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Effects of Melatonin on the Growth of Radish Seedlings under Salt Stress

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Abstract: A pot experiment was conducted to study the effects of melatonin (MT) on the growth of radish seedlings under salt stress. MT increased the biomass, chlorophyll content and antioxidant enzyme activity of radish seedlings under salt stress. When the concentrations of MT were 50, 100, 150 and 200 μmol/L, the activity of SOD improved by 17.26%, 35.20%, 18.97%and 17.27%, respectively, compared with the control, and the activity of CAT improved by 118.44%, 132.55%, 114.82% and 103.69% respectively. When the concentration of MT was 100 μmol/L, the biomass, chlorophyll content and antioxidant enzyme activity of radish seedlings got the maximums. Therefore, MT could relieve the damage of radish seedlings under salt stress, and the dose of 100 μmol/L was the best.

Introduction

China is one of the most serious salt-affected countries in the world, and the total area of saline soil is about 36 million hectare, accounting for 4.88% of the available land area [1]. Not only the soil resources are wasted, but also the crop yield has been seriously affected, which threatens the sustainable development of Chinese agriculture [2]. Therefore, the development of salt tolerance of vegetables study has become an important issue in agricultural production [3].

Melatonin (MT) plays a role as an antioxidant defense system in unicellular organisms, and is mainly concentrated in mammals to regulate the rhythms and accomplishing various immune responses in early study [4]. MT is also found in plants, and has many physiological functions such as protecting chlorophyll, regulating plant photoperiod, similar to IAA growth regulation [5-7]. In recent years, more and more studies have been done on MT in higher plants. Exogenous MT treatment on *Isatis indigotica* seeds can increase the activity of antioxidant enzyme and alleviate the stress on seedlings growth under cold stress, and may stimulate plant growth by influencing plant IAA levels [8]. Exogenous MT has a certain effect on the germination of rice seeds under cadmium stress, which could improve the germination rate and germination potential and promote the growth of young roots and shoots [9].

Radish is a widely distributed vegetable in China, and has many varieties and large cultivated area [10]. In this study, we planted radish seedlings in salt stress environment, and studied the effects of MT on the growth of radish seedlings under salt stress, which could provide the reference for its application in vegetables.

Materials and Methods

Experimental Design. The vermiculites and pearlites (1:1) were put into polyethylene pot (10 cm high, 10 cm in diameter). Three uniform radish seedlings with three leaves expand were transplanted into each pot in November 2015, and 5 concentrations (0, 50, 100, 150 and 200 μmol/L) of MT with 3 replicates were sprayed on the leaves of plants for each pot, respectively. From the third day of transplanting, the Hogland nutrient solutions containing 50 mmol/L NaCl were watered every two days, and 30 ml solutions for each pot. When radish seedlings grow two months under salt stress, the upper mature leaves of radish seedlings were collected to determine the photosynthetic pigment (chlorophyll *a*, chlorophyll *b* and total chlorophyll) contents [11]. The upper young leaves (2 cm in length) were collected to determine the superoxide dismutase (SOD) activity, peroxidase (POD) activity, catalase (CAT) activity and soluble protein content [11]. Then, the whole plants were then gently removed, and the plant height, tuberous root length and root length was measured. The roots, tuberous roots and leaves were washed with tap water followed by deionized water, and the biomasses of root, tuberous root and leaf were measured.

Statistical Analyses. Statistical analyses were conducted using SPSS 13.0 statistical software (IBM, Chicago, IL, USA). Data were analyzed by one-way analysis of variance with Duncan's multiple range test (p = 0.05 confidence level).

Results and Discussion

Biomass of Radish. The root, tuberous root and leaf biomasses of radish increased in the all treatments of MT compared with the control (Table 1). With the increase of MT concentrations, the root, tuberous root, leaf biomasses of radish increased when the dose of MT was not more than 100 μmol/L, and decreased when the dose of MT was more than 100 μmol/L. The biomass of radish was ranked as: 100 μmol/L > 150 μmol/L > 200 μmol/L > 50 μmol/L > 0 μmol/L. When the dose of MT was 100 μmol/L, the root, tuberous root and leaf biomasses of radish increased by 48.39% ($p < 0.05$), 233.78% ($p < 0.05$) and 13.60% ($p > 0.05$) respectively compared with the control. Therefore, MT increased the growth of radish, which was suitable for enhancing the yield of radish.

Table 1 The biomass of radish

MT concentrations (μmol/L)	Root (g/plant)	Tuberous root (g/plant)	Leaf (g/plant)
0	0.062±0.018b	0.373±0.069d	1.654±0.057a
50	0.071±0.008b	0.717±0.074c	1.816±0.060a
100	0.092±0.006a	1.245±0.065a	1.879±0.055a
150	0.091±0.006a	1.181±0.054a	1.862±0.062a
200	0.090±0.010a	0.933±0.036b	1.848±0.054a

Values are means (±SE) of three replicate pots. Different lowercase letters within a column indicate significant difference ($p < 0.05$).

Root Length and Plant Height of Radish. MT promoted the growth of radish root, and increased the root length of radish (Table 1). The root length of radish was ranked as: 100 μmol/L > 150 μmol/L > 200 μmol/L > 50 μmol/L > 0 μmol/L. When the doses of MT were 50, 100, 150 and 200 μmol/L, the root length of radish increased by 14.66% ($p < 0.05$), 34.97% ($p < 0.05$), 15.24% ($p < 0.05$) and 14.82% ($p < 0.05$) respectively compared with the control. The tuberous root length also increased by MT treatments, and order was the same as root length. When the doses of MT were 50, 100, 150 and 200 μmol/L, the root length of radish increased by 1.23% ($p > 0.05$), 10.80% ($p < 0.05$), 9.81% ($p > 0.05$) and 4.48% ($p > 0.05$) respectively compared with the control. The plant height increased with the increase of MT concentrations when the dose of was not more than 100 μmol/L, and decreased when the dose of MT was more than 100 μmol/L. The order of plant height was the same as root length, too. When the doses of MT were 50, 100, 150 and 200 μmol/L, the root length of radish increased by 0.42% ($p > 0.05$), 6.54% ($p > 0.05$), 4.29% ($p > 0.05$) and 3.52% ($p > 0.05$) respectively compared with the control.

Chlorophyll Content in Radish. MT treatments increased the chlorophyll content in leaves of radish (Table 3). When the dose of MT was not more than 100 μmol/L, the contents of chlorophyll *a*, chlorophyll *b* and total chlorophyll increased with the increase of MT concentrations, and decreased when the dose of MT was more than 100 μmol/L. The contents of chlorophyll *a* and total chlorophyll were ranked as: 100 μmol/L > 50 μmol/L > 150 μmol/L > 200 μmol/L > 0 μmol/L, and the chlorophyll *b* content was ranked as: 100 μmol/L > 200 μmol/L > 50 μmol/L > 150 μmol/L > 0 μmol/L. When the doses of MT were 50, 100, 150 and 200 μmol/L, the total chlorophyll content of radish increased by 6.88% ($p > 0.05$), 11.22% ($p > 0.05$), 6.58% ($p > 0.05$) and 4.26% ($p > 0.05$) respectively compared with the control. The chlorophyll a/b was increased by MT compared with the control, which had the increase trend when the dose of MT was not more than 150 μmol/L, and had the decreased trend when the dose of MT was more than 150 μmol/L (Table 3).

Table 2 The root length and plant height of radish

MT concentrations (μmol/L)	Root length (cm)	Tuberous root length (cm)	Plant height (cm)
0	18.96±0.41c	2.121±0.144b	14.22±0.90a
50	21.74±0.60b	2.147±0.189ab	14.28±0.94a
100	25.59±0.72a	2.350±0.079a	15.15±0.82a
150	21.85±0.55b	2.329±0.094ab	14.83±0.83a
200	21.77±0.74b	2.216±0.129ab	14.72±0.98a

Values are means (±SE) of three replicate pots. Different lowercase letters within a column indicate significant difference ($p < 0.05$).

Table 3 The chlorophyll content in radish

MT concentrations (μmol/L)	Chlorophyll *a* (mg/g)	Chlorophyll *b* (mg/g)	Total chlorophyll (mg/g)	Chlorophyll a/b
0	1.029±0.070a	0.309±0.076a	1.337±0.146a	3.406±0.616a
50	1.139±0.048a	0.321±0.008a	1.429±0.084a	3.454±0.369a
100	1.153±0.101a	0.329±0.082a	1.487±0.012a	3.668±1.198a
150	1.123±0.223a	0.312±0.025a	1.425±0.248a	3.692±0.431a
200	1.068±0.244a	0.327±0.081a	1.394±0.163a	3.469±1.609a

Values are means (±SE) of three replicate pots. Different lowercase letters within a column indicate significant difference ($p < 0.05$).

Antioxidant Enzyme Activity of Radish. MT improved the antioxidant enzyme (POD, SOD and CAT) activity of radish in all treatments compared with the control (Table 4). The POD activity of radish was ranked as: 100 μmol/L > 150 μmol/L > 50 μmol/L > 200 μmol/L > 0 μmol/L. When the doses of MT were 50, 100, 150 and 200 μmol/L, the POD activity of radish improved by 6.35% ($p > 0.05$), 23.62% ($p < 0.05$), 6.74% ($p > 0.05$) and 2.42% ($p > 0.05$) respectively compared with the control. The SOD activity of radish was ranked as: 100 μmol/L > 150 μmol/L > 200 μmol/L > 50 μmol/L > 0 μmol/L. When the doses of MT were 50, 100, 150 and 200 μmol/L, the SOD activity of radish improved by 17.26% ($p > 0.05$), 35.20% ($p < 0.05$), 18.97% ($p > 0.05$) and 17.27% ($p > 0.05$) respectively compared with the control. The CAT activity of radish was ranked as: 100 μmol/L > 150 μmol/L > 200 μmol/L > 50 μmol/L > 0 μmol/L. When the doses of MT were 50, 100, 150 and 200 μmol/L, the CAT activity of radish improved by 98.49% ($p > 0.05$), 132.52% ($p < 0.05$), 114.82% ($p < 0.05$) and 103.69% ($p > 0.05$) respectively compared with the control. MT also increased the soluble protein content of radish in all treatments compared with the control (Table 4). The ranked of soluble protein content was the same as the CAT activity. When the doses of MT were 50, 100, 150 and 200 μmol/L, the soluble protein content of radish increased by 20.05% ($p >0.05$), 40.60% ($p < 0.05$), 25.31% ($p > 0.05$) and 24.40% ($p > 0.05$) respectively compared with the control.

Conclusions

Different concentrations (50, 100, 150 and 200 μmol/L) of MT increased the biomass, chlorophyll content and antioxidant enzyme activity of radish seedlings under salt stress. When the concentration of MT was 100 μmol/L, the biomass, chlorophyll content and antioxidant enzyme activity of radish seedlings got the maximums. Therefore, MT could relieve the damage of radish seedlings under salt stress, and the dose of 100 μmol/L was the best.

Table 4 The antioxidant enzyme activity of radish

MT concentrations (μmol/L)	POD activity (U/g/min)	SOD activity (U/g)	CAT activity (mg/g/min)	Soluble protein content (mg/g)
0	996.305±26.162b	1883.512±40.980b	19.704±9.289b	3.512±0.485b
50	1059.567±28.087ab	2208.537±60.064ab	39.110±7.658ab	4.216±0.523ab
100	1231.602±9.183a	2546.473±288.101a	45.815±3.571a	4.938±0.204a
150	1063.492±19.642ab	2240.896±132.046ab	42.328±9.535a	4.401±0.249ab
200	1020.408±28.862b	2208.884±135.8119ab	40.136±8.658ab	4.369±0.115ab

Values are means (±SE) of three replicate pots. Different lowercase letters within a column indicate significant difference ($p < 0.05$).

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