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Effects of manganese on growth and development of peanut (*Arachis hypogaea* L.) seedlings

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Abstract. The effects of different menganses (Mn) concentrations on the growth and development of peanut seedlings were analysed in the present study. The results showed that the main root length, lateral root number, plant height, dry weight of aboveground and underground parts of peanut seedlings were all influenced by the concentrations of Mn obviously. Moreover, the growth of peanut could be significantly promoted at low concentration of Mn (150 μmol/L), while inhibited by high concentration of Mn (900 μmol/L). Therefore, these conclusions could help us to understand the most suitable concentration range of Mn for the growth of peanut, and could also analyze the specific performance of the harm of Mn toxicity on peanut, so as to lay a theoretical foundation for improving the yield of peanut and expanding the cultivation area.

1 Introduction

Arachis hypogaea is an annual herb of the genus of *Arachis* in leguminous family [1]. The provinces of Shandong, Guangdong, Guangxi, Hebei, Henan, Liaoning, Anhui and Sichuan are the main producing areas of peanut in China [2]. Peanut is an important oil and cash crop [3], which can be used to extract edible oil, as lubricant in textile industry, and as quenching agent in machine manufacturing industry and so on [4]. Peanut is rich in oil and protein. The oil contains 19%-43% linoleic acid, which is the essential fatty acid for human body, and its protein contains a large number of essential amino acids for human body; and the composition proportion of oil and protein is appropriate, and the effective utilization rate is also high [4]. In addition, it also contains calcium, iron, phosphorus and a variety of vitamins, which are extremely rich in nutrients and play a very important role in human growth and disease resistance maintenance [4].

Plants growing in acid soil will be affected by many obstacles in the growth and development process, among which Mn toxicity is one of the main toxic factors [5]. Mn toxicity is the limiting factor of plant growth in acid soil second only to aluminum toxicity [6]. Moreover, the acid soil in China accounts for 21% of the cultivated land area, and peanut is planted in a large area in China. Meanwhile, affected by sewage irrigation, industrial waste residue, industrial waste piling, urban garbage and atmospheric deposition, etc., the high concentration of Mn is easy to cause Mn toxicity [7]. Mn toxicity can significantly reduce the yield of peanut, and excess Mn are enriched in peanut and can accumulate in human body through the food chain, causing harm to human body [8, 9]. Therefore, studying the effects of Mn on peanut could help us to understand the most suitable concentration range of Mn for the growth of peanut, and could also analyze the specific performance of the harm of Mn toxicity on peanut, so as to lay a theoretical foundation for improving the yield of peanut and expanding the cultivation area.

Compared to the complex soil environment, the ion concentration, pH and temperature conditions are easier to be controled under hydroponic environment, in which the interference of many unknown factors in the soil can be eliminated. So that, hydroponic experiment was used to study the effects of Mn on seedling growth of peanut in the present study. The results might provide references for studying the mechanism of transport and absorption of other ions in plants.

2 Materials and Methods

2.1 Experimental materials

The peanut seeds, named Dabaisha 171 were purchased from Yantai Qishan Seed Co., Ltd in China.

2.2 Experiment reagents

The hydroponic nutrient solution is an improved Hoagland nutrient solution [10]. NH_4NO_3, $MgCl_2\cdot 6H_2O$, $C_{10}H_{12}FeN_2NaO_8\cdot 3H_2O$, $MgSO_4\cdot 7H_2O$, K_2SO_4, $(NH_4)_2SO_4$, $ZnSO_4\cdot 7H_2O$, $(NH_4)_6Mo_7O_{24}\cdot 4H_2O$, KH_2PO_4, $Na_2B_4O_7\cdot 10H_2O$, $Ca(NO_3)_2\cdot 4H_2O$,

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$CuSO_4·5H_2O$, $MnSO_4·H_2O$, and KNO_3 were purchased from Beijing Solarbio Science & Technology Co., Ltd in China.

2.3 Experimental apparatus

The main instruments required for the experiment were: electric heat distilled water device (YN-ZD-Z), magnetic stirrers (MS-H280-Pro), analytical balance (DTT-FA200), micropipetteor (Eppendorf), pH meter (PHS-3E), refrigerators (BCD-201E/A), air conditioning (KFR-35G/A9(D)-D2), LED light (ODT514), electric heating blast drying oven (PCHB-C6000) and water purifier (MRC1796A-400G), etc.

2.4 Experimental methods

2.4.1 Seed germination

The peanut seeds with good color were selected as the material, which were neatly inoculated into the sterilized quartz sand with spaced 2-3 cm apart. After sowing, the sand layer with a thickness of 2 cm was overlaid on the seeds in cultivating box. And then the seeds were placed in a greenhouse with light intensity of 1500-2000 Lx at 25℃, and the light time was 12 h/day.

2.4.2 Preparation of nutrient solutions

The hydroponic nutrient solutions containing 0, 150, 300, 600 and 900 μmol/L $MnSO_4$ were prepared according to the reported methods [11], respectively.

2.4.3 Peanut seedlings were treated with hydroponics

The seedlings of peanut cultured in quartz sand for 5 days were transplanted into plastic boxes (length×width×height = 67×42×15 cm) with hydroponic nutrient solution contained various concentrations of $MnSO_4$ (0, 150, 300, 600 and 900 μmol/L) and treated for 15 days, respectively. The nutrient solution should be replaced every 5 days and the pH should be adjusted to pH=4.9-5.0 every 3 days.

2.4.4 Data recording

The data of lateral root number, main root length, plant height, dry weight of aboveground and underground parts were measured respectively in 5 replicates of each treatment on the 0, 5 and 10 days after the peanut seedlings transferred into the hydroponic nutrient solution contained various concentrations of $MnSO_4$ (0, 150, 300, 600 and 900 μmol/L).

2.4.5 Data processing

Excel software was used to input and calculate the data, and SPSS 20.0 statistical analysis software was used for variance analysis and Duncan's multiple comparison ($P≤0.05$). The significant difference was marked with different lowercase letters.

3 Results

3.1 Effects of different Mn concentration on plant height of peanut seedlings

According to Table 1 and Figure 1(A-D), the results suggested that the plant height of peanut seedlings firstly increased and then decreased with the increase of Mn concentration. The value of plant height was the highest when Mn concentration was 150 μmol/L, followed by 300 μmol/L on the 10th day, but there was no significant difference between the two treatments. However, when Mn was at the concentration of 900 μmol/L, the plant height of peanut was the lowest, indicating that high concentration of Mn might inhibit the growth of peanut seedlings. In conclusion, 150 or 300 μmol/L of Mn might be the suitable concentration for growth of peanut seedlings.

Table 1. Effects of different Mn concentrations on plant height of peanut seedlings

Concentrations of $MnSO_4$ (μmol/L)	Plant height (cm)		
	0 day	5th day	10th day
0	6.02±0.18a	8.62±0.21a	12.30±0.06b
150	6.14±0.23a	9.41±0.74a	13.77±0.18a
300	6.09±0.15a	9.15±0.49a	13.60±0.12a
600	6.17±0.12a	8.42±0.15a	12.20±0.09b
900	6.23±0.22a	8.83±0.18a	11.47±0.15c

Note: Different letters in the same column indicate significant difference at $P≤0.05$ level.

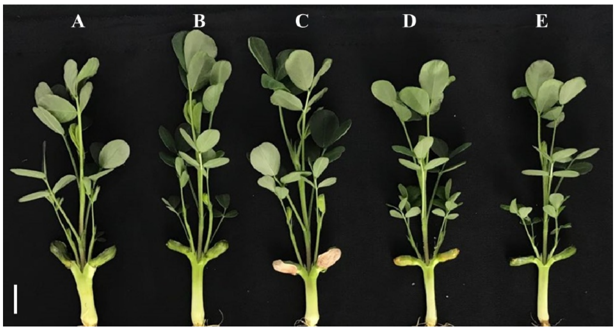

Figure.1 Effects of different Mn concentrations on plant height of peanut seedlings on the 10th day.

A: 0 μmol/L; B: 150 μmol/L; C: 300 μmol/L; D: 600 μmol/L; E: 900 μmol/L. (Bars=2 cm)

3.2 Influences of different Mn concentrations on main root length of peanut seedlings

In order to investigate the effects of different concentrations of Mn on the root length of peanut seedlings, the root length was measured and statistically analysed at 0, 5 and 10 days after transplantation, and the results were shown in Table 2. After 5 days of culture, the maximum of root length was achieved at the concentrations of 150 and 300 μmol/L. The longest root was obtained on the 10th day, while the root length was significantly lower than that of the other treatments at the 900 μmol/L Mn, indicating that high concentration of Mn inhibited root growth of peanut seedlings.

Table 2. Results of different Mn concentrations on main root length of peanut seedlings

Concentrations of $MnSO_4$ (μmol/L)	Main root length (cm)		
	0 day	5th day	10th day
0	11.82±0.62a	13.40±0.65ab	19.21±0.12c
150	11.78±0.28a	14.80±0.39a	23.27±0.24a
300	11.86±0.36a	14.53±0.17a	21.10±0.29b
600	11.75±0.41a	13.00±0.29b	16.07±0.34d
900	11.91±0.59a	12.70±0.42b	13.03±0.42e

Note: Different letters in the same column indicate significant difference at $P \leqslant 0.05$ level.

3.3 Results of different Mn concentrations on lateral root number of peanut seedlings

As seen in Table 3, the formation of lateral roots was affected by the concentration of Mn. The largest number of lateral roots of peanut seedlings was gained when Mn was at the concentrations of 0-300 μmol/L on the fifth day. Furthermore, the highest number of lateral roots acquired on the 10th day, when Mn was 0 and 150 μmol/L. However, when Mn was above 300 μmol/L, the number of lateral roots gradually decreased, and the lowest number of lateral roots was received at the concentration of 900 μmol/L. The results showed that the growth of lateral roots might be inhibited at high concentration of Mn.

Table 3. Effects of different Mn concentrations on lateral root number of peanut seedlings

Concentrations of $MnSO_4$ (μmol/L)	Number of lateral roots		
	0 day	5th day	10th day
0	40.33±2.03a	74.00±2.07a	92.00±1.00a
150	40.54±1.05a	72.21±2.65a	91.67±1.39a
300	40.68±2.12a	71.33±1.89ab	80.33±1.95b
600	40.74±1.58a	69.67±1.45b	77.33±2.11c
900	41.36±1.24a	66.67±1.63b	54.00±2.65d

Note: Different letters in the same column indicate significant difference at $P \leqslant 0.05$ level.

3.4 Effects of various Mn concentrations on dry weight of peanut seedlings

In order to investigate the effects of Mn on dry weight, the peanut seedlings were dried on the 10th day after transplantation, and the dry weight of the aboveground and underground parts were measured respectively. From the data in Table 4, the dry weights of aboveground and underground parts from 150 to 300 μmol/L Mn were higher than that from 600 to 900 μmol/L Mn. While the dry weight would decrease when the concentration of Mn over 300 μmol/L Mn, and the minimum of dry weight was gained at the concentration of 900 μmol/L Mn.

Table 4. Effects of different Mn concentrations on dry weight of peanut seedlings

Concentrations of $MnSO_4$ (μmol/L)	Dry weight (g)	
	Underground part	Overground part
0	0.14±0.01ab	0.65±0.03ab
150	0.17±0.02a	0.71±0.05a
300	0.15±0.01a	0.67±0.04a
600	0.13±0.01b	0.59±0.03b
900	0.11±0.01b	0.45±0.04c

Note: Different letters in the same column indicate significant difference at $P \leqslant 0.05$ level.

4 Discussion

Our results suggested that the growth and development of peanut seedlings would increase firstly and then decrease with the increase of Mn concentration, indicating that low concentration of Mn could significantly promote the growth of peanut, while high concentration of Mn could inhibit the growth of peanut seedlings. Some studies have shown that a large amount of Mn can be transported into the growing plant tissues, which increases the activity of auxin oxidase and destroys the auxin, resulting in the lack of auxin in the plant tissues, thus affecting the increase of plant height [5]. In addition, high concentration of Mn could inhibit the accumulation of dry matter in the upper and underground parts of the peanut seedlings. This may be because the growth of root is inhibited by high concentration of Mn severely, and then the growth of aboveground part will be impeded, leading to the reduction of biomass [12]. And there are other studies that show that when plants absorb excessive Mn, leading to reduce plant photosynthetic efficiency and chlorophyll content, young leaf etiolation, increase of superoxide dismutase (SOD) activity [13, 14]. High menganes also seriously affects plant growthm development and yield [15]. Therefore, Mn toxicity stress can cause great harm

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to plants and has become an important factor limiting plant growth and development [16, 17].

5 Conclusion

In the present study, the effects of different Mn concentrations on the growth and development of peanut seedlings were investigated. These results suggested that the main root length, lateral root number, plant height, dry weight of aboveground and underground parts of peanut seedlings were all affected by the concentrations of Mn obviously. Furthermore, the growth of peanut could be significantly promoted at low concentration of Mn (150 μmol/L), while high concentration of Mn (900 μmol/L) could inhibit the growth of peanut seedlings.

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