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EFFECTS OF FOLIAR APPLICATION OF ZINC FERTILIZER ON YIELD AND FRUIT QUALITY OF PEAR-JUJUBE (*ZIZIPHUS JUJUBE* MILL.)

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Abstract

To study the effects of foliar application of zinc ($ZnSO_4$) on yield and fruit quality of pear-jujube (*Ziziphus jujube* Mill.) present study was conducted. $ZnSO_4$ in different concentrations were applied as a foliar spray, i.e. 0 (CK), 0.2 (X_1), 0.4 (X_2), 0.6 (X_3) and 0.8% (X_4) during the present experiment. The results showed that the single fruit weight of each treatment was higher than control (CK). The highest (25.75 g) single fruit was found at X_4 as compared to X_3 (23.91 g) and 41.2% higher than that of control. The highest fruit set rate (15.46%) and yield (14988.68 kg/hm^2) was found at X_3 which were 9.34 and 51.1%, respectively higher than CK. The different concentrations of $ZnSO_4$ can effectively improve the plant growth and fruit quality of pear-jujube. The fruit water content of X_3 and X_4 were found to be 81.1 and 80.5%, respectively. The highest total sugar (156.1 mg/g), reducing sugar (90.89 mg/g), soluble solids (20.75 mg/g), vitamin C (2.61 mg/g) and total flavonoids (2.36 mg/g) at X_3 were significantly higher than other treatments. Comprehensive analysis showed that X_3 (0.6% of $ZnSO_4$) was best in the present experiment. It was beneficial to increase yield and improve the quality of pear-jujube.

Introduction

Pear-jujube (*Ziziphus jujuba* Mill.) is a *Zimyphus* Mill. plant belonging to Rhamnaceae family (Yan *et al.* 2010). It is China's unique fruit tree. Now it has 3000 years of history and culture. There are many varieties of jujube, fresh jujube rich in nutrients and has a health care effects (Lu *et al.* 2010, Zhen 2018). Jujube planting in the hilly areas of the Loess Plateau can not only green barren hills, resist natural disasters, maintain water and soil, but also improve farmers' economic benefits (Hong *et al.* 2015). However, jujube planting management is extensive, lack of fertilization technology, and the economic benefits are very low in recent years (Zong 2017, Wang 2018). It seriously affects the enthusiasm of jujube farmers for planting pear-jujube, which in turn affects the improvement of the ecological environment in northern Shaanxi.

Plants need a lot of nutrients in the growth process, and the demands for nitrogen, phosphorus, potassium were relatively large, but trace elements and rare earth elements are also indispensable in improving crop quality (White 1999). The application of trace elements in agricultural production in China has reached more than 7 decades. The application of trace elements can significantly affect the yield and quality of different fruit crop trees. Zinc fertilizer is one of the indispensable elements. Zinc indirectly affects the synthesis of auxin in crop plants. When the crop is deficient in zinc, the auxin content in the stems and buds is reduced, the growth is in a stagnant state, and the plants are short in height. There are more zinc-deficient soils in China. Zinc fertilizer application in zinc-deficient soil has a significant effect on the improvement of crop output. Previous studies have shown that the application of zinc fertilizer can effectively improve the content of titratable acid in loquat fruit and promote the yellow coloration of loquat skin. At the

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same time, boron, zinc, magnesium and molybdenum mixed mineral nutrient fertilizer significantly reduce the pH value of fruits (Yu *et al.* 2018). Liang (2018) showed that the application of zinc fertilizer to the navel orange garden can significantly improve the fruit setting rate, yield and quality of fruits. However, for different types of fruit trees, the application of the same micro-fertilizer has different effects on mineral elements in the fruit. At present, the research on micro-fertilizer of jujube trees in the experimental area is still in the preliminary exploration stage. In this experiment, under the condition of drip irrigation, the specific yield-increasing effect and quality improvement of foliar application of zinc fertilizer on mountain pear jujube were studied, in order to obtain the best zinc fertilizer concentration which is beneficial to the high yield and quality of pear jujube.

Materials and Methods

The experiment was carried out at the Zaoyuan in Mizhi County, Yulin City, Shaanxi Province, China. There are soil erosion and desertification in this area, and the variety and quantity of vegetation are few, and the ecological environment is extremely fragile. The experimental site is located in arid and semi-arid areas, belonging to the loess hilly and gully region, with less precipitation and uneven distribution throughout the year. The average annual temperature, the highest temperature, the extreme minimum temperature, and the frost-free period were 8.5, 38.2, 25.5°C and 162 days, respectively. The average annual rainfall was 451.6 mm. The soil is dominated by Lossiah soil, with pH 8.6, and the bulk density of soil 1.21 g/cm^3. The availability of soil elements such as nitrogen (34.73 mg/kg), phosphorus (2.90 mg/kg), potassium (101.9 mg/kg) and organic matter content was 2.1 g/kg (Yan *et al.* 2008). The contents of organic matter, nitrogen and phosphorus in the soil are less, and the trace elements are regularly depleted (Marschner 1995). The contents of soil available Fe, Zn, Mn and Cu were 6.1, 0.12, 5.6 and 0.71 mg/kg, respectively. During the experiment, drip irrigation method was used in this experiment. The irrigation quota was set to 130 m^3/hm^2 and each irrigation was carried out in May and June.

In the present experiment pear-jujubes of the similar plant height was selected. Besides the normal fertilization, the leaves were sprayed with different concentrations of zinc fertilizer. In the germination stage of jujube, the application of urea 450, superphosphate 1800 and potassium sulfate 200 kg/hm^2 were applied. Urea was applied at 450 kg/hm^2 during fruit development period. In the sprouting and spreading stage, zinc sulfate was sprayed according to Table 1 and the spraying amount was 4 l/plant. The spray was done once in every ten days (treatment frequency @ 3 times). The planting density of the experimental plot was 4 m^2/tree, and the total area of experimental plot was about 450 m^2.

Table 1. Trial treatment of fertilization on Jujube tree.

Treatment	CK	X_1	X_2	X_3	X_4
$ZnSO_4$	0	0.2%	0.4%	0.6%	0.8%

The leaf area measured in the experimental plot following certain selection principles. Eight new shoots with consistent growth were selected in four different directions for the plant to determine the new length; the fourth leaf from the selected new tip was used to determine the leaf area.

Newly developing shoot length was measured by a steel tape with specific time interval. Leaf area expansion was measured by MSD-971 leaf area meter, Venetian thickness measured with

Vernier calipers, and Venetian weight with one ten thousandth of a balance. Chlorophyll (leaf greenness) content was determined by CCM200 chlorophyll meter.

The ratio of fruit number to flowering number is the fruit setting rate. After maturity, the total yield was calculated from the actual yield per plant.

The water content in jujube fruit was determined by the drying method (Yang *et al.* 2002) and calculated as (fresh weight-dry weight) / fresh weight × 100%.

Soluble solids were determined by 2WAJ-Abbe refractometer, content of reducing vitamin C (Gao 2006): determined by 2,6-dichloroindophenol method. Total glycogen content (Han *et al.* 2007, Yang *et al.* 2010) was determined by 3,5-dinitrosalicylic acid colorimetric method. Titratable acid content was determined by acid-base titration (Gao *et al.* 2006, Ning 1998). Total flavonoid content was measured using sodium nitrite-aluminum nitrate-sodium hydroxide coloring method (Sun and Hu 2006).

In each treatment 4 trees were considered with three biological replicates. The experimental data were analyzed using Microsoft Excel 2003 and DPS 7.0 and took the average of each paraconules was taken as the final result.

Results and Discussion

Jujube has a great amount of flowering, but the fruit setting rate is very low. The fruit setting rate directly affects the yield of jujube. Table 2 reveals that the foliar application of different concentrations of zinc sulphate significantly affected the reproductive growth of pear-jujube. The single fruit weight of each treatment was higher than that of control, in which the highest value (25.11 g) was at X4, followed by X_3 (23.02 g), which was 45.6 and 33.5%, respectively higher than control. It showed significant difference with CK ($p<0.05$), but the difference between the two was non-significant. The rate of fruit set in all the treatments after fertilization was significantly higher than that of CK, and the highest rate of fruit set was found at X_3 (15.46%), which was 9.26% higher than that of CK. The yield was obtained highest at X_3 followed by X_3, X_2, X_4, X_1 and CK. The yield of X_3 treatment was 51.1% higher than that of CK, and it was significantly different ($p< 0.05$). Different concentrations of zinc fertilizer treatment have different effects on the reproductive growth of pear-jujube. In combination with the above indicators, X_3 treatment has the most significant effect on reproductive plant growth, development and productivity.

Table 2. Effects of foliar spray of different concentrations of $ZnSO_4$ on reproductive growth of pear-jujube.

Treatment	Single fruit weight (g)	Fruit setting rate (%)	Yield (kg/hm^2)
CK	17.24 ± 0.89 c	6.12 ± 0.62 d	9918.45 ± 634 e
X_1	19.45 ± 1.08 bc	10.98 ± 0.79 c	11707.98 ± 813 de
X_2	21.89 ± 1.18 ab	12.79 ± 0.78 bc	13697.65 ± 899 bc
X_3	23.02 ± 1.08 a	15.46 ± 1.06 ab	14988.68 ± 789 ab
X_4	25.11 ± 1.18 a	11.33 ± 0.70 c	12901.01 ± 734 cd

Values followed by different letters in a column are significant among treatment at the 5% level.

Pear-jujube is a fresh jujube, and its crispy texture is mainly due to its higher water content. Fig. 1 shows that the water content of pear-jujube with different zinc treatments was higher than CK. The water content of the fruits treated with different concentrations of zinc fertilizer was found to be 78.2, 79.3, 81.1 and 80.5% at X_1, X_2, X_3 and X_4, respectively. They were 2.1, 3.2, 5.0 and 4.4%, respectively higher than that of CK, and significantly different from CK ($p < 0.05$). The fruit moisture content of X_3 treatment reached the maximum. The water content of fruits was significantly increased. The increase of water content depends on the concentration of $ZnSO_4$. As the concentration increases, the water content of the fruit increases at first and then decline. This might be due to the increase in the concentration of zinc fertilizer, the increase in the absorption of zinc fertilizer by jujube trees. Thus, the content of mineral elements in the fruit increases. As the amount of various mineral elements in the fruit increases, the water absorption capacity of the cells increases and ultimately affects the water content of pear-jujube.

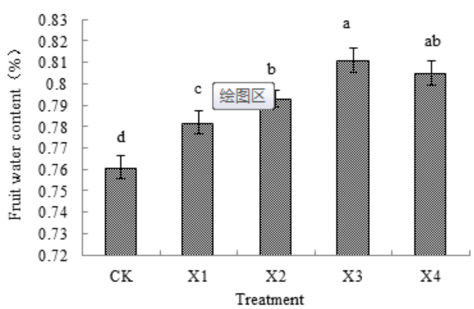

Fig. 1. Effect of foliar spray of $ZnSO_4$ on fruit water content of pear-jujube CK - 0, X_1 - 0.2, X_2 - 0.4, X_3 – 0.6 and X_4 - 0.8% of $ZnSO_4$.

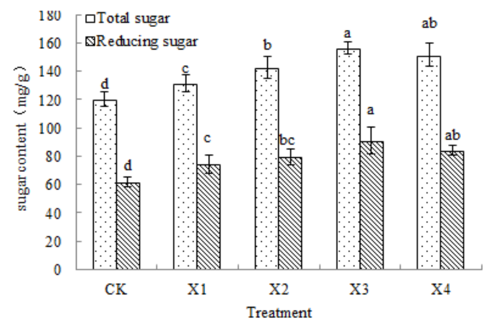

Fig. 2. Effect of foliar spray of $ZnSO_4$ on sugar content of pear-jujube. CK - 0, X_1 - 0.2, X_2 - 0.4, X_3 - 0.6 and X_4 - 0.8% of $ZnSO_4$.

The sugar, acid content and solid acid ratio in the fruit affect the taste of the fruit, and the effect of acid is obviously greater than that of sweetness. In tomato processing, the titratable acid content affects 50% of the total factor, while the sugar content accounts for only 25% (Ni 1995). Soluble solids are a general term for a large class of compounds that are soluble in water in fruits; the solid-acid ratio refers to the ratio of soluble solids to acid content in fruits, and this indicator can effectively indicate the maturity and quality of fruits. It can be seen from Table 3 that the content of soluble solids of the treatment in jujube fruits was significantly higher than CK ($p < 0.05$). The soluble solid content of X_3 was found to be the highest (20.75%). Followed by X_4 (20.55%) and 4.5 and 4.3%, respectively higher than CK. On the other hand, the titration of acid (TA) content in all the treatment after spraying zinc fertilizer was significantly lower than CK ($p < 0.05$), and the titratable acid content was found to be CK > X_4 > X_2 > X_1 > X_3. The lowest titratable acid content (0.93%) was at X_3.

Table 3. Effect of foliar spray of different concentration of $ZnSO_4$ on TSS/TA of pear-jujube.

Treatment	TSS (%)	TA (%)	TSS/TA
CK	16.25 ± 0.51 c	1.28 ± 0.07 a	12.70 ± 0.09 d
X_1	18.50 ± 0.53 b	1.05 ± 0.03 bc	17.57 ± 0.13 c
X_2	19.12 ± 0.61 b	1.13 ± 0.03 b	18.32 ± 0.10 b
X_3	20.75 ± 0.69 a	0.93 ± 0.03 c	20.60 ± 0.11 a
X_4	20.55 ± 0.69 a	1.12 ± 0.10 b	18.33 ± 0.22 b

TSS - Total soluble solid. TA - Titratable acid. CK - 0, X_1 - 0.2, X_2 - 0.4, X_3 - 0.6 and X_4 - 0.8% of $ZnSO_4$.

Zinc fertilization significantly affected the solid-acid ratio of the fruit and significantly different from CK ($p < 0.05$). The specific performance was $X_3 > X_4 > X_2 > X_1 >$ CK. The solid acid ratio of X_3 treatment reached the maximum. It was 20.60, which was 62.2% higher than CK. It can be assumed that spraying different concentrations of zinc fertilizer can effectively improve the content of soluble solids in pear jujube, reduce the amount of titratable acid, and thus improve the taste of the fruit.

Fig. 2 shows that different concentrations of zinc fertilizer increased the total and reducing sugar content in pear-jujube, and the difference between treatments were significant. High concentrations of zinc fertilizer can significantly increase the total and reducing sugar content in pear-jujube. The total sugar and reducing sugar content of pear jujube treated with fertilization showed $X_3 > X_4 > X_2 > X_1 >$ CK. The total sugar content of different fertilization treatments was found to be 131.2, 142.9, 156.1 and 151.4 mg/g. They were 9.0, 18.7, 29.7 and 25.7%, respectively higher than CK. Reducing sugar content of different concentrations of $ZnSO_4$ increased significantly. The X_3 treatment (90.89 mg/g) was found highest compared to X_4 (84.33 mg/g). They increased by 46.5 and 35.9%, respectively compared to CK. Different concentrations of $ZnSO_4$ significantly increased the total and reducing sugar content in pear-jujube, and improved the commercial value of pear-jujube, among which the treatment with X_3 was found to be the best.

It can be seen from Fig. 3, that different treatments increased the content of vitamin C in pear-jujube. The vitamin C content of X_3 was maximum (2.61 mg/g), followed by X_4 (2.58 mg/g), which was 15.5 and 14.2%, respectively higher than CK, and significantly different from CK ($p < 0.05$). But the difference between treatments was not significant. It was found that the application of zinc fertilizer can effectively increase the content of vitamin C in pear-jujube, among which the X_3 has the most significant impact.

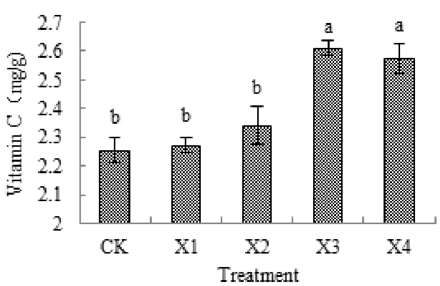

Fig. 3. Effect of foliar spray of $ZnSO_4$ on vitamin C of pear-jujube. CK - 0, X_1 - 0.2, X_2 - 0.4, X_3 - 0.6 and X_4 - 0.8% of $ZnSO_4$

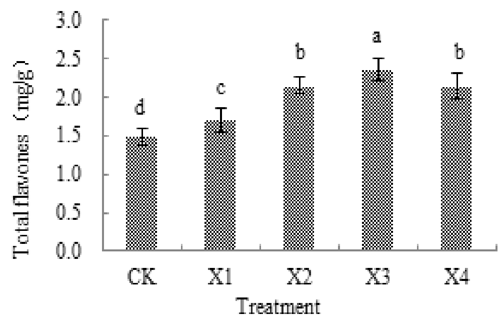

Fig. 4. Effect of foliar spray of $ZnSO_4$ on total flavonoid in pear-jujube. CK- 0, X_1 - 0.2, X_2 - 0.4, X_3 - 0.6 and X_4 - 0.8% of $ZnSO_4$

Total flavonoids are flavonoids which are a large class of natural products. Flavonoids can improve the role of vitamin C in the human body and have important functions such as scavenging free radicals, preventing vascular sclerosis, enhancing blood vessel elasticity, delaying senility, preventing and treating cardiovascular and cerebrovascular diseases, lowering blood pressure, and lowering blood lipids. Jujube contains a variety of health care substances; one of the most important is rutin. Fig. 4 shows that different fertilization treatments significantly increased the content of total flavonoids in pear-jujube. The total flavonoid content of foliar spray of different concentrations of zinc fertilizer showed $X_3 > X_4 > X_2 > X_1 >$ CK. The highest total flavonoid content was found (2.36 mg/g) at X_3 followed by X_4 (2.14 mg/g). They were 59.5 and 44.6%, respectively higher than that of CK. However, on the whole, the content of total flavonoids in pear-jujube increased with the increase of concentration of $ZnSO_4$.

Zinc fertilizer plays an important role in fruit trees. The field experiment was conducted to study the effects of foliar application of $ZnSO_4$ on the yield and fruit quality of pear jujube in the north Shaanxi slope.

Tan (2017) and Liang (2018) showed that by spraying different concentrations of zinc fertilizer on apples, navel oranges and other fruit trees, the fruit setting rate and yield of fruit trees can be significantly improved. At the same time Wang *et al.* (2016), Wang *et al.* (2017), Si *et al.* (2018) have shown that the application of zinc fertilizer has a significant yield-increasing effect on peanuts, wheat and other crops. This was found to be consistent with the results of this study. The fruit setting rate of pear jujube was significantly improved by spraying zinc fertilizer on the foliar surface. The fruit setting rate of 0.6% zinc sulfate reached 15.46%, which was 9.31% higher than that of CK. The single fruit weight and yield of pear jujube in all the treatment were significantly higher than the control. This is mainly because zinc is one of the essential trace elements in plants. Zinc indirectly affects the synthesis of auxin in crops. When the crop is deficient in zinc, the auxin content in the stems and shoots is reduced, and the growth is in a stagnant state. At the same time, zinc is also an activator of many enzymes, which contributes to photosynthesis by exerting a wide range of effects on plant carbon and nitrogen metabolism.

Sha *et al.* (2018) studied on the 'Early Golden Crisp' pears. They found that the application of zinc fertilizer on the foliar surface increased significant the fructose content, while the acid content decreased significantly. Yu *et al.* (2018) shown that zinc fertilizer can significantly promote the yellow coloration of the husk, while reducing the titratable acid content. Tan (2018) showed that the content of flavonoids, soluble sugars and total crude protein in potato roots and the content of iron, zinc, calcium and magnesium are improved. In this experiment, the quality of pear jujube can be effectively improved by spraying different concentrations of zinc fertilizer on the foliage. The water content, sugar content, vitamin C and total flavonoid content of pear jujube treated with different concentrations of $ZnSO_4$ were higher than the control. Different treatment methods improved the content of soluble solids in jujube fruit, effectively reduce the titratable acid content, increase the acid ratio, and improve the taste of jujube fruit. The promoting effect of 0.6% $ZnSO_4$ on fruit quality was significantly higher than other treatments.

Foliar application of zinc fertilizer can effectively promote the reproductive growth of pear jujube, improve the fruit set rate and yield; improve the taste and quality of pear jujube. Among them, the effect of spraying 0.6% $ZnSO_4$ at X_3 was found most suitable for the production of pear jujube in the region. The comprehensive research results showed that the best effect was found at 0.6% $ZnSO_4$.

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