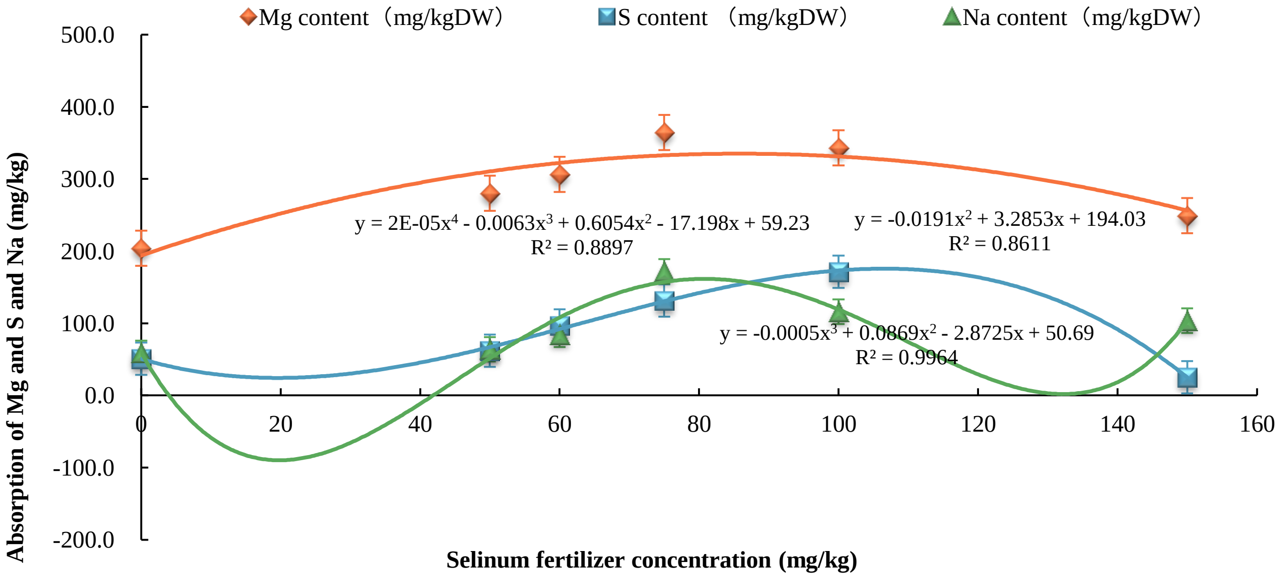


Fig. 2. Effect of different concentrations of selenium fertilizer on absorption of Mg, Na, and S of pear.

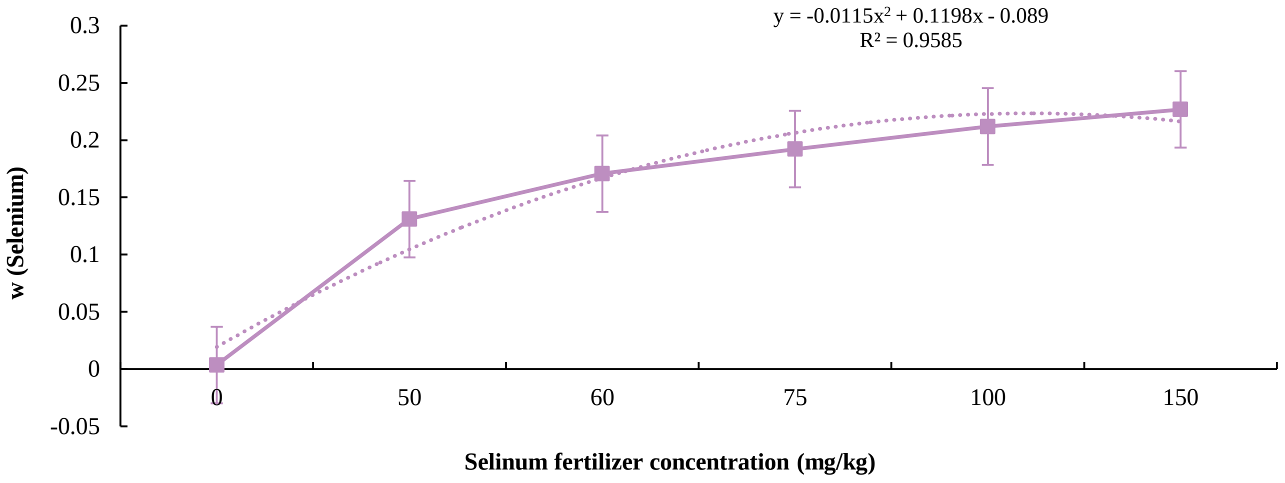


Fig. 3. Effect of different concentrations of selenium fertilizer on absorption of Se (selenium) of pear

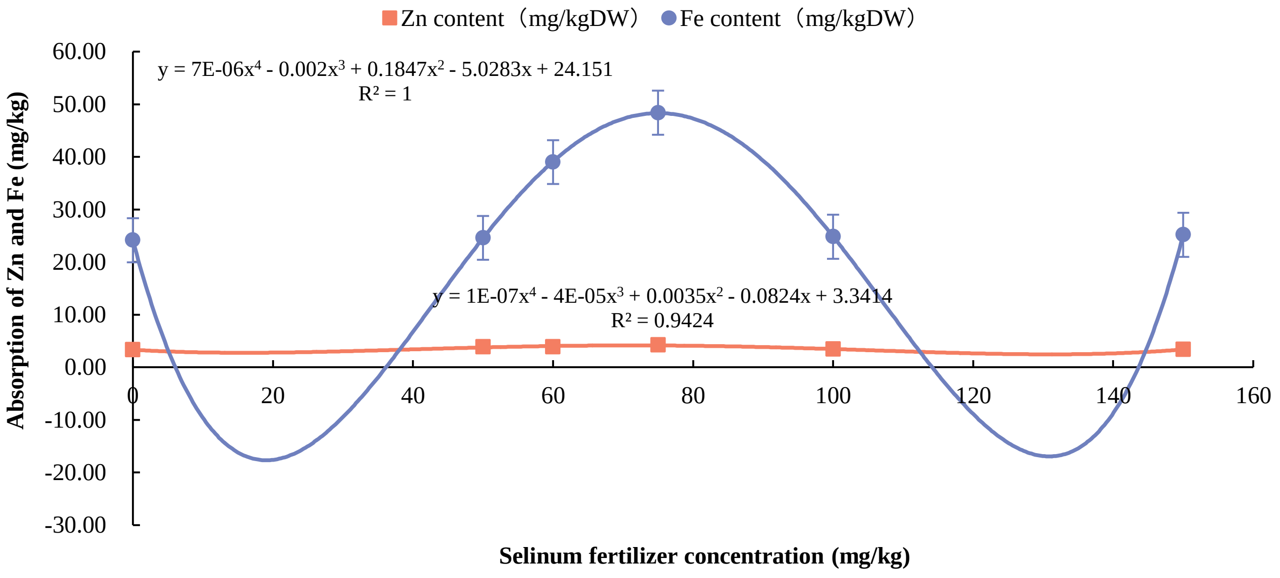


Fig. 4. Effect of different concentrations of selenium fertilizer on absorption of Zn (zinc) and Fe (iron) of pear.

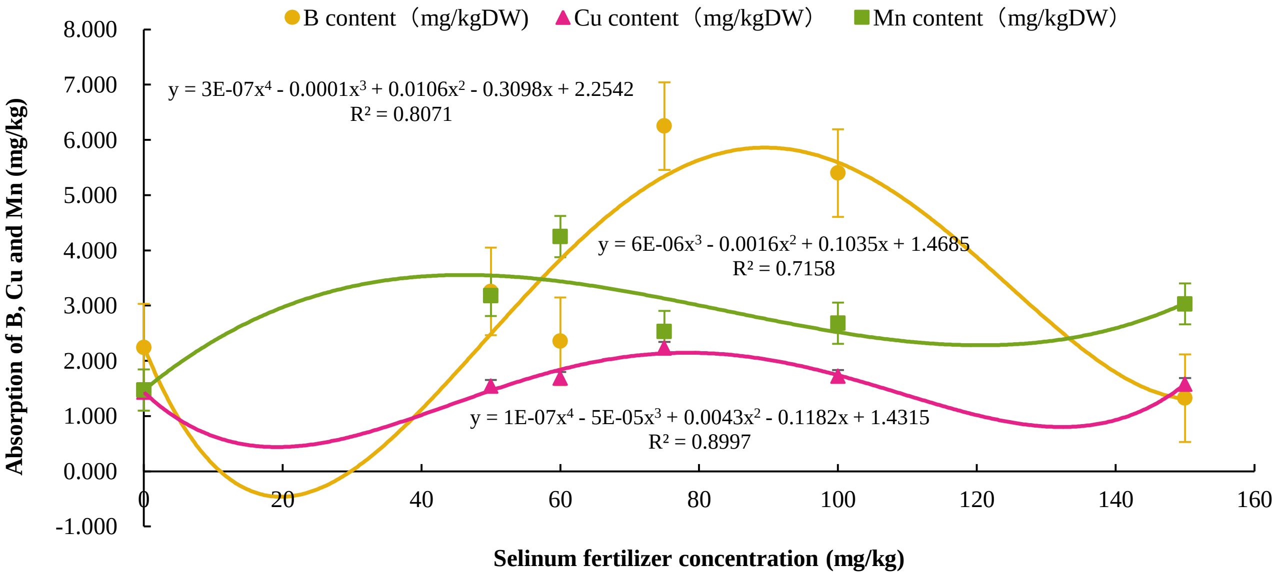
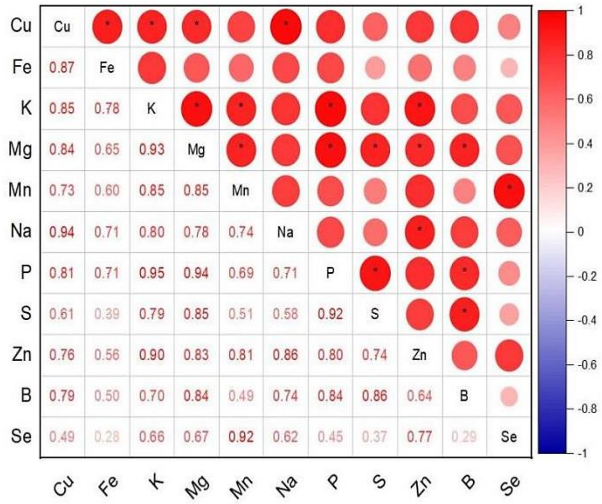


Fig. 5. Effect of different concentrations of selenium fertilizer on absorption of Cu (copper), B (boron) >, and Mn (manganese) of pear.

Table 2. Correlation between concentrations of selenium fertilizer and absorption of major, medium, and trace elements of pear.

P (Selenium fertilizer/ (mg plant^{-1}))	Cu	Fe	K	Mg	Mn	Na	P	S	Zn	B	Se
≤75	0.92*	0.95*	0.97*	0.98**	0.95*	0.88	0.98**	0.95*	0.97*	0.76	0.92*
>75	-1.00**	1.00**	-1.00**	-1.00**	-1.00**	-1.00**	-1.000**	-1.00**	-1.00**	-1.00**	1.00**



	Cu	Fe	K	Mg	Mn	Na	P	S	Zn	B	Se
Cu	Cu	●	●	●	●	●	●	●	●	●	●
Fe	0.87	Fe	●	●	●	●	●	●	●	●	●
K	0.85	0.78	K	●	●	●	●	●	●	●	●
Mg	0.84	0.65	0.93	Mg	●	●	●	●	●	●	●
Mn	0.73	0.60	0.85	0.85	Mn	●	●	●	●	●	●
Na	0.94	0.71	0.80	0.78	0.74	Na	●	●	●	●	●
P	0.81	0.71	0.95	0.94	0.69	0.71	P	●	●	●	●
S	0.61	0.39	0.79	0.85	0.51	0.58	0.92	S	●	●	●
Zn	0.76	0.56	0.90	0.83	0.81	0.86	0.80	0.74	Zn	●	●
B	0.79	0.50	0.70	0.84	0.49	0.74	0.84	0.86	0.64	B	●
Se	0.49	0.28	0.66	0.67	0.92	0.62	0.45	0.37	0.77	0.29	Se

Note: * and ** denote remarkable differences of $p<0.05$ and $p<0.01$, respectively.

Fig. 6. Correlation analysis between major, medium, and trace elements of pear

Discussion

The optimum application of selenium fertilizer improves the pear fruit yield and quality, substantially increases the selenium content in the pulp, and reduces the stone cell content (Wang *et al*., 2012). Our findings showed that foliar spray of the selenium fertilizer could increase the content of soluble solids and vitamin-C of the pear, reduce the titratable acid content, and improve the ratio of sugar to acid, thereby enhancing the pear yield and quality. Our results agree with Deng *et al*., (2018) and Dou *et al*., (2021) studies. They also noticed an obvious effect of selenium fertilization on fruit trees, particularly enhancing photosynthetic rate, increasing the soluble solids, vitamin-C and sugar accumulation. In the present study, the significant effect of selenium fertilizer on pear fruit yield and its qualitative characteristics could be attributed to selenium mainly improves the plant's antioxidant capacity by enhancing the synthesis of antioxidants in the non-enzymatic system, strengthening the synthesis of vitamin-C, increasing the assimilation products in fruits, and ultimately raising the content of soluble solids (Rui *et al*., 2012).

Furthermore, results demonstrated that the absorption efficiency of selenium is related to the application of selenium fertilizer concentrations. The selenium content would increase with the increase of the selenium concentration. The selenium content peaked when the mass concentration was higher than 75 mg plant^{-1}, which is consistent with Liu *et al*., (2020), and Zhang *et al*., (2021) research studies. They investigated the effect of selenium fertilizer and concentrations on different types of plants. Selenium-rich organic fertilizer applied during the fruit expansion period resulted in selenium content reaching 0.02 mg kg^{-1} in fruit. The increasing range was considerably large, while the effect was satisfactory and economical. Du *et al*., (2020) found that when the mass concentration of sodium selenite reached 60 mg L^{-1}, the watermelon had the highest yield.

The relationship between selenium and various nutrient elements is relatively complicated. The effects of selenium are closely associated with the variety of crops, the application amount of selenium fertilizer, and the type of nutrient elements (Gupta & Gupta, 2017; Kan *et al*., 2021; Konate *et al*., 2018). In the present study, the impact of selenium fertilizer on the absorption of numerous nutrient elements in pear was potassium > phosphorus, and its negative effects on potassium/ phosphorus absorption were significant. The extremely high concentration of selenium fertilizer can inhibit the absorption of phosphorus. With the increase of fertilization, the impact of the selenium fertilizer on the absorption of magnesium, sodium, and sulfur was consistent, the content of which first increased and then decreased with the increase of the selenium concentration. As a beneficial nutrient element (Rui *et al*., 2008), selenium fertilizer significantly promoted the absorption of boron, manganese, zinc, iron, and copper. When its mass concentration exceeded 75 mg plant^{-1}, the increase of the content of zinc, iron, and copper was not significant, which is basically consistent with the previous research results of Yuan *et al*., (2020), found that the potassium content would improve with the increase of selenium fertilization; Xiao *et al*., (2015) and Tian *et al*., (2009) found that the appropriate application of selenium fertilizer could substantially improve the nitrogen content of rice and Tartary buckwheat, and Jiang *et al*., (2021) observed that the excessive selenium fertilization could improve the level of nutritional selenium, iron, and zinc of the corn kernel. Moreover, Yang *et al*., (2021) concluded that the foliar spray of the sodium selenite selenium fertilizer on pakchoi could facilitate its over ground absorption of nitrogen, phosphorus, magnesium, sodium, and underground absorption of nitrogen, phosphorus, copper, Iron, and sodium. While research by Guo *et al*., (2020) indicated that low selenium concentrations would promote the absorption of nitrogen, phosphorus, and potassium in brassica, a high concentration can inhibit their absorption.

The results of our research demonstrated that the mass concentration of selenium fertilizer smaller than or equal to 75 mg plant^{-1} would improve the absorption of the major, medium, and trace elements except for sodium and boron. Excessive levels of selenium fertilizer will negatively affect the absorption of copper, potassium, magnesium, manganese, sodium, phosphorus, sulfur, zinc, and boron. Nonetheless, some research results indicate different performances. For example, Qin *et al*., (2020) found that the concentration of selenium fertilizer sprayed on the mango foliage was positive for the K content but did not show effects on zinc, chlorine, and Iron. Shang *et al*., (1998) concluded that with the increase of selenium concentration in the nutrient solution, the selenium content of lettuce was positively correlated with that of phosphorus but negatively associated with that of chlorine, potassium, and manganese. Therefore, the effect of the exogenous selenium on the absorption efficiency of nutrient elements of plants varies in terms of the species, varieties, genes, parts, and growth regions, which deserves further investigation.

In the present study, the determined selenium content of Beijing Huangtukan pear was 0.0036 mg kg^{-1} in the control group, whereas that sprayed with selenium fertilizer reached 0.13-0.28 mg kg^{-1}. This conforms to China's Classification Standards of the selenium content of selenium-rich and selenium-containing food (HB001/T-2013), i.e., the required selenium content of 0.01-0.50 mg kg^{-1} in selenium-rich fruits. Therefore, the reasonable application of the exogenous selenium fertilizer would contribute to rural revitalization. Vigorously developing the selenium-rich pear industry in rural areas is of great significance.

Conclusion

It is concluded that an appropriate foliar concentration of selenium fertilizer promotes the pear yield, quality, and absorption efficiency of nutrient elements, whereas relatively high concentrations will have negative effects. The selenium fertilizer concentration of 75 mg plant^{-1} is critical. A dose of selenium fertilizer smaller than or equal to 75 mg plant^{-1} would improve pear yield, soluble solids, and the sugar-to-acid ratio. In contrast, higher foliar application of selenium fertilizer will decrease titratable acidity. There was an obvious correlation between selenium fertilizer concentrations and absorption of major, medium, and trace elements except for sodium and boron. In contrast, our results exhibited that increasing selenium fertilizer concentrations could improve the absorption of iron and selenium in pears. After comprehensive comparisons and analysis of the yield, quality, and nutrient contents of pear under different concentrations of selenium fertilizer, the optimum concentration of foliar selenium spray on Huangtukan pear was determined as 75 mg plant^{-1}, which would be most conducive to the production of the selenium-rich pears.

Acknowledgments

This research was funded by the Beijing Academy of Agricultural and Forestry Sciences youth fund, Beijing Rural Revitalization science, technology project and Special project of scientific (QNJJ202214) and technological innovation for the protection and utilization of black land (XDA28130200) and General Program of NSFC (41977095).

We appreciate and thank the anonymous reviewers for constructive comments that helped us to improve the paper. We also thank the Journal Editorial Board for the efficient process.

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(Received for publication 11 March 2022)