Effects of Naphthalene Acetic Acid (NAA) on Growth of *Cosmos sulphureus*

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Abstract: A pot experiment was carried out to investigate the effects of applying naphthalene acetic acid (NAA) on growth and physiology of *Cosmos sulphureus*. The results showed that application of NAA promoted the growth of *C. sulphureus* when the dose of NAA was not more than 15 mg/L. When the dose of NAA was lower than 15 mg/L, the biomass, the contents of chlorophyll a, chlorophyll b, total chlorophyll and carotenoid, the activities of SOD and POD, and the soluble sugar content of *C. sulphureus* increased, and got the maxima at the dose of 5 mg/L NAA. With the increase of concentration of NAA, the soluble protein and the CAT activity of *C. sulphureus* had the decreasing trend. Therefore, application of NAA could promote the growth of *C. sulphureus* at the dose of 5-15 mg/L.

Introduction

Naphthalene acetic acid (NAA) is one of plant hormones, which can regulate the growth and development of plants [1]. NAA extendes the storage time of the kiwi fruits [2] and red bayberry fruits [3]. When using different concentrations of NAA treat the hard branches of pyracantha, the number of roots increase, and the survival rates increase [4]. NAA treatment also promotes the rooting of Platanus orientalis [5]. The other studies also show that NAA promote the rooting of plants [6-9]. Howere, there are few studies on whether NAA could promote the growth of plants.

Cosmos sulphureus is one of annual herbaceous floricultural plants, origining from in Mexico [10]. In this study, we used the different concentrations of NAA to treat *C. sulphureus*, and studied the effects of NAA on growth and physiology of *C. sulphureus*. The aim of the study was to screen the best NAA concentration which could promote the growth of *C. sulphureus*, and provided a reference for applying the plant hormones on other floricultural plants.

Materials and Methods

Experimental Design. The nutrient soils and pearlites (2:1) were put into polyethylene pot (15 cm high, 18 cm in diameter). Two uniform *C. sulphureus* seedlings with four euphyllas were transplanted into each pot in April 2016. When the plants grew to 10 euphyllas, 5 concentrations (0, 5, 10, 15 and 20 mg/L) of NAA with 3 replicates were sprayed on the leaves of plants, respectively. The soil moisture was maintained at 80% of field capacity during the plant seedlings' growth process. At 60 days after planting (July 2016), the plants were harvested. The upper mature leaves of plants 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, the roots, stems and leaves were washed with tap water followed by deionized water, and the biomasses of root, stem and leaf were measured. The soluble sugar contents in roots, stems and leaves were determined by the anthrone colorimetry with dry weight plant samples [11].

Experimental Design. Statistical analyses were conducted using SPSS 13.0 statistical software (IBM, Chicago, IL, USA). Data were analyzed by one-way analysis of variance with least significant difference (LSD) at the $p = 0.05$ confidence level.

Results and Discussion

Biomass of *C. sulphureus*. With the increase of NAA concentrations, the root, stem, leaf and shoot biomasses of *C. sulphureus* increased when the dose of NAA was not more than 5 mg/L, and decreased when the dose of NAA was higher than 5 mg/L (Table 1). The order of root, stem, leaf and shoot biomasses of *C. sulphureus* were 5 mg/L NAA > 10 mg/L NAA > 15 mg/L NAA > 0 mg/L NAA > 20 mg/L NAA. When the dose of NAA was 5, 10 and 15 mg/L, the root biomass increased by 40.22% ($P < 0.05$), 35.60% ($P < 0.05$) and 3.53% ($P > 0.05$) respectively compared with the control, the stem biomass increased by 36.38% ($P < 0.05$), 17.38% ($P < 0.05$) and 12.54% ($P < 0.05$) respectively compared with the control, the leaf biomass increased by 48.84% ($P < 0.05$), 25.81% ($P < 0.05$) and 9.07% ($P < 0.05$) respectively compared with the control, and the shoot biomass increased by 41.80% ($P < 0.05$), 21.05% ($P < 0.05$) and 11.03% ($P < 0.05$) respectively compared with the control. So, When the dose of NAA was not more than 15 mg/L, it could promote the growth of *C. sulphureus*.

Table 1 Biomass of *C. sulphureus*

Treatments (mg/L)	Root biomass (g/plant)	Stem biomass (g/plant)	leaf biomass (g/plant)	Shoot biomass (g/plant)
0	3.68±0.103b	5.58±0.347c	4.30±0.190cd	9.88±0.158d
5	5.16±0.209a	7.61±0.170a	6.40±0.212a	14.01±0.042a
10	4.99±0.252a	6.55±0.214ab	5.41±0.260b	11.96±0.045b
15	3.81±0.191b	6.28±0.294b	4.69±0.182c	10.97±0.112c
20	3.45±0.199b	5.30±0.235c	3.90±0.086d	9.20±0.149e

Photosynthetic pigment content in *C. sulphureus*. The same as the biomass, the chlorophyll a, chlorophyll b, total chlorophyll and carotenoid contents of *C. sulphureus* increased when the dose of NAA was not more than 5 mg/L, and decreased when the dose of NAA was higher than 5 mg/L (Table 2). The contents of chlorophyll a, chlorophyll b, total chlorophyll and carotenoid reached the maxmium when the dose of NAA was 5 mg/L. When the dose of NAA was 5, 10 and 15 mg/L, the contents of chlorophyll a, chlorophyll b, total chlorophyll and carotenoid increased, and the dose of 20 mg/L NAA decreased that. When the dose of NAA was 5, 10 and 15 mg/L, the chlorophyll a content increased by 24.31% ($P < 0.05$), 19.23% ($P < 0.05$) and 16.38% ($P < 0.05$) respectively compared with the control, the chlorophyll b content increased by 21.51% ($P > 0.05$), 17.60% ($P > 0.05$) and 15.08% ($P > 0.05$) respectively compared with the control, the total chlorophyll content increased by 23.63% ($P < 0.05$), 18.84% ($P < 0.05$) and 16.07% ($P < 0.05$) respectively compared with the control, and the content of carotenoid increased by 23.08% ($P < 0.05$), 18.72% ($P < 0.05$) and 16.15% ($P < 0.05$) respectively compared with the control. So, When the dose of NAA was not more than 15 mg/L, it could improve the photosynthesis of *C. sulphureus*.

Soluble sugar content in *C. sulphureus*. The application of NAA increased the soluble sugar contents in roots, stems, leaves and shoots of *C. sulphureus* (Table 3). With the increase of NAA concentrations, the soluble sugar contents in roots, stems, leaves and shoots of *C. sulphureus* had the increasing trend when the dose of NAA was not more than 5 mg/L, and had the decreasing trend when the dose of NAA was higher than 5 mg/L. The order of the soluble sugar contents in roots, stems, leaves and shoots of *C. sulphureus* were 5 mg/L NAA > 10 mg/L NAA > 15 mg/L NAA > 20 mg/L NAA > 0 mg/L NAA. When the dose of NAA was 5 mg/L, the soluble sugar contents in roots, stems, leaves and shoots got the maxma, respectively. When the dose of NAA was 5, 10, 15 and 20 mg/L, the soluble sugar contents in roots increased by 62.03% ($P < 0.05$), 55.14% ($P < 0.05$), 5.01% ($P < 0.05$) and 1.88% ($P > 0.05$) respectively compared with the control, the soluble sugar contents in stems increased by 41.10% ($P < 0.05$), 39.36% ($P < 0.05$), 34.93% ($P <0.05$) and 18.74% ($P < 0.05$) respectively compared with the control, the soluble sugar contents in leaves increased by 106.13% ($P < 0.05$), 96.84% ($P < 0.05$), 59.11% ($P < 0.05$) and 52.60% ($P < 0.05$) respectively compared with the control, and the soluble sugar contents in shoots increased by 54.35% ($P < 0.05$), 51.19% ($P < 0.05$), 41.30% ($P < 0.05$) and 27.47% ($P < 0.05$) respectively compared with the control. Therefore, NAA redistributed the soluble sugar in different organs of *C. sulphureus*.

Table 2 Photosynthetic pigment content in *C. sulphureus*

Treatments (mg/L)	Chlorophyll a (mg/g)	Chlorophyll b (mg/g)	Total chlorophyll (mg/g)	Carotenoid (mg/g)
0	1.123±0.060b	0.358±0.043a	1.481±1.481b	0.39±0.390ab
5	1.396±0.024a	0.435±0.014a	1.831±1.831a	0.480±0.480a
10	1.339±0.046a	0.421±0.025a	1.760±1.760a	0.463±0.463a
15	1.307±0.013a	0.412±0.026a	1.719±1.719a	0.453±0.453a
20	1.108±0.053b	0.351±0.019a	1.459±1.459b	0.366±0.366b

Table 3 Soluble sugar content in *C. sulphureus*

Treatments (mg/L)	Roots (mg/g)	Stems (mg/g)	leaves (mg/g)	Shoots (mg/g)
0	7.98±0.209d	13.77±0.253d	5.38±0.005c	10.12±0.078d
5	12.93±0.102a	19.43±0.044a	11.09±0.332a	15.62±0.061a
10	12.38±0.208b	19.19±0.094a	10.59±0.078a	15.30±0.259a
15	8.38±0.177b	18.58±0.030b	8.56±0.144b	14.30±0.166b
20	8.13±0.030cd	16.35±0.264c	8.21±0.010b	12.90±0.024c

Antioxidant enzyme activity of *C. sulphureus*. The application of NAA decreased the soluble protein content of *C. sulphureus* (Table 4). With the increase of NAA concentrations, the soluble protein content of *C. sulphureus* had the decreasing trend. When the dose of NAA was 5, 10, 15 and 20 mg/L, the soluble protein content decreased by 14.83% ($P < 0.05$), 25.54% ($P < 0.05$), 30.12% ($P < 0.05$) and 37.77% ($P < 0.05$) respectively compared with the control. Different with the soluble protein content, when the dose of NAA was 5, 10 and 15 mg/L, the activities of SOD and POD improved, and 20 mg/L NAA reduced that (Table 4). When the dose of NAA was 5, 10 and 15 mg/L, the activity of SOD improved by 17.67% ($P < 0.05$), 5.86% ($P > 0.05$) and 1.02% ($P > 0.05$) respectively compared with the control, and the activity of POD improved by 76.02% ($P < 0.05$), 13.19% ($P < 0.05$) and 10.43% ($P < 0.05$) respectively. NAA reduced the activity of CAT, and the CAT activity of *C. sulphureus* had the decreasing trend with the increase of NAA concentrations (Table 4). When the dose of NAA was 5, 10, 15 and 20 mg/L, the soluble protein content decreased by 6.56% ($P < 0.05$), 22.95% ($P < 0.05$), 29.51% ($P < 0.05$) and 47.54% ($P < 0.05$) respectively compared with the control.

Conclusions

The application of NAA promoted the growth of *C. sulphureus* when the dose of NAA was not more than 15 mg/L. When the dose of NAA was lower than 15 mg/L, the biomass, the contents of chlorophyll a, chlorophyll b, total chlorophyll and carotenoid, the activities of SOD and POD, and the soluble sugar content of *C. sulphureus* increased, and got the maxima at the dose of 5 mg/L NAA. With the increase of concentration of NAA, the soluble protein and the CAT activity of *C. sulphureus* had the decreasing trend. Therefore, application of NAA could promote the growth of *C. sulphureus* at the dose of 5-15 mg/L.

Table 4 Antioxidant enzyme activities of *C. sulphureus*

Treatments (mg/L)	Soluble protein content (mg/g)	SOD activity (U/g)	POD activity (U/g)	CAT activity [mg/(g·min)]
0	6.54±0.14a	253.84±5.07b	1011.15±14.14c	0.061±0.002a
5	5.57±0.08b	298.70±10.08a	1779.87±28.73a	0.057±0.001b
10	4.87±0.11c	268.72±3.36b	1144.55±40.06b	0.047±0,002c
15	4.57±0.13d	256.43±6.65b	1116.62±19.34b	0.043±0.001d
20	4.07±0.07e	227.60±1.72c	756.49±4.59d	0.032±0.002e

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