Cu^{2+}与 Zn^{2+}递进胁迫下高羊茅的初期生长效应及生态阈限研究

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摘要:通过重金属 Cu^{2+}、Zn^{2+}递进胁迫高羊茅初期生长效应及生态阈限的研究,结果表明:在 Cu^{2+}与 Zn^{2+}递进胁迫作用下,高羊茅生长在各处理浓度均不同程度上受到抑制作用,其抑制效应随重金属浓度的增加而增强,各项测定指标与胁迫浓度呈极显著负线性关系,并各相关系数均达到极显著水平($r>-0.9000^{**}$);生长综合效应分析比较,Cu^{2+}比 Zn^{2+}的负向效应为明显。根与茎叶对 Cu^{2+}与 Zn^{2+}的富集状况分析采用 ICP-AES 法,分析结果表明,随着重金属 Cu^{2+}与 Zn^{2+}胁迫浓度的增加,高羊茅根系和茎叶的重金属含量均随之增加,根系对 Cu^{2+}与 Zn^{2+}的富集系数均明显大于茎叶。从绿度分析看,本实验条件下的 Cu^{2+}与 Zn^{2+}胁迫,均未出现草坪草绿度的明显变化。

关键词:Cu^{2+}与 Zn^{2+}递进胁迫; 高羊茅; 初期生长效应; 生态阈限

Initial Growth Effect and Ecological Threshold of *Festuca arundinacea* L. Under Progressive Stress of Cu^{2+} and Zn^{2+}

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Abstract: Initial growth effect and ecological threshold of *F. arundinacea* under progressive stress of heavy metal Cu^{2+} and Zn^{2+} were investigated. The results showed that under progressive stress of Cu^{2+} and Zn^{2+}, the growth of *F. arundinacea* was inhibited by different degrees in each treated concentration, and the inhibiting effect increased as increase of heavy metal concentration. The most significantly negative linear correlation was run between each index determined and stress concentration(C), and all coefficients reached the most significant level($r>-0.9000^{**}$). For Cu^{2+} stress, the correlated coefficients of *RIH* and C, *SLP* and C, *URP* and C, *PNP* and C were -0.9162^{**}, -0.9724^{**}, -0.9597^{**} and -0.9582^{**} respectively. With Zn^{2+} stress, coefficients of *RIH* and C, *SLP* and C, *URP* and C, *PNP* and C were -0.9680^{**}, -0.9543^{**}, -0.8876^{**} and -0.8967^{**} respectively. Through analyzing synthetical effect of growth, the negative effect of Cu^{2+} was greater than that of Zn^{2+}. Analysis on enrichment situation used ICP-AES method. The results showed that along with increase of Cu^{2+} and Zn^{2+} stress concentration, their contents in roots and stem-leaf all increased. The enrichment coefficients of roots to Cu^{2+} and Zn^{2+} were all obviously larger than that of stem-leaf. Seen from analysis on green degree of turfgrass, under Cu^{2+} and Zn^{2+} stress of the experimental conditions, obvious change of green degree didn't appear.

Key words: Cu^{2+} and Zn^{2+} progressive stress; *Festuca arundinacea* L.; initial growth effect; ecological threshold

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万方数据

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Heavy metals are stable in the environment. They are high toxic to living thing, and their pollution becomes serious day by day. So the problem of heavy metal toxicity has caused general attention by scholars[1,2]. Because the pollution of heavy metal elements to crops may be accumulated in food chain and it would be much harmful to human health, crops are always chosen as experimental materials seen from the range of study at present, for example, toxicity of heavy metals to *Hordeum vulgare*[3], uptake of Zn and Cd by hyphae of an arbuscular mycorrhizal fungi (*G. mosseae*) associated with red clover[4], and impact of heavy metal combined pollution on soybean growth[5], and so on. Especially heavy metal combined pollution on agricultural ecological system has been paid much attention in recent years[6, 7]. Lawn has its special ecological meanings in reducing pollution and protecting environment[8]. However, heavy metal toxicity on turfgrass has not been paid much attention[9]. *F. arundinacea* has strong stress resistance and wide adaptability. It is one of main turfgrass in lawn virescence in north China[10]. As we know, Cu^{2+} and Zn^{2+} are plant growth regulators in low concentrations. But they will become pollution stress factors when their environmental concentrations exceed threshold concentrations. They exist in industrial wastewaters. With the development of modern industry, large amount of Cu^{2+} and Zn^{2+} would enter the environment. This phenomenon looks more prominent in urban ecological environment. Cu^{2+} and Zn^{2+} are the two important pollutants of heavy metals in urban environment. So the current study on growth effect of *F. arundinacea* and ecological threshold under progressive stress of Cu^{2+} and Zn^{2+} can provide scientific basis for formulating heavy metal content standard in lawn irrigation water in China, for controlling heavy metal contents in turf culture medium, especially solid waste as medium, and planning lawn virescence in heavy metal pollution region. At the same time, the study can be used for reference on analyzing the growth effect under pollutant stress and quantitatively analyzing ecological threshold.

1 Materials and methods

1.1 Compounding medium

Garden mould and fine sand were used as media. They were air-dried naturally, sieved with 2.0mm× 2.0mm sifter and even mixed to the ratio of 3 and 2. The medium was neutral. The background contents of Cu^{2+} and Zn^{2+} in the medium were determined according to the method of ICP-AES. Digestion used aqua regia-perchloride acid. The concentrations of Cu^{2+} and Zn^{2+} were 15.7 and 159.0μg/g separately. The background contents of other mineral elements in the medium were Pb 20.1, Cd 5.81, As 66.6, Cr 21.1, Ni 9.82, Se 60.0, Fe 8482.0, B 13.7, Mo 4.04, Mn 27.0μg/g respectively.

1.2 Compounding Cu^{2+} and Zn^{2+} stress solutions

$ZnSO_4 \cdot 7H_2O$ and $CuSO_4 \cdot 5H_2O$ were used as heavy metal regents. The concentrations of Cu^{2+} were 0, 200, 400, 600, 800, 1000 and 1200μg/ml seven treatment levels, and that of Zn^{2+} were 0, 300, 600, 900, 1200, 1500 and 1800μg/ml.

1.3 Turfgrass culture

Because the method of ICP-AES was used to analyze in the experiment, it would need to do a lot of jobs in groping digestion condition and testing samples. On scale control, the study applied the following pattern: 50g compound medium even mixed was put into culture dish (Φ =10cm), then *F. arundinacea* seed 100 grains were even sowed in the medium respectively. After sowing, equal water of 10 ml was given to each dish each time in the morning and evening. The media were kept wet but not watery. Turfgrass was cultured on the plant culture table in the laboratory with temperature range of 17～20℃ in the daytime. The light was natural light through the laboratory with illumination of 1100～2800 lx in the

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daytime.

1.4 Treatment by progressive stress

The 28th day of culture was just a critical period for *F. arundinacea* initial growth. Roots grew rapidly which could be seen from the bottom of culture dish. Aboveground growth began to get across lay phase and to enter into logarithmic growth phase. So progressive stress with above Cu^{2+} and Zn^{2+} solutions was carried out at 28d, and with concentration of 0 as control. Every day 10ml heavy metal stress solution was equally put into, and stressed 5 days continuously. The experiment was repeated 2 times. In addition, water management still equally went on. To the 44th day after the experiment, the determination of each index was fulfilled.

1.5 Index determination and analysis

Before stress treatment, height and density of *F. arundinacea* were determined together. Finally plant height was determined again. Six random plants in each culture dish were selected to determine each index. In addition, on the 12th day after stress, roots were washed to cleanse medium, roots and stem-leaf were separated and dried in the oven to constant weight with temperature 80℃ (8 hours). Cu^{2+} and Zn^{2+} contents in roots and stem-leaf were determined by ICP-AES method, and digestion used nitric acid-perchloride acid.

2 Results and analyses

2.1 Plant growth

The relative net increase height ($RIH_{Cu/Zn}$) of *F. arundinacea* with different concentrations was determined via progressive stress of Cu^{2+} and Zn^{2+}, $RIH_{Cu/Zn}$ stands for plant height on the 44th day after Cu^{2+} and Zn^{2+} stress minus plant height before stress. The index can help to understand growth effect of *F. arundinacea* under different concentrations of Cu^{2+} and Zn^{2+} to a great extent. The results of $RIH_{Cu/Zn}$ indicated that the percentages of RIH_{Cu} relative effect with stress concentrations 0, 200, 400, 600, 800, 1000 and 1200μg/ml of Cu^{2+} were 100.00%, 83.22%, 62.42%, 61.07%, 55.37%, 53.02% and 49.33% respectively. Under Cu^{2+} progressive stress, RIH_{Cu} appeared extremely significant negative correlation with stress concentration (C), and its regressive equation was $RIH_{Cu} = 2.6779 - 1.2 \times 10^{-3} C$, $r = -0.9162^{**}$. Variance analysis on RIH_{Cu} of each stress concentration reached significant level. Thereinto, that of 0, 200, 400μg/ml appeared significant difference ($P < 0.01$), 600 and 800, 1000μg/ml didn't show significant difference ($P > 0.01$), but 600 and 1200μg/ml showed significant difference ($P < 0.01$). For RIH_{Zn}, the percentages of relative effect with concentrations 0, 300, 600, 900, 1200, 1500 and 1800 μg/ml of Zn^{2+} were 100.00%, 87.71%, 83.28%, 79.86%, 76.45%, 74.06% and 65.87% respectively. Like RIH_{Cu}, RIH_{Zn} appeared extremely significant negative correlation with C, and its regressive equation was $RIH_{Zn} = 2.8029 - 5.0 \times 10^{-4} C$, $r = -0.9680^{**}$. Variance analysis on RIH_{Zn} of each stress concentration reached significant level. Through further comparison, 0 and 600μg/ml appeared significant difference ($P < 0.01$), 600 and 900, 1200, 1500μg/ml didn't show significant difference ($P > 0.01$), but 600 and 1800μg/ml showed significant difference ($P < 0.01$).

2.2 Aboveground individual plant net primary production

Aboveground individual plant net primary production of *F. arundinacea* is individual plant stem-leaf net primary production ($SLP_{Cu/Zn}$). It is an important index reflecting photosynthesis of *F. arundinacea* under progressive stress of different concentrations of Cu^{2+} and Zn^{2+}. The results of $SLP_{Cu/Zn}$ indicated that the percentages of SLP_{Cu} relative effect with stress concentrations 0, 200, 400, 600, 800, 1000 and 1200μg/ml of Cu^{2+} were 100.00%, 98.12%, 98.43%, 97.49%, 96.67%, 94.04% and 93.42% respectively. SLP_{Cu} appeared extremely significant negative correlation with C, and its regressive equation

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was $SLP_{Cu}=3.2029-2.0\times10^{-4}C$, $r=-0.9724^{**}$. Variance analysis on SLP_{Cu} didn't reach significant level ($P>0.01$). This indicated that the negative effect formed by aboveground net primary production under Cu^{2+} progressive stress appeared distinct ecological time lag. For RIH_{Zn}, the percentages of relative effect with concentrations 0, 300, 600, 900, 1200, 1500 and 1800μg/ml of Zn^{2+} were 100.00%, 99.67%, 99.33%, 99.00%, 96.99%, 95.65% and 94.31% respectively. SLP_{Zn} also appeared extremely significant negative correlation with C, and its regressive equation was $SLP_{Zn}=3.0136-1.0\times10^{-4}C$, $r=-0.9543^{**}$. Variance analysis on SLP_{Zn} didn't reach significant level($P>0.01$). This also indicated that the negative effect formed by aboveground net primary production under Zn^{2+} progressive stress appeared distinct ecological time lag.

2.3 Underground individual plant net primary production

The growth status of turfgrass underground roots is an important index to scale turfgrass growth potential. The results showed that the percentages of underground net primary production (URP_{Cu}) relative effect with stress concentrations 0, 200, 400, 600, 800, 1000 and 1200μg/ml of Cu^{2+} were 100.00%, 95.56%, 94.81%, 94.07%, 93.33%, 91.11% and 89.26% respectively. URP_{Cu} appeared extremely significant negative correlation with C under Cu^{2+} progressive stress, and its regressive equation was $URP_{Cu}=2.6618-2.0\times10^{-4}C$, $r=-0.9597^{**}$. Variance analysis on URP_{Cu} reached significant level. Through further comparison, that of 0 and 1200μg/ml appeared significant difference($P<0.01$), between URP_{Cu} of other stress concentrations, there isn't significant difference($P>0.01$), but 600 and 1200μg/ml showed significant difference($P<0.01$). As to URP_{Zn}, the percentages of relative effect with stress concentrations 0, 300, 600, 900, 1200, 1500 and 1800 μg/ml of Zn^{2+} were 100.00%, 88.10%, 78.19%, 76.20%, 75.35%, 73.09% and 72.24%. Under progressive stress of Zn^{2+}, URP_{Zn} appeared extremely significant negative correlation with C too, and its regressive equation was $URP_{Zn}=3.2793-5.0\times10^{-4}C$, $r=-0.8876^{**}$. Variance analysis on URP_{Zn} reached significant level, among which, between 0, 300 and 600μg/ml, there exists significant difference($P<0.01$), but between 600 and 900, 1200, 1500, 1800 μg/ml, there isn't significant difference($P>0.01$).

2.4 Individual plant gross net photosynthetic production

The gross net photosynthetic production of *F. arundinacea* ($PNP_{Cu/Zn}$) equals to stem-leaf net primary production ($SLP_{Cu/Zn}$) plus underground net primary production($URP_{Cu/Zn}$)minus the energy consumed by respiration of turfgrass(TR). Its formula can be showed $PNP_{Cu/Zn}=SLP_{Cu/Zn}+URP_{Cu/Zn}-\mathrm{TR}$. According to the formula, the gross net photosynthetic production($PNP_{Cu/Zn}$) under progressive stress of Cu^{2+} and Zn^{2+} could be calculated. The results indicated that the percentages of PNP_{Cu} relative effect with stress concentrations 0, 200, 400, 600, 800, 1000 and 1200μg ml^{-1} of Cu^{2+} were 100.00%, 96.94%, 96.26%, 95.93%, 94.57%, 94.23% and 92.70% respectively. PNP_{Cu} appeared extremely significant negative correlation with C, and its regressive equation was $PNP_{Cu}=5.8261-3.0\times10^{-4}C$, $r=-0.9582^{**}$. Variance analysis on PNP_{Cu} between each stress concentration didn't show significant difference($P>0.01$). For PNP_{Zn}, the percentages of relative effect with stress concentrations 0, 300, 600, 900, 1200, 1500 and 1800μg/ml of Zn^{2+} were 100.00%, 91.56%, 87.88%, 86.35%, 85.74%, 85.43% and 82.36% respectively. PNP_{Zn} also showed extremely significant negative correlation with C, and its regressive equation was $PNP_{Zn}=6.2389-5.0\times10^{-4}C$, $r=-0.8967^{**}$. Variance analysis on PNP_{Zn} between each stress concentration showed significant difference. Through further comparison, between 0 and 300μg/ml there was significant difference($P<0.01$), but between 600, 900, 1200, 1500 and 1800μg/ml there wasn't significant difference($P>0.01$).

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2.5 Enrichment characteristics

Under progressive stress of Cu^{2+} and Zn^{2+}, ion content in stem-leaf and roots showed extremely significant positive correlation with C (Table 1 and Fig. 1). Remarkably, along with increase of C, Cu^{2+} content in stem-leaf and roots increased, but when C reached 1200μg/ml, Cu^{2+} content dropped. The phenomena illuminated that the absorption of *F. arundinacea* to Cu^{2+} existed a concentration threshold. In other words, when the absorption reached this concentration threshold, though stress concentration increased, Cu^{2+} content in stem-leaf and roots didn't increase, on the contrary, it may dropped because it may be controlled by interior mechanism. Compared with Cu^{2+}, Zn^{2+} didn't appear a clear concentration threshold like Cu^{2+} along with C increased continuously. This could give a preliminary determination that Zn^{2+} had high enrichment characteristics to *F. arundinacea*. As for Cu^{2+} and Zn^{2+}, their enrichment characteristics in stem-leaf and roots could be scaled by enrichment coefficient. It could be expressed by formula: enrichment coefficient (EC) = ion concentration in organism (Bc)/ion concentration in environment (Ic). The enrichment coefficients of Cu^{2+} and Zn^{2+} in stem-leaf and roots could be calculated according to the formula (Fig. 2). It can be seen that enrichment coefficient of Zn^{2+} in stem-leaf was bigger than that of Cu^{2+}, but in roots the result turned out contrary: $Cu^{2+} > Zn^{2+}$. This indicated that the distribution of Cu^{2+} and Zn^{2+} in roots was much more than that in stem-leaf. Namely, the average contents of Cu^{2+} and Zn^{2+} in roots were 12.13 and 3.07 times that in stem-leaf, showing that the ability of Cu^{2+} and Zn^{2+} moving aboveground was relatively weak.

Table 1 The regressive equation of Cu^{2+} and Zn^{2+} contents in stem-leaf and roots of *F. arundinacea* and stress concentration (μg/g)

Metal ions	Sorts	Regressive equation	Related coefficients
Cu^{2+}	Stem-leaf	$SL_C = 10.5157 + 0.1595C$	0.9135**
	Roots	$UR_C = 94.0421 + 2.1557C$	0.9805**
Zn^{2+}	Stem-leaf	$SL_C = 39.1261 + 0.5115C$	0.9715**
	Roots	$UR_C = 262.5507 + 1.2642C$	0.9919**

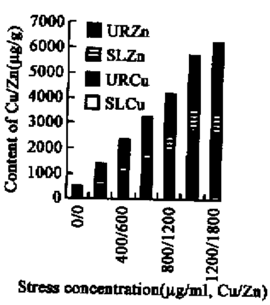

Fig. 1 Cu^{2+} and Zn^{2+} content in stem-leaf and roots of *F. arundinacea*

Notes: UR stands for ion content in roots SL stands for that in stem-leaf

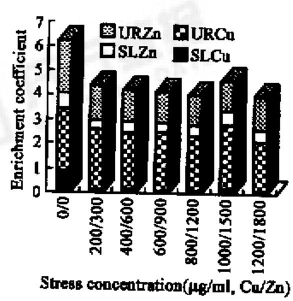

Fig. 2 Enrichment coefficient of Cu^{2+} and Zn^{2+} in stem-leaf and roots

Notes: UR stands for ion enrichment coefficient in roots, SL stands for that in stem-leaf

2.6 Growth synthetical effect

Growth synthetical effect index (SEI) can be used to evaluate stress effect of *F. arundinacea* by Cu^{2+} and Zn^{2+}. The index could quantitatively evaluate growth effect under Cu^{2+} and Zn^{2+} stress. We try to calculate it by the formula:

$$SEI_{Cu/Zn} = (\sum RIH_{RCu/Zn} + \sum URP_{RCu/Zn} + \sum SLP_{RCu/Zn}) \times CI_{Cu/Zn}/3$$

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In the formula, $SEI_{Cu/Zn}$ is growth synthetical effect index which represents synthetical weighted average of each index effect under Cu^{2+} and Zn^{2+} stress. $CI_{Cu/Zn}$ is relative conversion coefficient of Cu^{2+} and Zn^{2+} stress concentration. $\sum RIH_{RCu/Zn}$ is the sum of difference of relative net growth height of seedling height with each stress concentration of Cu^{2+}, Zn^{2+} and contrast. $\sum URP_{RCu/Zn}$ is the sum of difference of underground net primary production with Cu^{2+} and Zn^{2+} each stress concentration and contrast. $\sum SLP_{RCu/Zn}$ is the sum of difference of stem-leaf net primary production with Cu^{2+} and Zn^{2+} each stress concentration and contrast. *SEI* could be figured out by the formula above (Table 2). Seen from each parameter of *SEI*, synthetical negative effect under Cu^{2+} progressive stress was greater than that under Zn^{2+}, namely SEI_{Cu} was 1.44% times SEI_{Zn}. The cause was mainly that the negative contribution ratio of Cu^{2+} to *F. arundinacea* seedling plant growth was much greater than that of Zn^{2+}. With regard to concrete indexes of negative effect by Cu^{2+} and Zn^{2+}, the negative effect of Cu^{2+} to plant growth was greater than that of Zn^{2+}, thereinto, $\sum RIH_{RCu} \times CI_{Cu}$ was 2.70 times $\sum RIH_{RZn} \times CI_{Zn}$. The negative effect of Zn^{2+} to seedling root growth was greater than that of Cu^{2+}, thereinto, $\sum URP_{RZn} \times CI_{Zn}$ was 2.85 times $\sum URP_{RCu} \times CI_{Cu}$. But the negative effect of Cu^{2+} to aboveground photosynthetic system of *F. arundinacea* was greater than that of Zn^{2+}, among which $\sum SLP_{RCu} \times CI_{Cu}$ was 2.20 times $\sum SLP_{RZn} \times CI_{Zn}$.

Table 2 Growth synthetical effect index (SEI) under Cu^{2+} and Zn^{2+} stress

Metal ions	$\sum RIH_R \times CI$	$\sum URP_R \times CI$	$\sum SLP_R \times CI$	*CI*	*SEI*	Order
Cu^{2+}	−7.00	−1.13	−0.66	1	−2.93	2
Zn^{2+}	−2.59	−3.22	−0.30	2/3	−2.04	1

2.7 Ecological threshold concentration

Ecological threshold concentration of pollutant stress was always analyzed by choosing declined limited coefficient of growth index. The growth index was divided into aboveground growth index and underground growth index. In this way, ecological threshold concentration under Cu^{2+} and Zn^{2+} progressive stress could be impersonally evaluated and analyzed. Related study showed that height growth index of plant had positive correlation with net primary production[10]. Related analysis on RIH_{Cu} and SLP_{Cu}, RIH_{Zn} and SLP_{Zn} showed that RIH_{Cu} had positive correlation with SLP_{Cu} ($r=0.8420^*$), so did RIH_{Zn} with SLP_{Zn} ($r=0.8827^*$). Therefore, in the study *RIH* was selected as aboveground growth index, and *URP* underground growth index. In addition, it was stipulated that when RIH_i declined limited coefficient of growth was 30%, namely when relative net increase height RIH_i declined to 30% of control RIH_0, the progressive stress concentration corresponding to RIH_x growth index was assumed as ecological threshold concentration of *RIH* growth index. When URP_i declined limited coefficient of growth was 10%, namely when underground root net primary production URP_i declined to 10% of control URP_0, the progressive stress concentration corresponding to URP_x growth index was assumed as ecological threshold concentration of *URP* growth index. What needed to be pointed out was that *URP* declined limited coefficient of growth was defined lower than that of *RIH* because when pollutant stressed plant, negative response of its root was rapid. Ecological threshold concentration under Cu^{2+} and Zn^{2+} progressive stress could be evaluated by the index of synthetical ecological threshold concentration (*SETC*). The index can be expressed by the formula:

万方数据

$$SETC_{Cu/Zn} = (RIH_{C\,Cu/Zn} + URP_{C\,Cu/Zn})/2$$

Seen generally from the results of the index (Table 3), the negative effect of Cu^{2+} to *F. arundinacea* was greater than that of Zn^{2+}, namely ecological threshold concentration of Cu^{2+} was less than that of Zn^{2+}. Analyzed from selecting ecological threshold concentration of growth index, the negative effect of Cu^{2+} to aboveground growth was relatively great, but the negative effect of Zn^{2+} to underground growth was relatively great.

Table 3 Synthetical ecological threshold concentration under progressive stress of Cu^{2+} and Zn^{2+}

Metal ions	Declined limiting coefficient of growth(%)		Ecological threshold concentration of growth index (μg ml^{-1})		Synthetical ecological threshold concentration (μg ml^{-1})	Order
	RIH_C	URP_I	RIH_C	URP_I		
Cu^{2+}	30	10	493.25	1159.00	826.13	2
Zn^{2+}	30	10	1503.80	204.60	854.20	1

3 Discussion and Conclusion

In the limited range of the concentration set, along with stress concentration increase, the initial growth of turfgrass-*F. arundinacea* under Cu^{2+} and Zn^{2+} progressive stress was inhibited more clearly, especially notable on plant height growth. The correlated coefficients indicated that the negative effect of Cu^{2+} was stronger than that of Zn^{2+}. Seen from the observation of appearance, with the increase of stress concentration, *F. arundinacea* didn't appear bad form character such as becoming yellow, fading and so on. Therefore, we could get preliminary conclusion that *F. arundinacea* had relatively high ecological threshold to Cu^{2+} and Zn^{2+} pollution stress. The ecological threshold was higher than theoretical value in practical application. Because crops were in pursuit of high yield but green degree was "biosis" of turfgrass, it was concluded that in practical application, the ecological threshold of turfgrass to pollution stress could be made higher than that of crops if the stress affected green degree not greatly, and it should have objective rationality[9]。Comparing Cu^{2+} with Zn^{2+}, the *SEI* of *F. arundinacea* to Cu^{2+} progressive stress was 1.44 times that to Zn^{2+} stress, showing that the negative effect of Cu^{2+} was greater than that of Zn^{2+}, namely the capability of *F. arundinacea* to endure Zn^{2+} was relatively better. This could be reflected from the determined value of aboveground and underground net primary production. At present, related research achievements indicated that the biological ways brought by stress of superfluous Cu^{2+} and Zn^{2+} pollution to plants were probably that: firstly, large numbers of heavy metal ions entered into plant body so as to disturb intrinsic balance system among ions, to cause normal barrier on some aspects such as absorption, transportation, penetration and regulation of ion, and to make metabolism disorder[3]; secondly, heavy metal ions combined with non-active group of some apoenzymes in plant body so as to make them denaturalization[3]; in addition, also some study indicated that long-term enrichment of Cu^{2+} and Zn^{2+} in plant body could induce cytologic poison effect such as chromosomal aberration etc[3]. To sum up, the difference of enrichment distribution of Cu^{2+} and Zn^{2+} in *F. arundinacea* body and their negative effect to each growth index was certainly caused. The difference was closely related with geochemistry property of element, background concentration of elements in environment, physiological metabolism mechanism of living things and coordinated evolution of living things and environmental elements. Turfgrass could reduce environmental pollution through patterns of decomposition, transformation and enrichment etc. This could decrease the total amount of pollutants entering food chain to some extent, alleviating the pressure of environmental pollution. From this meaning, turfgrass is the first line of defence for protecting environment. So its study has important ecological theoretical significance. Through the current study on progressive stress of Cu^{2+} and Zn^{2+} to *F. arundinacea*, the more important purposes were to quantitatively probe into growth effect and synthetical effect by Cu^{2+} and Zn^{2+} stress and to judge ecological threshold concentration. Therefore, the study can not only provide basis for *F. arundinacea*

万方数据

utilization in Cu^{2+} and Zn^{2+} pollution region and irrigation of Cu^{2+} and Zn^{2+} sewage, but also offer reference for qualitative analysis of similar research.

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