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The effects of cooking oil fume condensates (COFCs) on the vegetative growth of *Salvinia natans* (L.) All.

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ABSTRACT

Cooking oil fumes (COF) and their condensates (COFCs), which are suspected of causing human lung cancers, are hazardous materials to environments. The effects of COFCs on the vegetative growth of *Salvinia natans* (L.) All., a free-floating aquatic fern, are discussed in this paper. The results showed that there were no differences of the number of floating leaves and the mean numbers of new leaves of *S. natans* in all groups, but these indices in experimental groups were influenced obviously at the late stage. COFCs also influenced stem length and number of buds of *S. natans*. COFCs could cause the floating leaves to turn yellow and individuals to die quickly. All these effects were correlated with the concentration of COFCs and the time. When the concentration of COFCs was ≥0.18 g/l, above 80% individuals would die in a short time. COFCs had significant impacts on the decrease in photosynthetic areas of *S. natans* by making the floating leaves turn yellow faster and accelerating the decomposition. There were some components in minute amount benefiting to the growth of *S. natans*. *S. natans* was sensitive to COFCs and could be a potential indicator for monitoring COFCs pollution in aquatic environments.

1. Introduction

Wok cooking is very common in Chinese families, historically and presently. One of the major characteristics of this cooking style is that cooking oils are often heated in a wok at high temperatures ranging from 190 °C to 280 °C [1,2], so a great amount of cooking oil fume (COF) is produced during cooking. A part of the COF will emanate directly into the atmosphere. Most of them will be collected by kitchen ventilators and become cooking oil fume condensates (COFCs) in Chinese families presently. Emissions from cooking oil heated are hazardous to the atmosphere [3]. They are also harmful to human health. A human exposed to COF will develop lung cancer [1,4–8]. There are over 100 components in COF, such as polycyclic aromatic hydrocarbons [9–11], hexanal and 2-heptenal [2,12], aromatic amines [13], and alkyl, alkene, aldehyde [14], which are harmful to human health and the atmosphere [15]. The components in COFCs and their concentrations are related closely to the temperature of heating oils [16]. Some studies showed that the cellular immune function of experimental animals would be influenced when they were kept under COF conditions for a long time [17]; the mutation of anti-oncogene *p*53 or FHIT, or modification of DNA bases might play an important role in lung cancers caused by COF [18,19]. COFCs collected from restaurants often contain 1,3-Butadiene, benzene, acrolein, formaldehyde [1]. Oil and grease pollution will influence the ecological functions of terrestrial and aquatic ecosystems [20–22]. These ecological effects would be sustained for a long time [23–25]. As a byproduct of oil and grease, COFCs may have some ecological effects on environments. Along with urbanization in China, the amount of COFCs accumulated will increase. It is easy to speculate that the production of COFCs will be high in the areas of high-density populations. So the way to deal with COFCs suitably is not only an ecological issue but also a social–economic concern. There is, however, no official standard or approach to dispose off COFCs presently. The harmfulness of COFCs to environments, especially to terrestrial and aquatic ecosystems, is obviously underestimated. Most of the COFCs are currently treated with municipal soil wastes. Parts of COFCs are occasionally dumped directly into aquatic ecosystems from the municipal sewage. Despite their serious harmfulness to human health, little is known about the ecological effects of COFCs on plants, especially aquatic plants until now. If COFCs are disposed into aquatic ecosystems, they will form an oleaginous cover on the water surface. Is there any influence of this oleaginous film on the growth and population dynamics of aquatic plants? The answer to this question will be useful not only to evaluate the influence of COFCs on the environment and monitor the aquatic environmental situation, but also to discover the plants that have the ability to remove COFCs from the environments.

Salvinia natans (L.) All. is a free-floating fern distributed mainly in tropical and temperate regions in Eurasia and New Zealand [26,27].

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It is considered to be a wide-spreading and invasive plant in temperate regions and plays a vital role in the structure of aquatic ecosystems [28,29]. However, it is also an endangered species listed in *The Red Data Book* in Japan for its decreasing populations in recent years, and very susceptible to herbicides, such as bensulfuron methyl [30]. *Salvinia* biomass has strong metal-complexation capacity [31], many species show the ability of removing heavy metals in aquatic environments [32,33]. As a biomass sorbent for oil removal, *Salvinia* biomass shows a great potential and value [34]. In China, *S. natans* is used traditionally as an important feed for livestock for its great biomass production and nutrients. In this paper, we will discuss about the effects of COFCs on the vegetative growth of *S. natans* based on experimental data.

2. Methods and materials

2.1. Material collection and cultivation

S. natans is a common aquatic plant distributed widely in the east and south China [27]. Summer and autumn are the best seasons for *S. natans* growth in the east of China. All plant materials for the experiment were collected from wetlands near Yangzhou City of Jiangsu Province, China from July to September of 2008 and May to June of 2009 respectively. The materials were transferred to plastic pots and cultivated for accommodation in a greenhouse (the temperature was 30 ± 2 °C, the light provided by metal halid bulbs for 12 h/d) for a week before treatment. The nutrient medium of Hogland was added periodically into the plastic pots during the whole experiment.

2.2. Preparation of COFCs

COFCs were collected from a kitchen ventilator from a household that often used a certain type of refined cooking oil commonly sold in supermarkets in Yangzhou, China. The peroxide value and acid value of the COFCs used in the experiment were 13.11 ± 2.84 mg/100 g and 7.409 ± 0.130 mg KOH/g respectively (n = 7), much larger than that of edible vegetable oil (≤0.25 mg/100 g and ≤3 mg KOH/g respectively). COFCs were diluted in distilled water to prepare cultivation medium before experiment. COFCs were added into the water and stirred to make them mixed with water equably. The concentration gradients of COFCs were prepared as follows: 0 g/l (Control), 0.02 g/l (Group 1), 0.04 g/l (Group 2), 0.08 g/l (Group 3), 0.18 g/l (Group 4), 0.28 g/l (Group 5), 0.38 g/l (Group 6), 0.48 g/l (Group 7), 0.58 g/l (Group 8), 0.68 g/l (Group 9), and 0.78 g/l (Group 10).

2.3. Treatment and data analysis

Similar size and healthy individuals of *S. natans* were selected as materials for treatment. Each individual was dissected into two parts, the one with apical bud and 8 leaves left was used for experiment. The experiment materials were divided randomly into 11 groups, each group included 20 individuals of *S. natans*. And their fresh weights were measured (W_0) before treatment. All materials were cultivated in plastic pots (with diameter of 12 cm and height of 10 cm) containing cultivation mediums with different concentrations of COFCs. Each pot had only one individual of *S. natans* for eliminating the effect of density.

The numbers of leaves and buds, pH values and the length of stem of each experimental material were recorded every day from the second day after treatment. The fresh weight (W_1) and dry weights of each individual were measured at the end of the treatment.

The following equation was used to calculate the relative growth rate (RGR) of each individual:

$$\mathrm{RGR} = \frac{\ln W_1 - \ln W_0}{\Delta t}$$

where W_0 and W_1 are fresh weights (g) of each individual at the beginning and end of the experiment, Δt is time span (day) of experiment [30,35]. Because after the day 9, the growth of some individuals in Groups 5–10 stopped entirely, we only calculated the RGRs of *S. natans* in Control, Groups 1–4 when $\Delta t = 16$.

One-way analysis of variance (ANOVA) was used to determine the differences among different treatments with SPSS 11.5. The differences were statistically significant when $p < 0.05$.

3. Results and analysis

3.1. Effects of COFCs on the death of S. natans

During the experiment, there was no individual of *S. natans* died only in Control, Groups 1 and 2. Other groups appeared died individuals more or less at different times. There was no died individual in Group 3 until the day 15 after treatment with COFCs. From Groups 5 to 10, some individuals began to die after the day 3, and all individuals died at a certain time (Table 1). This result suggested that if the concentration of COFCs was ≤0.04 g/l, it would not cause *S. natans* die, but when the concentration of COFCs was above 0.08 g/l, some individuals of *S. natans* would die, especially when the concentration of COFCs was ≥0.28 g/l, all individuals would die. The higher the concentration of COFCs was, the earlier this effect was.

3.2. Effects of COFCs on the floating leaves of S. natans

Floating leaves are the most important organs of photosynthesis for *S. natans*. They were direct contact with the oleaginous cover formed by COFCs on the water surface during the treatment. The floating leaf number of *S. natans* at different concentrations of COFCs showed an increasing trend along with cultivation times (Fig. 1). But there were no differences among the mean numbers of floating leaves of *S. natans* in different groups before the day 9 (df = 87, F = 1.358, p = 0.216). Form the day 9 to the end of the experiment (the day 17), all individuals in some groups with higher COFCs concentrations were died. At the end of the experiment, there were only 5 groups (including Control, Groups 1–4) had living individuals (Table 1). The mean number of floating leaves in these 5 groups increased along with the treatment time. However, the mean num-

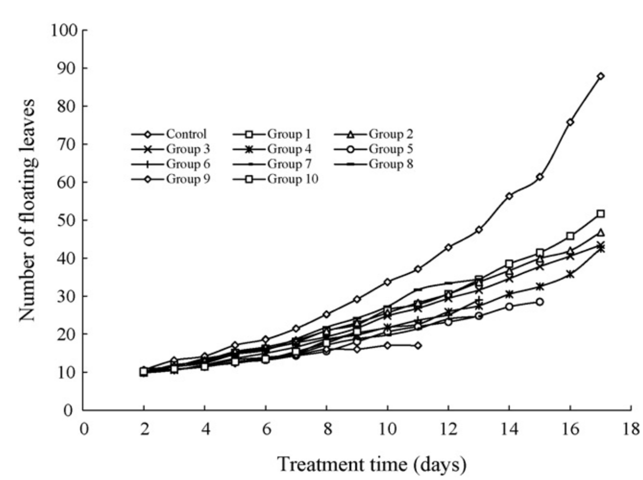

Fig. 1. The changes of the numbers of floating leaves of *Salvinia natans* in different groups along with treatment time.