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Allelopathic Effects of Water Extracts of Sweet Potato (*Ipomoea batatas*) on Seed Germination of *Ageratum conyzoides*

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Abstract

Sustainable weed management strategies are essential to reduce chemical and labor inputs. This study aimed to evaluate the effect of water extracts from sweet potato [*Ipomoea batatas* (L.) Lamarck] on seed germination of *Ageratum conyzoides* L. under controlled conditions. The aqueous was produced from plant parts *i.e.*, roots, stems, and leaves of sweet potato at concentrations of 0.025, 0.050, 0.075, and 0.100 g·mL^{-1}. The results showed that the plant parts of sweet potato all contained allelopathic substances, which showed high-concentration inhibition and low-concentration promotion of seed germination of *A. conyzoides*. When the aqueous extract concentrations were 0.050, 0.075, and 0.100 g·mL^{-1}, the germination of *A. conyzoides* seeds was inhibited, while the germination was promoted at a concentration of 0.025 g·mL^{-1}. This shows that when the planting density of sweet potato is large, it can form an obvious prevention and control effect on *A. conyzoides*, and thus improve herbicide resistance management.

Keywords

Sweet Potato, *Ageratum conyzoides*, Water Extracts, Allelopathic Effect

1. Introduction

Weeds reduce crop economic yield by 10% to 15% yearly, according to the Food and Agriculture Organization of the United Nations [1]. Among the most common weeds found in farmland in China, *Ageratum conyzoides* L., known to cause serious damage to crops and native plants [2], and is therefore classified as Class I invasive plant in China [3]. *A. conyzoides* is an annual herb that belongs to the Family Asteraceae, which is a native of central South America, and was introduced into China as a horticulture plant in the 19th century. For the efficient seed dispersal mechanism, *A. conyzoides* it is now very common in tropical and subtropical China [4].

Currently, the commonly used weeding methods in agricultural production mainly include mechanical weeding, cover weeding, and chemical weeding [5]. Most of these methods are time-consuming, labor-intensive or may be harmful to the environment [6] and lead to the herbicide resistance in weeds [7]. Nowadays, integrated weed management is carried out in the context of sustainable agriculture, exploitation of allelopathic potential of different crops for weed management under field conditions is one such approach and shown promising results [8] [9]. For example, the use of legume as intercropping crops to produce allelopathic substances has been suggested in the management of weed in the maize field, which favors weed suppression [10]. However, there have been few studies using staple food crops as intercropping sources for weed control.

Sweet potato [*Ipomoea batatas* (L.) Lamarck], is an annual vine of the Family Convolvulaceae [11]. Due to its high yield, nutrition, and the fact that it can be grown on poor soil [12], it is one of the fifth most important food crops in China [13]. It has a strong ability to cover by crawling, so it usually has an obvious advantage when growing with other plants. In addition, studies have shown that sweet potato contains allelopathic substances, which have obvious allelopathic effects on many invasive plants of the Family Asteraceae and Family Poaceae [14].

Therefore, the present study was conducted to determine whether the water extracts of roots, stems, and leaves of sweet potato had allelopathic effects on *A. conyzoides*, and how different concentrations of water extracts would affect seed germination of it. Results from this study would help modify crop cultivation patterns with resulting yields increments.

2. Materials and Methods

2.1. Materials

Sweet potato cv. Yanshu 25 was provided by the Yantai Academy of Agricultural Sciences, China. Seedlings of sweet potato were planted in the greenhouse of the Agricultural and Biological College of Kunming University, Kunming City, Yunnan Province, China (102˚48'21.28"E and 24˚58'53.94"N). In the early stage of the experiment, cuttings of sweet potato were planted by the oblique insertion method.

The mature seeds of *A. conyzoides* were collected in the greenhouse of the Agricultural and Biological College of Kunming University and stored at 4˚C until use in this experiment.

2.2. Preparation of Sweet Potato Water Extract

The roots, stems, and leaves of sweet potato were harvested from the greenhouse in September 2021. Samples were cut into pieces, dried in the oven at 50˚C to constant weight, and fully ground into powders. The roots, stems, and leaves extracts of sweet potato were prepared by dissolving 40 g of powder in 200 ml distilled water, and shake for 48 hours at 27˚C. Extracts were filtered twice with three layers of gauze served as the initial aqueous. Three types of initial aqueous extract were diluted with distilled water to four concentrations: 0.025, 0.050, 0.075, and 0.100 g·mL^{-1}, and stored at 4˚C to use.

2.3. Methods

According to the germination time of natural population of *A. conyzoides* in the Kunming region, the germination experiment was conducted from May to June 2022. Seeds of *A. conyzoides* were rinsed the impurities with sterile water and surface-sterilized with sodium hypochlorite (NaClO) 10% (v/v) for 10 minutes, then washed with clean water three times. In each treatment, 30 seeds of *A. conyzoides* were evenly placed in 11 cm diameter Petri dishes covered with filter paper. Four concentrations (0.025, 0.050, 0.075, and 0.100 g·mL^{-1}) of sweet potato water extract and distilled water treated as a control (CK) were added. The treated seeds were then incubated in the artificial climate box, keep the temperature at about 27˚C, and light for 12 h every day. When the radicles and bud break through the seed coat, the seeds were considered germinated. Number of germinated seed was recorded every two days until no more seeds germinated.

2.4. Statistical Analysis

The germination rate (GR) was computed as in:

$$\text{GR}=\frac{\text{germinated seeds}}{\text{tested seeds}}\times 100\% \tag{1}$$

The germination potential (GP) was calculated as follows:

$$\text{GP}=\frac{\text{seeds germinated within 18 days}}{\text{tested seeds}}\times 100\% \tag{2}$$

The germination index (GI) was calculated using the formula (3):

$$\text{GI}=\sum\frac{Gt}{Dt}\times 100\% \tag{3}$$

where G_t is the number of seeds germinated on day t, D_t is number of days [15].

The allelopathic response index (RI), which represents the intensity of the allelopathic effect, was using the formula described by Williamson and Richardson [16] as follows:

$$\text{RI}=1-C/T \tag{4}$$

where C represents control data, and T represents treatment data. RI > 0 showed that seedling germination or seedling growth was promoted. RI < 0 showed an inhibitory effect. This formula was used to measure the intensity of the effect of sweet potato water extract on *A. conyzoides* seed germination.

The sensitive effect (SE) index is used as an indicator to evaluate allelopathy potential effects, which was calculated using the mean value of RI values of germination rate, germination potential and germination index [17].

Analysis of variance (ANOVA) followed by the least significant difference test

(LSD) was performed to indicate any significant difference among the treatment studied.

Differences were considered to be significant at a level of $P < 0.05$. Statistical and plot drawing were conducted using the software SPSS 22.0 and Origin 2018, respectively.

3. Results and Discussion

3.1. Effects of Sweet Potato Extract on Germination of *A. conyzoides*

The germination curve is used to judge seed germination. When the curve tends to flatten, it suggests that the seeds were no longer germinating. As can be seen from **Figures 1(A)-(C)**, seeds begin to germinate six days after sowing, and the germination curve of each treatment tends to flatten after 16 days, that is, final germination was achieved.

The results indicated that the seed germination rate of *A. conyzoides* was stimulated by the water extracts of sweet potato root, stem, and leaf at 0.025 $g \cdot mL^{-1}$ concentration, but inhibited at 0.050, 0.075, and 0.100 $g \cdot mL^{-1}$ concentration (**Figures 1(A)-(C)**), significantly ($P < 0.05$). This suggests that a low concentration of sweet potato water extract can promote the activity of seeds to a certain extent, while high concentration of sweet potato water extract will inhibit the seeds activity.

The leaves water extract showed the greatest allelopathic effects on *A. conyzoides*, and reduced seed germination rate by 67.78%, 31.11%, and 8.89% when compared with CK, roots, and stems water extract at 0.100 $g \cdot mL^{-1}$ concentration, respectively (**Figure 1(D)**). Therefore, the high concentration of leaves water extract of sweet potato was significantly detrimental to the activity of *A. conyzoides* seeds.

A similar trend was also observed in germination potential and germination index (**Figure 1(E)**, **Figure 1(F)**). Compared with the control group, the 0.025 $g \cdot mL^{-1}$ water extract of sweet potato significantly ($P < 0.05$) increased the germination potential and germination index of *A. conyzoides* seeds. This shows that low concentration of sweet potato water extract can improve seed vitality of *A. conyzoides* and make them emerge vigorously (high germination potential). However, the other three concentrations of water extract (0.050, 0.075, and 0.100 $g \cdot mL^{-1}$) significantly reduced the germination potential and germination index of *A. conyzoides* seeds. Typically, the higher the water extract concentration, the stronger the inhibitory effect. This indicates that with the increase of the concentration of water extract, the toxicity of it to the seeds of *A. conyzoides* is increasing (the germination index is decreasing), so that the activity of the seeds of *A. conyzoides* is weakened (the germination potential is decreasing).

In addition, the effect of water extract of roots, stems, and leaves on the germination of *A. conyzoides* seeds was also different. Under the concentration of 0.100 $g \cdot mL^{-1}$, the water extract of leaves had the strongest toxic effect, and the proportion of germination potential decreased by 44.78% and 14.78% compared with the CK control and the aqueous extract of roots, equal to the influence of the aqueous extract of the stems. However, when exposed to CK control, roots, and stems water extract at concentration of 0.100 g·mL^{-1}, the germination index of *A. conyzoides* seeds reduced by 7.77%, 2.74%, and 0.46%, respectively, compared with leaf water extract at the same concentration.

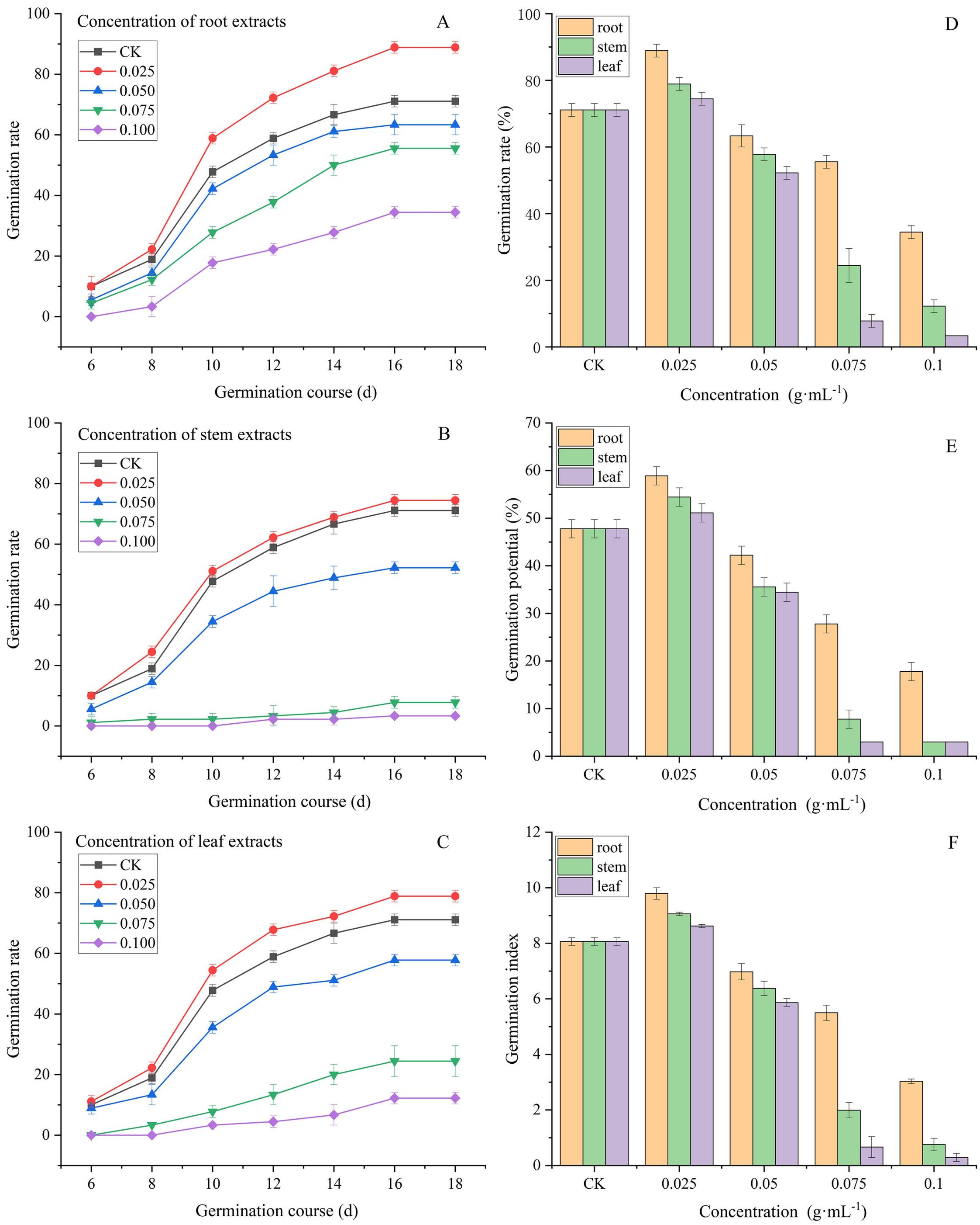

Figure 1. Accumulated germination (%) of *A. conyzoides* seeds exposed to different concentrations water extract concentrations of sweet potato roots (A), stems (B) and leaves (C), for 18 d, and the effects on the *A. conyzoides* seeds' germination rate (D), germination potential (E), and germination index (F).

Therefore, compared with roots and stems water extract, high concentration of sweet potato leaves water extract is the most toxic to *A. conyzoides* seeds and can significantly inhibit its activity.

3.2. Allelopathic Effect of Sweet Potato Extract on Seed Germination of *A. conyzoides*

The allelopathic response index (RI) is an important indicator to measure the intensity of allelopathy. The allelopathic effects of sweet potato roots, stems, and leaves water extract on seed germination rate, germination potential, and germination index of *A. conyzoides* are shown in **Table 1**. Positive and negative values indicate the promoting and inhibiting effects of the water extract on seed germination, respectively. RI value for seed germination was positive (**Table 1**) only when the concentration of sweet potato water extract was 0.025 $g \cdot mL^{-1}$. Therefore, except for this concentration, the other three concentrations of sweet potato water extract had certain allelopathic effects on seed germination of *A. conyzoides*. The degree of seed germination inhibition depends on the concentration of the extract, the higher the concentration, the stronger inhibition. At the same concentration, leaves water extracts showed the strongest inhibition on germination rate, germination potential and germination index.

Sensitive effect (SE) calculated from low concentration to high concentration. With the increase of extract concentration of sweet potato, the degree of inhibition to *A. conyzoides* also increased (**Figure 2**), and the leaves extract has a greater inhibitory effect on seed germination in *A. conyzoides* than root and stems extract at the same concentration.

Table 1. Effects of different water extract concentration (0.025, 0.050, 0.075, and 0.100 $g \cdot mL^{-1}$) of sweet potato roots, stems and leaves on response index of *A. conyzoides* seeds.

Plant parts	Concentration ($g \cdot mL^{-1}$)	Response index (RI)		
		Germination rate (GR)	Germination potential (GP)	Germination index (GI)
Root	0.025	0.18	0.19	0.17
	0.050	−0.09	−0.12	−0.13
	0.075	−0.21	−0.42	−0.32
	0.100	−0.51	−0.63	−0.62
Stem	0.025	0.09	0.12	0.11
	0.050	−0.18	−0.26	−0.21
	0.075	−0.66	−0.84	−0.75
	0.100	−0.81	−0.95	−0.90
Leaf	0.025	0.04	0.07	0.06
	0.050	−0.28	−0.28	−0.28
	0.075	−0.90	−0.95	−0.92
	0.100	−0.94	−0.95	−0.96

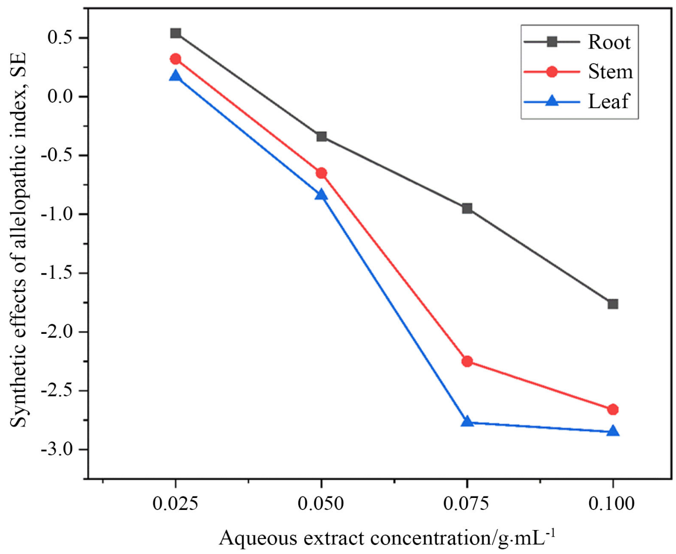

Figure 2. Effects of different water extract concentrations (0.025, 0.050, 0.075, and 0.100 g·mL^{-1}) of sweet potato roots, stems and leaves on sensitive effect (SE) of *A. conyzoides* seeds.

Allelopathy index (RI) and sensitivity effect (SE) directly reflected the allelopathy characteristics of sweet potato roots, stems, and leaves water extract on seed germination of *A. conyzoides*. It can be summarized into two points: 1) the concentration of 0.025 g·mL^{-1} sweet potato water extract showed a positive promoting effect on the germination of *A. conyzoides* seeds, while the concentration of 0.050, 0.075, and 0.100 g·mL^{-1} sweet potato water extract showed a negative inhibitory effect on the germination of *A. conyzoides* seeds. 2) The water extract of leaves contains the strongest allelopathic substance, so it reflects the strongest allelopathic inhibition compared with roots and stems.

4. Discussion

Allelopathy is an important mechanism of interference in which plants releases bioactive compounds into the surrounding environment that positively or negatively affect the growth of neighboring plants [18] [19]. Therefore, weeding by allelopathy is a good method for biological control.

High germination rate, germination potential and germination index are fundamental for the weed to quickly occupy the ecological niche. The seed germination potential of a plant depends on the speed and uniformity of seed germination [20]. The germination rate is dependent on survival rate, while the germination index amplifies the characteristics of seed activity and can reflect the changes of adversity environment more sensitively [21].

Seed germination is affected by various inhibitors in the surrounding environment. The inhibitory effect on seed germination may be due to the presence of water-soluble inhibitors affecting the physiological process of the recipient plant [22]. For example, phytotoxins found in *Artemisia capillaris* [23], *Acacia dealbata* [24], *Satureja species* [25] and so on, are known can be converted into chemicals that inhibit germination. Sweet potatoes are seen as good crops to use for biological weeding. First, the structural characteristics of sweet potato make it very competitive. It reduces the photosynthesis of other weeds by covering and shading the upper part of the weeds, and competes with other weeds for soil nutrients and water through a larger number of adventitious roots on the stem nodes and root tubers in the underground portion. The results of this study suggest that the sweet potato's competitive advantage may also be related to its production of allelopathic substances that inhibit other plants with which it coexists.

This study portrayed that when the concentration of sweet potato extracts was greater than 0.025, the seeds germination potential, seed germination rate and seed germination index of *A. conyzoides* were significantly inhibited, and the inhibitory effects of the extracts increased with increasing concentrations. This means that it is possible to suppress *A. conyzoides* by intercropping sweet potatoes with other crops and using the allelopathic substances of sweet potatoes. In addition, compared with the water extract of roots and stems, the water extract of the leaf shows the strongest allelopathic inhibition. This provides some suggestions for sweet potato growing habits. In many parts of China, it is customary to collect sweet potato petioles as vegetables, which, according to the results of this study, reduces the concentration of water extract of sweet potato leaf, thereby promoting or less inhibiting the germination of *A. conyzoides* seeds. Therefore, try not to remove sweet potato leaves after planting, so as to retain more leaf extract in the soil is a suitable planting method to inhibit *A. conyzoides*.

5. Conclusion

In summary, our results demonstrated that the sweet potato water extract has a significant inhibitory effect on the germination of *A. conyzoides* seeds. Therefore, sweet potatoes can be intercropped with other crops to suppress *A. conyzoides* to increase efficiency of agricultural production. The next step is to separate and identify the chemical substances and study the mechanism of action of the sweet potato water extract, which will provide a theoretical basis for the field control of *A. conyzoides*. It would be a luminous direction to proceed in order to improve agricultural sustainability, environmental safety, food security, resource conservation and economic stability.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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