ISSN:2790-1688 DOI: 10.56028/aetr.1.1.55

# Distribution and accumulation characteristics of nitrogen and phosphorus of 16 species of plants on ecological floating-bed

Chengxia Jia[1,2], Mu Yang[1,2], Jiangqi Qu[1,2], Pan Liu[1,2], Zhiming Xin[1,2], Qingjing Zhang[1,2,*]

[1]Beijing Key Laboratory of Fishery Biotechnology, Beijing, China;

[2]Academy of Agriculture & Forestry Sciences, Beijing, China;

* 545031646@qq.com

**Abstract.** The distribution and accumulation characteristics of total nitrogen (TN) and total phosphorus (TP) in the aerial and underground parts of 16 species of plants on ecological floating-bed were studied, and showed significant differences. The TN contents in the aerial part and underground part were 1.09%-2.91% and 0.68%-2.22%, respectively. The TN contents in the aerial and underground parts of Dracaena sanderiana were both the highest among the 16 species of plants. The TP content in the aerial part ranged from 0.15% to 0.45%, and in the underground part ranged from 0.12% to 0.76%, respectively. The TP contents in the aerial part of Dieffenbachia picta was the highest, while in the underground part of Anthurium andraeanum was the highest. Translocation factors of 14 species of plants for TN were greater than 1, and 12 species of plants for TP were greater than 1, respectively. Arundo donax var. versicolor which had considerable absolute accumulation of TN and TP both in the aerial and underground parts, can effectively remove nitrogen and phosphorus from water, will be a promising potential plant in applying of ecological floating-bed technology.

**Keywords:** Floating bed; nitrogen; phosphorus; distribution characteristics; accumulation effect;

## 1. Introduction

Ecological floating-bed technology, which can effectively remove nitrogen, phosphorus, and other pollutants from water, has been widely considered green and safe. Aquatic plants absorb pollutants from water by roots, and accumulate them in various tissues [1-3]. Regularly cutting the stems and leaves of plants on the floating-bed can effectively transfer the pollutants out of the water, and reduce the cost of replanting plants. Studies have shown that plants of different species or genotypes might have significant differences in the absorption and enrichment of pollutants, as well as the distribution of pollutants in various parts of plants [4-7]. The high transport and accumulation ability, especially in stems and leaves of plants on the floating-bed, was the critical factor affecting the efficiency of water treatment of ecological floating-bed technology.

Therefore, the distribution and accumulation characteristics of TN and TP in the aerial and underground parts among 16 species of plants were studied, aiming at screening out the plants with high efficiency in transport and accumulation of TN and TP for ecological floating-bed technology.

## 2. Material and Methods

### 2.1 Test materials

16 test plants were included in this research, namely Arundo donax var. versicolor, Canna glauca, Lythrum salicaria, Canna warszewiczii, Iris pseudacorus, Iris lactea var. chinensis, Schefflera octophylla, Coleus blumei, Dracaena sanderiana, Phnom Penh Chlorophytum, Philodendron congo, Hylotelephium erythrostictum, Dieffenbachia picta, Calathea veitchiana, Chamaedorea elegans, and Anthurium andraeanum. The floating-bed was made of polyethylene foam board with a size of 100.0cm(L) × 100.0cm(W) × 13.8cm(H), and 16 holes were distributed in it, with an aperture size of 7.5 cm and a hole spacing of 7.2 cm.

ISSN:2790-1688 DOI: 10.56028/aetr.1.1.55

### 2.2 Methods

The experiment was carried out for 110 days in industrialized circulating aquaculture for breeding Cyprinus carpio in Beijing during the peak breeding period from June to October. The initial culture density was 20 kg·m-3, and the feeding ratio was 1% of body weight. The feeding time points were at 9:00, 13:00 and 17:00 every day. The floating-bed was placed on the surface of the culture pond. 16 plants of the same species were planted on the floating bed per square meter. At the end of the experiment, the plants were clean with distilled water. Every plant was divided into the aerial part (stems and leaves) and the underground part (roots). The wet weights of the two parts were measured respectively. Then they were placed in the laboratory to dry naturally. After that, they were dried at 105℃ in the 101-2AB electric blast drying oven until constant weight, and then the dry weights were measured again. Finally, the aerial and underground parts of plants were ground respectively, and the contents of TN and TP were measured [8], respectively. Means of triplicate measurements were calculated.

### 2.3 Data Analysis

The data were analyzed by Microsoft Excel 2007 and SPSS 16.0. Calculation formulas of translocation factor (TF) and effective translocation factor (ETF) between the aerial part and the underground part were as follows:

$$\text{Translocation Factor} = (1)\ \frac{C_{iA}}{C_{iU}} \tag{1}$$

$$\text{Effective Translocation Factor} = \frac{C_{iA} \times M_{iA}}{C_{iU} \times M_{iU}} \tag{2}$$

Among them, CiA and CiU were the contents of heavy metal in the aerial part and underground part of plants (mg·kg-1), respectively; MiA and MiU were the dry weights of the aerial part and underground part of plants (mg·kg-1) per unit area (kg·m-2), respectively.

## 3. Results and Analysis

### 3.1 Contents of TN and TP in the aerial and underground parts of plants

The dry weights, TN contents, and TP contents in the aerial and underground parts of 16 species of plants tested are shown in Figure 1, and they showed significant differences. The dry weights of the aerial parts ranged from 6.36g to 51.84g. The dry weight of Arundo donax var. versicolor was the highest, followed by Canna glauca and Canna warszewiczii, and that of Coleus blumei was the lowest.The dry weights of the underground parts ranged from 1.47 g to 23.35 g. The dry weight of Arundo donax var. versicolor was the highest, followed by Iris pseudacorus and Iris lactea var. chinensis, and that of Dieffenbachia picta was the lowest.

The TN contents in the aerial parts ranged from 1.09% to 2.91%. The TN content in the aerial part of Dracaena sanderiana was significantly higher than those in other plants ($P<0.01$), followed by Iris pseudacorus and Lythrum salicaria, and that of Iris lactea var. chinensis was the lowest. The TN contents in the underground parts ranged from 0.68% to 2.22%. The TN content in the underground part of Dracaena sanderiana was extremely significantly higher than those in other plants ($P<0.01$). Those of Dieffenbachia picta and Anthurium andraeanum were significantly higher than those in other plants ($P<0.05$). That of Iris lactea var. chinensis was the lowest. There was a weak correlation between the TN contents in the aerial and underground parts (R2=0.42).

The TP contents in the aerial parts ranged from 0.15% to 0.45%. Dieffenbachia picta and Iris pseudacorus had higher TP contents in the aerial parts than those in other plants, followed by Hylotelephium erythrostictum and Canna glauca. The TP contents in the aerial parts of Calathea veitchiana, Iris lactea var. chinensis, and Dracaena sanderiana were low. The TP contents in the underground parts ranged from 0.12% to 0.76%. The TP content in the underground part of Anthurium andraeanum was significantly higher than those in other plants (P<0.01), followed by Schefflera octophylla and Iris pseudacorus, and that of Dracaena sanderiana and Iris lactea var. chinensis were significantly lower than those in other plants (P<0.05). There was no correlation between the TP contents in the aerial and underground parts (R2=0.05).

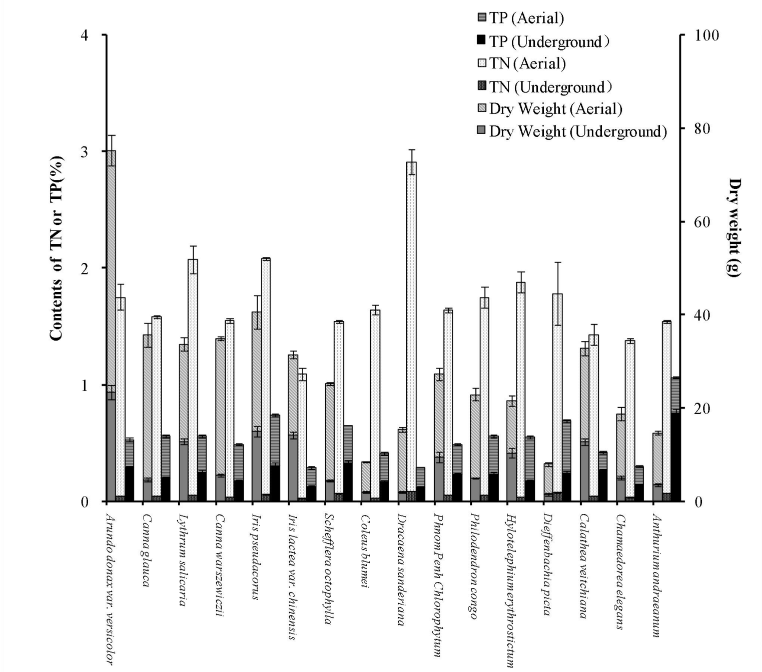

Figure 1. TN, TP, and dry weights in the aerial and underground parts

## 3.2 TN and TP accumulation in the aerial and underground parts of plants

The TN and TP accumulations in the aerial and underground parts of the 16 species of plants are shown in Figure 2, and they showed significant differences among the 16 species of plants. The TN accumulation in the aerial parts ranged from 1.67g·m-2 to 14.51g m-2. The TN accumulation in the aerial parts of Arundo donax var. versicolor was extremely significantly higher than those of other plants (P<0.01), followed by Iris pseudacorus, Canna glauca, and Canna warszewiczii. That of Coleus blumei was the lowest. TN accumulation in underground parts ranged from 0.25 g·m-2 to 4.56 g·m-2. The TN accumulation in underground parts of Arundo donax var. versicolor was extremely significantly higher than those of other plants (P<0.01), followed by Iris pseudacorus, and that of Coleus blumei was the lowest.

The TP accumulation in the aerial parts of 16 species plants ranged from 0.25g·m-2 to 2.02g m-2. The TP accumulation in the aerial parts of Arundo donax var. versicolor was extremely significantly higher than those of other plants (P<0.01), followed by Canna glauca and Iris pseudacorus, which were significantly higher than those of other plants (P<0.05), and that of Coleus blumei was the lowest. The TP accumulation in underground parts of Arundo donax var. versicolor was extremely significantly higher than those of other plants (P<0.01), followed by Iris pseudacorus, and that of Coleus blumei was the lowest.

Through linear fitting, it was found that the TN accumulation in the aerial and underground parts had a good correlation with the dry weights of 16 species of plants (R2=0.89 and 0.75, respectively), as did the TP accumulation with the dry weights (R2=0.87and 0.80, respectively).

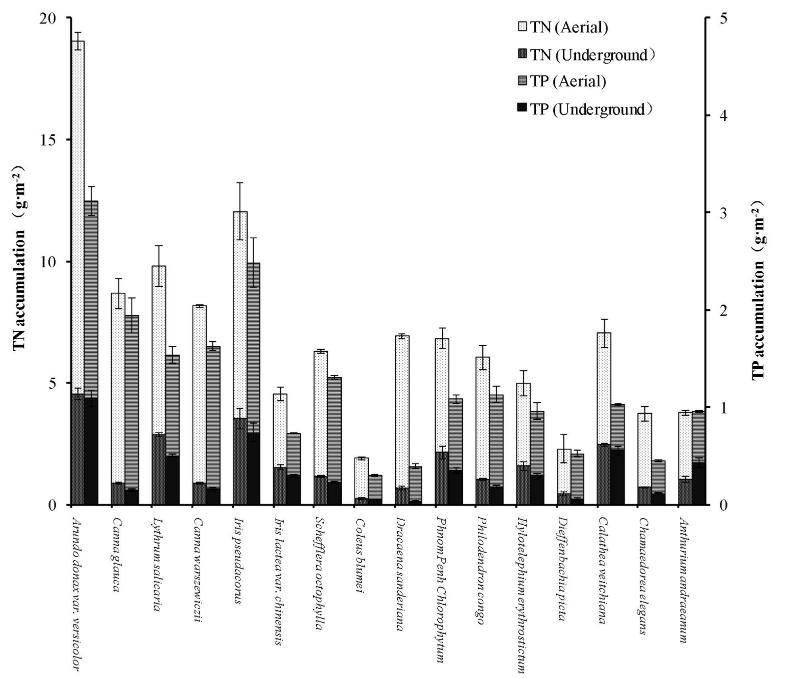


Figure 2. TN and TP accumulation in the aerial and underground parts

### 3.3 Translocation factors and effective translocation factors of plants

The translocation factors of TN and TP of the 16 species of plants are shown in Figure 3, and they showed significant differences among 16 species plants. Translocation factors of TN ranged from 0.83 to 2.11. There was no significant difference in translocation factors of TN among the 16 species ($P>0.05$). 14 species of plants had high TN translocation factors greater than 1. The translocation factor of Coleus blumei was the biggest, followed by Hylotelephium erythrostictum, and that of Anthurium andraeanum was the smallest. The translocation factors of TP ranged from 0.41 to 1.98. There was no significant difference in translocation factors of TP among the 16 species ($P>0.05$). 12 species of plants had high translocation factors of TP greater than 1. The translocation factor of Hylotelephium erythrostictum was the biggest, followed by Dieffenbachia picta, and that of Anthurium andraeanum was the smallest.

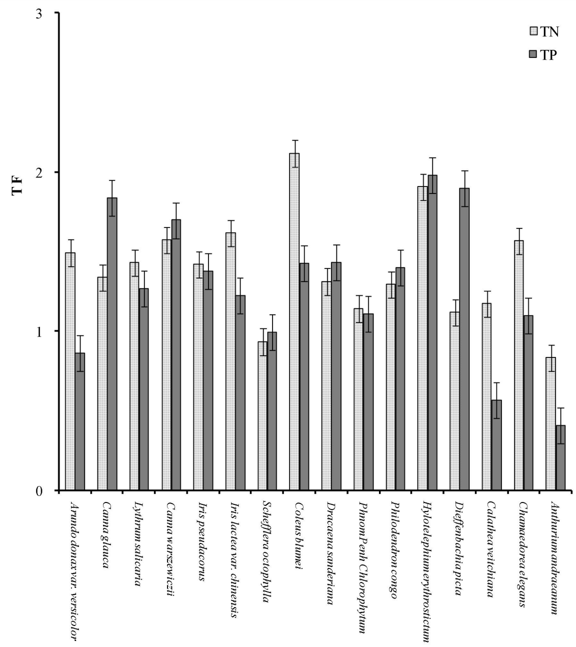


Figure 3. The translocation factors of TN and TP of 16 species of plants

ISSN:2790-1688 DOI: 10.56028/aetr.1.1.55

The effective translocation factors of TN and TP of 16 species of plants are shown in Figure 4. The result showed significant differences between effective translocation factors and translocation factors either for TN or TP. The effective translocation factors of TN were all greater than 1, ranging from 1.86 to 8.89, and there was no significant difference among the 16 species ($P>0.05$). The effective translocation factors of TN of Dracaena sanderiana was the highest, followed by Canna glauca and Canna warszewiczii, and that of Calathea veitchiana was the lowest. The effective translocation factors of TP ranged from 0.84 to 11.83, and only the effective translocation factor of Calathea veitchiana was smaller than 1. The effective translocation factor of Canna glauca was higher than those of other plants ($P<0.01$), followed by Dracaena sanderiana, and that of Calathea veitchiana was the lowest.

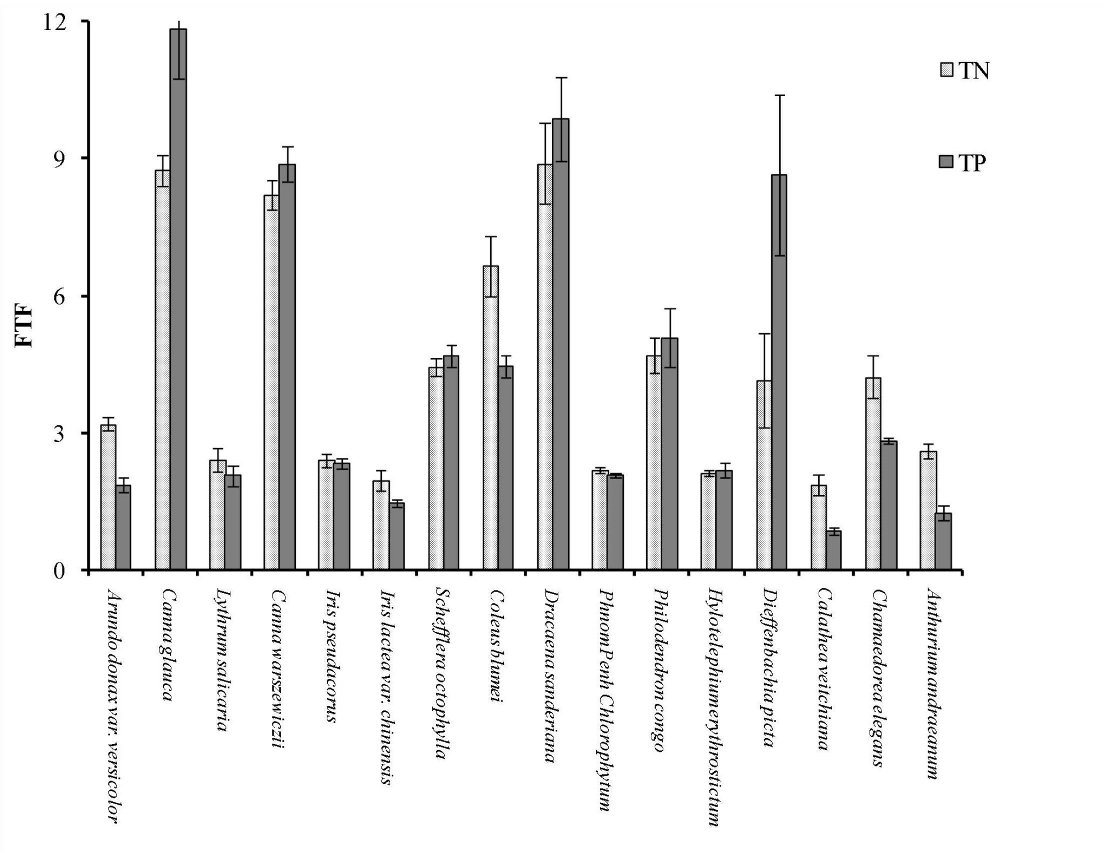


Figure 4. The effective translocation factors of TN and TP of 16 species of plants

## 4. Discussion

The removal ability of pollutants by ecological floating-bed technology is closely related to plant species, biomass, pollutant concentration, et al [3-5]. Plant roots continuously absorb nitrogen, phosphorus, and other trace elements from water, and transfer them to stems and leaves. Because different plants and their issues have different demands for various elements, the distribution and contents of elements in the roots, stems, and leaves were differed significantly. Therefore, in this study, distribution and accumulation characteristics of nitrogen and phosphorus 16 species plants on ecological floating-bed were investigated and analyzed to identify the plants with high purification potential.

Results showed that the TN and TP distribution, as well as accumulation characteristics of the 16 species of plants on ecological floating-bed were significantly different. No strong relationship between the TN or TP contents in the aerial and underground parts of plants was found. The TN

ISSN:2790-1688 DOI: 10.56028/aetr.1.1.55
contents in both the aerial and underground parts of Dracaena sanderiana were the highest among the 16 species of plants, showing its high ability of absorption and translocation. In Anthurium andraeanum, the TN and TP contents were both high in the aerial and underground part, indicating its high absorption ability and low transport ability. The high TN and TP contents in the aerial part of Iris pseudacorus were also due to its efficient transport ability from roots to stems and leaves. The translocation factors can directly reflect the ability of plants to transport pollutants from roots to stems and leaves. It is an important indicator to evaluate the transport ability and remediation potential of plants for pollutants [9,10]. Most translocation factors of tested plants in this study were greater than 1, which indicates that most plants had a high demand for nitrogen and phosphorus for the growth of stems and leaves. Coleus blumei and Hylotelephium erythrostictum had the highest translocation factors of TN and TP, respectively, and they both showed the difference in the demands of TN and TP.

However, considering the massive contribution of biomass of difference of plants, Arundo donax var. versicolor showed considerable accumulation capacity either for TN or TP. Arundo donax var. versicolor had high TN contents in the aerial part and large biomass. Generally, macrophyte had well-developed root systems and robust stems and leaves, which enhance their ability to absorb and transport pollutants from water. In contrast, small aquatic plants with underdeveloped root systems had weaker purification capacity[11,12]. The strong relationship between accumulation and dry weights of plants demonstrated the importance of the biomass of plants. The distribution characteristics of nitrogen and phosphorus in plants can also reflect the variation of plant adaptation to specific ecological environment and survival strategy [13,14]. The roots of aquatic plants can secrete enzymes, promote the growth of phosphate and nitrogen bacteria, and improve the degradation of organic nitrogen and phosphorus, thereby indirectly improving the effect of water purification [15,16].

The above results suggested that we should pay more attention to the absolute quantity of TN and TP in the aerial part in applying ecological floating-bed technology, rather than the contents of pollutants or transport factors of plants. Biomass was the critical factor affecting the removal ability of plants, and the content of pollutants in the aerial part of plants also plays an important role.

## 5. Conclusion

The distribution and accumulation characteristics of TN and TP in the 16 species of plants on the ecological floating-bed were significantly different. No strong relationship between the TN or TP contents in aerial and underground parts of plants was found in this study. Among the16 species of plants, Dracaena sanderiana had the highest TN contents in both the aerial part and underground part. In contrast, Dieffenbachia picta had the highest TP content in the aerial part. Most translocation factors of the tested plants were greater than 1. Arundo donax var. versicolor showed considerable accumulation capacity either for TN or TP, due to the contribution of high biomass and contents of TN and TP in the aerial part. Results indicate that biomass and content of pollutants in the aerial part of plants were important for applying of plants in ecological floating-bed technology.

## Acknowledgments

This work was financially supported by the National Key Research and Development Program (2020YFD0900103), Beijing Innovation Team Project for Modern Agricultural Industrial Technology System.

## References

[1] Kumar P B, Dushenkov V. Phytoextraction: The use of plants to remove heavy metals from soils. Environmental Science and Technology, 1995, 29(5): 1232-1238.

ISSN:2790-1688 DOI: 10.56028/aetr.1.1.55
[2] Yaashikaa P R, Kumar P S, Jeevanantham S, et al. A review on bioremediation approach for heavy metal detoxification and accumulation in plants. Environmental Pollution, 2022, 301:1-15.

[3] Jeevanantham S, Saravanan A, Hemavathy M V, et al. Removal of toxic pollutants from water environment by phytoremediation: A survey on application and future prospects. Environmental Technology & Innovation, 2019, 13: 264-276.

[4] Li S C. Remediation and evaluation of different plants on typical heavy metal contaminated sediment. Tianjin: Tianjin University, 2014.

[5] Yang J R. Study on heavy metal enrichment effect of sedum macrophylla-citrus under different planting patterns. Xi’an: Chang’an University, 2019.

[6] Islam E, Yang X, Li T. Effect of Pb toxicity on root morphology, physiology and ultrastructure in the two ecotypes of Elsholtzia argyi. Journal of hazardous materials, 2007, 147(3): 806-816.

[7] Archer M J G, Caldwell R A. Response of six Australian plant species to heavy metal contamination at an abandoned mine site. Water, Air, and Soil Pollution, 2004, 157(1-4):257-267.

[8] Lago-Vila M, Arenas-Lago D, Rodríguez-Seijo A, et al. Ability of Cytisus scoparius for phytoremediation of soils from a Pb/Zn mine: Assessment of metal bioavailability and bioaccumulation. Journal of Environmental Management, 2019, 235: 152-160.

[9] Li Q H. Spatial distribution and accumulation characteristics of heavy metals in constructed wetlands plants. Xi’an: Chang’an University, 2014.

[10] Lu Y, Xiao M, Zhang W H, et al. Case project of phytoremediation of heavy metal contaminated soil by rotation Sedum spectabile with Triticum aestivum. Environmental Ecology, 2020, 2(8), 74-81.

[11] Dai B Q, Xin S G, Kang Y H, et al. Physiological responses and absorption of heavy metals by sedum spectabile boreau under the stress of combined heavy metal pollution. Journal of Agro-Environment Science, 2008, 27(3): 1051-1056.

[12] Ramos I, Esteban E, Lucena J J, et al. Cadmium uptake and subcellular distribution in plants of Lactuca sp. Cd-Mn interaction. Plant Science, 2002, 162(5): 761-767.

[13] Jiang W, Liu D. Pb-induced cellular defense system in the root meristematic cells of Allium sativum L. Plant Biology, 2010, 10(1): 1-8.

[14] Ying C, Liu S, Yang R, Zhang S, Luo C D. Effects of cadmium on growth, plasma membrane ATP activity, and absorption of N, P and K in Solanum nigrum L. Chinese Journal of Applied and Environmental Biology, 2015, 21(01): 121-128.

[15] Nouairi I, Ben Ammar W, Ben Youssef N, et al. Antioxidant defense system in leaves of Indian mustard (Brassica juncea) and rape (Brassica napus) under cadmium stress. Acta Physiologiae Plantarum, 2009, 31(2): 237-247.

[16] Assche F V, Clijsters H. Effects of metals on enzyme activity in plants. Plant Cell and Environment, 2010, 13(3): 195-206.