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Uptake and distribution of trace elements in growing cucumber

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Multitracer technique was used to study the uptake and distribution of some relatively long half-life radionuclides Be, Na, Mn, Co, Sc to growing cucumber (*Cucumis Sativus* L.) with two different treatments. In Hoagland solution, only ^{54}Mn and ^{60}Co accumulated in the every part of plants. ^{54}Mn, ^{60}Co and other radionuclides were absorbed in distilled water. The results indicate that there were major differences in the accumulation of trace elements between the two different treatments.

Introduction

In recent years, multitracer technique has been extensively applied due to its advantages over the conventional radioactive tracer techniques.[1–3] It enables simultaneously tracing a number of elements under strictly identical experimental conditions in various chemical, environmental and biological systems.[4–6]

Although plants grow on soil containing various elements, little is known about uptake and accumulation of metal elements other than those regarded as essential ones. On the other hand, elements artificially introduced to the environment in polluted factories can change the equilibrium in nature, and their behavior in partition between soil and water often differs from that of elements originally existing in soil, which would effect the uptake of elements by plants. Therefore, it is of importance to investigate the uptake and distribution of metal ions in plants.

AMBE et al.[4] have made a multitracer study of the absorption of radionuclides through the roots of rice and soybean plants cultivated in nutrient solutions and obtained the distribution of the radionuclides of 24 elements in the grain, leaves, stems and roots. The uptake rate of trace elements ^{95m}Tc, ^{83}Rb and ^{65}Zn were discussed.[7] In this paper, we used the multitracer technique to study the uptake and distribution of ^{7}Be, ^{22}Na, ^{46}Sc, ^{54}Mn and ^{60}Co to growing cucumber cultivated in nutrient solutions and distilled water. The results give us a more information on the behavior of trace elements in plants, and are expected to be useful for the understanding of the uptake system of trace elements by plants in the environment.

Experimental

Multitracer preparation

The radioactive multitracer was produced by irradiating $Th(NO_3)_3$ power wrapped with thin aluminum foil with 30 Mev/nucleon ^{40}Ar ions at Heavy Ions Research Facility Lanzhou (HIRFL). The irradiated target was dissolved in 12M of HCl solution. The 20% $TBP\text{-}CCl_4$ extraction solvent was utilized to remove a large amount of thorium from the solution. The aqueous phase was heated to dryness. The residues was dissolved with the distilled water and adjusted finally to pH 7.The detailed separation procedure was described otherwhere.[8] Various radioactive tracers including the elements regarded as essential elements in biology were obtained.

Cucumber cultivation

Cucumber (*Cucumis Sativus* L.) seeds were disinfected with a 0.1% NaClO solution, washed with water and imbibed for 24 hours. After germination, they were planted in sterile quartz sand at 25±0.5 °C under exposure to 20000 lux light from fluorescent lamps in 12-hour light/dark cycles. The seedlings were divided into two groups, one group was added fresh Hoagland solution[9] every 4 days, and another one was added distilled water. By the time of 25 days, the plants were removed from the sand and grew in the same solution for 5 days. Then they were supplied, respectively, the known activities multitracer solution. After 4 days, the sampled plants were separated into roots, stems and leaves.

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A part of leaves were used as the measurement of chlorophyll according to ARNON.[10] The γ-ray spectra presented in the samples were measured using a high-purity Ge detector with energy resolution of 2.0 keV for 1332.5 keV γ-ray. The peak area of the spectra were computed using SPECanal-code on personal computer.[11] The γ-rays were assigned on the basis of their energy and half-lives, as well as their branching.

Results and discussion

The distribution of elements in each part of the plants was represented as the uptake rate obtained by dividing 100 times the radioactivity in each part by the total amount of radioactivity added to the uptake solution and by the weight of corresponding part (%g).Each data was given as the mean±standard deviation of three replications.

The chlorophyll content and uptake rate of the multitracer elements in chloroplast

In contrast to plants treated with Hoagland solution, the plants treated with distilled water contain less content of chlorophyll, in addition, uptake rate of ^{54}Mn and ^{60}Co in chloroplast were 5 to 10 times higher. Remarkably, ^{47}Sc was accumulated in large amounts while not detected in chloroplast treated with Hoagland solution (Table 1).

Uptake of multitracer elements into leaves, stems and roots

In the leaves, the kinds of elements were as same as those in the chloroplast. But the contents were different. The uptake rates of ^{54}Mn, ^{60}Co and ^{47}Sc were all higher than those corresponding ones in chloroplast (Fig. 1). In the stems, only ^{54}Mn and ^{60}Co were accumulated. The uptake rate of ^{54}Mn in stems treated with Hoagland solution was three times lower than those treated with distilled water, while there was little difference in the uptake rate of ^{60}Co in stems between these two different treatments (Fig. 2). In the roots, the results are distinctly different between these two treatments. In the distilled water, the roots accumulated five kinds of elements,^{54}Mn, ^{60}Co, ^{47}Sc, ^{7}Be and ^{22}Na, while in the Hoagland solution, there were only ^{54}Mn and ^{60}Co (Fig. 3).

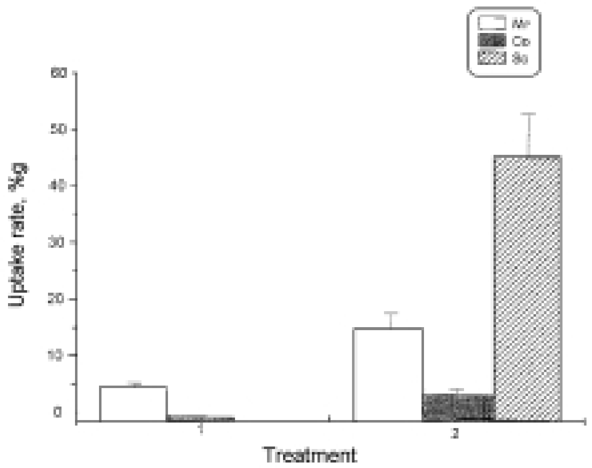

Fig. 1. The uptake rate of the multitracer elements in cucumber leaves. Represented treatment with Hoagland solution (1), and represented treatment with distilled water (2). The mean values are for three replications. Solid lines show the range of standard deviation

Table 1. The results of chlorophyll measurement and uptake rate of the multitracer elements in cucumber chloroplast of two different treatments

Treatment	Chlorophyll content, μg/g	Uptake rate of the multitracer elements, % μg chlorophyll		
		^{54}Mn	^{60}Co	^{47}Sc
Hoagland solution	153.76 ± 3.2**	$2.47 \cdot 10^{-2}$	$4.81 \cdot 10^{-3}$	*
Distilled water	108.16 ± 1.4	$1.39 \cdot 10^{-1}$	$4.54 \cdot 10^{-2}$	$2.92 \cdot 10^{-1}$

* The element was not detected.

** Each value represents the mean ± S.D. of data from three replications.

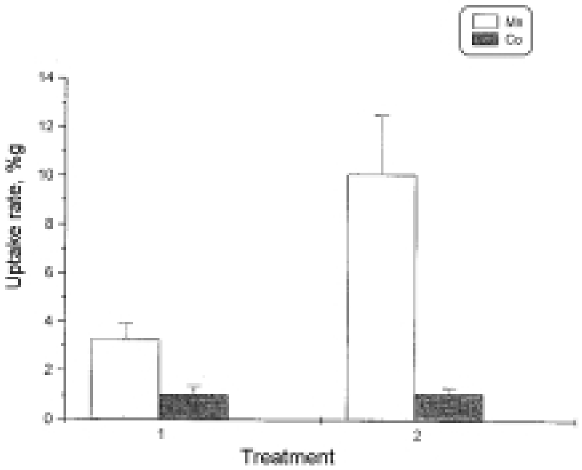

Fig. 2. The uptake rate of the multitracer elements in cucumber stems. Represented treatment with Hoagland solution (1), represented treatment with distilled water (2). The mean values are for three replications. Solid lines show the range of standard deviation

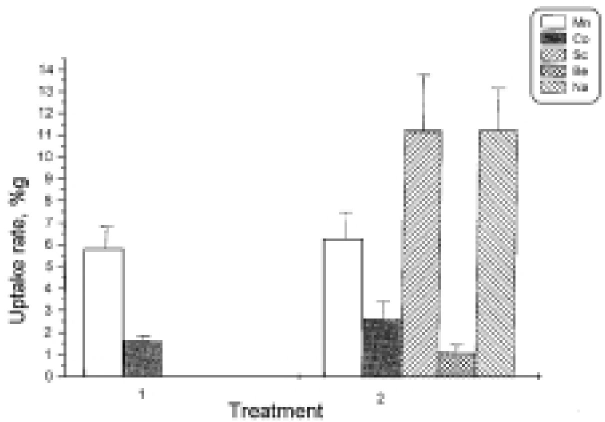

Fig. 3. The uptake rate of the multitracer elements in cucumber roots. Represented treatment with Hoagland solution (1), represented treatment with distilled water (2). The mean values are for three replications. Solid lines show the range of standard deviation

Radioactivity was detected in cucumber treated with Hoagland solution only for ^{54}Mn and ^{60}Co. The main reason for this is presumably that this experiment was conducted for a relatively short period of time. For another, although sufficient nutrition is supplied by the Hoagland solution, the cucumber also has the ability to accumulate certain elements. In distilled water, ^{54}Mn, ^{60}Co, ^{47}Sc, ^{7}Be and ^{22}Na were detected and the contents were higher than those treated with Hoagland solution, which indicates that the uptake of the elements occurred primarily as a biological process and not just as a result of chemical absorption. It is to be noted that elements such as Sc, which are neither essential nor beneficial, were also absorbed into plant bodies. On the other hand, the radionuclides accumulation for growing cucumber with two different treatments was in the order of ^{54}Mn>^{60}Co, which is the same as the previous study.[12,13]

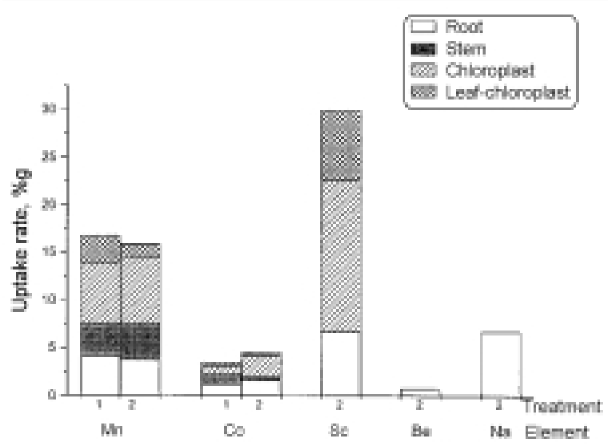

Fig. 4. The uptake percentage distribution of metal elements among various parts of the cucumber plant. Represented treatment with Hoagland solution (1), represented treatment with distilled water (2)

Translocation of the multitracer elements

The amount of radionuclides taken up by each part of the plant was represented as percentage distribution obtained by dividing the radioactivity in one part of a plant by the total amount of radioactivity added to the culture solution.

The cucumber plant accumulates radionuclides through roots (Fig. 4). Treated with Hoagland solution, the plant accumulates ^{54}Mn in the order of leaves > chloroplast > roots > stems, while ^{60}Co was in the order of leaves > stems > roots > chloroplast. The accumulation of ^{54}Mn, ^{60}Co, ^{47}Sc in plants treated with distilled water were leaves > chloroplast > roots > stems, in which ^{47}Sc was not detected in stems, this indicates that Sc was transported to all the leaves from the roots and had no accumulation in stems. For ^{7}Be and ^{22}Na, the accumulations exist only in roots, which means that there is not enough time to transport them to the stems and leaves. Therefore, the different treatments will lead to the different uptake of radionuclides. The scare of nutrition will make plants to accumulate more metal elements .On the other hand, in plants treated with either Hoagland solution or distilled water, the radionuclides ^{54}Mn and ^{60}Co are all detected in each part of the plant within a short period. In order to protect against radiation attention must be paid to the levels of these nuclides in contaminated ecosystems.

Conclusions

The results of this study suggested that artificial treatments to growing cucumber lead to the change of uptake of radionuclides. The scarce of nutrition will cause the more uptakes of elements. Our findings can be used to understand the behavior of radionuclides in the environment and make proofs to the complicated uptake system of the plants.

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