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Growth disturbance of extracts from several crops straw (residue) on *Ageratina adenophora* and biological-control implications in hazardous weed invasion for eco-restoration

Fu-ke Yu[a], Xin-hui Huang[b,*], Yong He[b], Deng-gao Fu[a], Chang-e Liu[a], Xue-xiu Chang[a], Shu-zhuang He[a], Chang-qun Duan[a], Hong-bo Shao[c,d,**]

[a] *Institute of Environmental Sciences and Ecological Restoration, School of Life Sciences, Yunnan University, Kunming 650091, China*
[b] *College of Environmental Science and Engineering, Southwest Forestry University, Kunming 650224, China*
[c] *Key Laboratory of Coastal Biology & Bioresources Utilization, Yantai Institute of Coastal Zone Research (YIC), Chinese Academy of Sciences (CAS), Yantai 264003, China*
[d] *Institute for Life Sciences, Qingdao University of Science & Technology (QUST), Qingdao 266042, China*

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ABSTRACT

Laboratory biological simulation experiment was conducted to investigate growth disturbance of high, moderate, low concentration of aqueous extracts (i.e. the original extracts with a solid–liquid ratio of 1:40 g mL^{-1} and its 5 times diluents and 25 times diluents) from several crops straw (residue) on *Ageratina adenophora*, a worldwide notorious invasive weed. The results showed: (a) aqueous extracts from several crops straw (residue) brought about different impacts on the single index for germination and growth of *A. adenophora*, e.g., high concentration of aqueous extracts from *Brassica oleracea* waste leaves showed a strong inhibition against the germination rate (*GR*) and germination index (*GI*) of *A. adenophora*, while high concentration of aqueous extracts from *Vicia cracca* straw showed a strong inhibition against radicle length (*RL*) and hypocotyl length (*HL*) of *A. adenophora*; (b) high concentration of aqueous extracts from *B. oleracea* waste leaves and high, moderate and low concentration of aqueous extracts from *Oryza sativa* straw and *Triticum aestivum* straw showed rather strong synthetic effects (inhibition) on *GR* and *GI* of *A. adenophora*, which could be chosen for the control over the seeds germination of *A. adenophora*; (c) high and moderate concentrations of aqueous extracts from *V. cracca* straw, high concentration of aqueous extracts from *B. campestris* waste leaves, and moderate and low concentrations of aqueous extracts from *O. sativa* straw and *T. aestivum* straw showed rather strong synthetic effects (inhibition) on *RL* and *HL* of *A. adenophora*, which could be selected as ideal materials for the control over the seedlings growth of *A. adenophora*; and (d) high concentrations of aqueous extracts from *V. cracca* straw, *B. oleracea* waste leaves and *B. campestris* waste leaves, and high, moderate and low concentrations of aqueous extracts from *O. sativa* straw and *T. aestivum* straw showed rather strong synthetic effects (inhibition) on *GR*, *GI*, *RL* and *HL* of *A. adenophora*, which could be selected as ideal materials for the control over the seeds germination and seedlings growth of *A. adenophora*. Thus, this study would provide a theoretic guidance and technical support for the resources utilization of crops straw (residue) and the prevention and control over invasive weeds as well.

1. Introduction

Ageratina adenophora, a worldwide notorious invasive weed, spreads over agro-ecosystem, which has greatly threatened regional bio-diversity, ecological safety and environment health (Wan et al., 2010; Wang and Wang, 2006; Xie et al., 2001), featured with great hidden danger; meanwhile, crops straw (residue) was abandoned or burned in the agro-ecosystem as waste and thus brings about potential pollution afterwards, which could possibly have a direct impact or potential damage on regional agriculture development and ecological sustainable development (Liu et al., 2008; Cao et al., 2008; Duan et al., 2004). Thus, it would be a good way to turn the waste into wealth if the abandoned crops straw (residue) could be used as a way for the prevention and control over invasive weeds. In this paper, based on lab biological

* Corresponding author. Tel.: +86 871 65090855; fax: +86 871 65090855.
** Corresponding author at: Institute for Life Sciences, Qingdao University of Science & Technology (QUST), Qingdao 266042, China.
E-mail addresses: ylyfk2005@aliyun.com, ylhxh2001@163.com (X.-h. Huang), shaohongbochu@126.com (H.-b. Shao).

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simulation experiment, the growth disturbance of several crops straw (residue) on the invasive *A. adenophora* was investigated, aimed at the exploration on an ideal material and technique for the effective prevention and control over the seeds germination and seedlings growth of *A. adenophora*, which would be of great importance in guiding the resources utilization of crops straw (residue) and the prevention and control over *A. adenophora* as well.

2. Materials and methods

2.1. Materials collection and pre-treatment

Seven commonly seen crops straw (residue), i.e., the straw of *Oryza sativa, Zea mays*, *Triticum aestivum*, *Pisum sativum*, and *Vicia cracca*, and waste leaves of *Brassica campestris* and *Brassica oleracea*, were selected as the experiment donors, which were all collected in October, 2011 in the crop field at Duanqi village, Shangsuan, Jinning County, Kunming, where *A. adenophora* was characterized with serious invasion. The materials collected were dried with the wind power in the shade place and grinded as powder for further use.

A. adenophora seeds were selected as the experiment receptors, which were collected at Huma Hill bordering the 3rd Ring Road East of Kunming city in April, 2012. Before experiment, the full seeds of *A. adenophora* with almost the same size and rather dark in color were selected and sterilized with 0.1% sodium hypochlorite solution for 10 min, and watered 3 times with distilled water for further use.

2.2. Experiment design and observation

2.2.1. The preparation of aqueous extracts

1.5 g of powder sample of one single crop straw (residue) was selected to be put into a 150 ml conical flask, filled with distilled water with a solid–liquid ratio of 1:40 g mL^{-1}, and put into the oscillator to process for 30 min after seal, then filtered with qualitative filter paper after placing for 2 h, thus the filtered liquid, namely, the original liquid of the aqueous extract (1×), was obtained, and then part of 1× was selected to make 5 times diluents (5×) and 25 times diluents (25×).

2.2.2. Experiment design and observation

In this paper, lab biological simulation was conducted, with Petri dish method for both the seeds germination simulation experiment and seedlings growth simulation experiment.

Design and observation of seeds germination simulation experiment: 56 glass Petri dishes with 10 cm in diameter (washed with distilled water and dried in the dryer at a temperature of 80 °C) were selected and divided into 7 groups, with 8 dishes for each group; 2 pieces of qualitative filter paper with 9 cm in diameter were place in the bottom of each Petri dish; 7 groups of Petri dishes with filter paper inside were filled with aqueous extracts of crops straw (residue) with different concentrations respectively (each group of Petri dish was filled with a certain crops straw (residue)). Specifically speaking, there were 2 Petri dishes for 1×, 5× and 25×, respectively, and another 2 Petri dishes filled with distilled water as CK; in each Petri dish, 3 ml of liquid was added and 30 seeds of *A. adenophora* were evenly placed in each Petri dish (3 even sectors, with 10 seeds in each sector); the Petri dishes with seeds well placed were put into the incubator with constant temperature (the temperature of 25 °C, humidity of 80%) for a 7 d dark culture. During the culture period, the number of germinated seeds was observed and recorded every 1 d (with radicle breaking through seed coat as the standard for germination); meanwhile, distilled water was added into the Petri dishes to keep humidity. The whole experiment was repeated 3 times.

Design and observation of seedlings growth simulation experiment: this experiment was a little different from the seeds germination simulation experiment mentioned above. The difference lied in seeds presprouting, namely, a number of the seeds of *A. adenophora* were placed in the Petri dish with qualitative filter paper as the germinating bed for presprouting. The germinated seeds were selected as samples for seedlings growth simulation experiment while the design, culture media and added material were the same to the seeds germination simulation experiment. At the 7th day of seedlings growth simulation experiment, radicle length (*RL*) and hypocotyl length (*HL*) of receptors' seedlings were measured. The whole experiment was repeated 3 times.

2.3. Tested indexes and calculation methods

2.3.1. Indexes for seeds germination and seedlings growth

As for the seeds germination, germination rate (*GR*) and germination index (*GI*) were adopted as the tested indexes, with the calculation formula as below respectively:

$$GR = \frac{\text{total germinated seeds}}{\text{total seeds for experiment}} \times 100\%$$

$$GI = \sum \frac{Gt}{Dt}$$

where *Gt* is the germination number in the day of *t*; *Dt* is the accordingly germination days.

Seedling growth indexes would be directly gained through measuring the *RL* and *HL* of receptors' seedlings.

SPSS 11.5 was adopted for the calculation of the mean and standard error, and the analysis of significant difference for the tested indexes for seeds germination and seedlings growth under different experiments.

2.3.2. Allelopathic effect indexes

Allelopathic effect indexes include response index (*RI*) for single index and synthetic effect index (*SEI*) for multiple indexes.

RI is calculated according to the following formula:

$$RI = 1 - \frac{C}{T} \quad (\text{when} \quad T \geq C) \quad \text{or} \quad RI = \frac{T}{C} - 1 \quad (\text{when} \quad T < C)$$

where *C* is the check value, *T* is the treatment value. When $RI > 0$, it is described as promoting effect, while when $RI < 0$, it is described as inhibitory effect, the bigger the absolute value of *RI*, the greater the potential of allelopathic effects (promotion or inhibition) is.

SEI is the arithmetic mean of *RI* for the same donor on multiple (two) testing items of receptors. *SEI* can be positive and negative, the positive value means promotion, while negative value inhibition, with 0 as CK value.

3. Results

3.1. The impact of water-soluble materials of donors on the single index for seeds germination and seedlings growth of A. adenophora

3.1.1. The impact of water-soluble materials of donors on the single index for seeds germination of A. adenophora

The statistics results of single tested index for the seeds germination simulation experiment were shown in Table 1. It showed that aqueous extracts from 7 crops straw (residue) were characterized with universal impacts on the single index for seeds germination of *A. adenophora* as shown in Table 1.

Table 1
The impacts of aqueous extracts from several crops straw (residue) on single index for *A. adenophora* seed germination. *Note*: Different letters (same letters) stand for significant difference (no significant difference) when $p = 0.05$ and significant difference at $p = 0.01$.

Donor materials	Aqueous extracts	Germination rate (*GR*)		Germination index (*GI*)	
		Mean ± *SE* (%)	RI_1	*Mean* ± *SE*	RI_2
O. sativa straw	1×	44.17 ± 17.82a	**−0.48**	3.26 ± 1.64a	**−0.61**
	5×	57.50 ± 21.79b	**−0.32**	4.07 ± 1.52a	**−0.51**
	25×	67.50 ± 12.88b	**−0.20**	5.50 ± 2.02b	−0.34
	CK	84.44 ± 13.33c	0.00	8.39 ± 1.06c	0.00
Z. mays straw	1×	54.17 ± 17.30a	**−0.17**	4.02 ± 1.12a	**−0.39**
	5×	60.00 ± 14.14b	−0.08	5.69 ± 1.63b	−0.13
	25×	84.17 ± 10.84c	0.23	8.11 ± 1.69c	0.19
	CK	65.00 ± 20.23b	0.00	6.57 ± 2.23b	0.00
T. aestivum straw	1×	54.17 ± 27.46a	**−0.30**	3.67 ± 2.17a	**−0.50**
	5×	60.00 ± 25.23a	**−0.23**	4.61 ± 2.04b	−0.38
	25×	69.17 ± 18.32b	**−0.11**	5.61 ± 1.93b	−0.24
	CK	77.78 ± 15.63c	0.00	7.40 ± 2.14c	0.00
B. campestris waste leaves	1×	47.50 ± 17.12a	**−0.32**	2.39 ± 0.84a	**−0.63**
	5×	77.50 ± 16.58b	0.10	4.93 ± 1.80b	−0.24
	25×	86.67 ± 10.73c	0.19	8.66 ± 1.82d	0.26
	CK	70.00 ± 25.98b	0.00	6.45 ± 2.18c	0.00
B. oleracea waste leaves	1×	33.33 ± 22.70a	**−0.49**	1.31 ± 0.93a	**−0.71**
	5×	69.17 ± 25.03b	0.06	6.08 ± 1.71c	0.25
	25×	77.50 ± 17.12c	0.16	6.83 ± 2.08c	0.33
	CK	65.00 ± 18.03b	0.00	4.58 ± 1.82b	0.00
P. sativum straw	1×	55.00 ± 16.79a	**−0.35**	4.61 ± 1.76a	**−0.47**
	5×	78.33 ± 12.67b	−0.07	7.70 ± 2.37b	−0.12
	25×	81.67 ± 16.97c	−0.03	7.72 ± 1.63b	−0.11
	CK	84.44 ± 7.26c	0.00	8.71 ± 1.59c	0.00
V. cracca straw	1×	62.50 ± 17.12a	**−0.20**	3.24 ± 0.92a	**−0.62**
	5×	68.33 ± 15.28b	−0.13	7.09 ± 1.63b	−0.16
	25×	78.33 ± 8.35c	0.00	8.28 ± 1.05c	−0.02
	CK	78.33 ± 13.37c	0.00	8.46 ± 1.41c	0.00

From Table 1, it can be found that 1× of aqueous extracts from 7 crops straw (residue) had significant inhibitions against *GR* of *A. adenophora*, with *RI* between −0.49 and −0.20. Among them, the inhibition of 1× of aqueous extracts from *B. oleracea* waste leaves and *O. sativa* straw was the strongest, with *RI* of −0.49 and −0.48 respectively; 5× of aqueous extracts from *O. sativa* straw was characterized with rather a strong inhibition against *GR*, with *RI* of −0.32. Also, 1× of aqueous extracts from 7 crops straw (residue) was characterized with a significant inhibition against *GI* of *A. adenophora*, with *RI* between −0.71 and −0.39. Among them, the inhibition of 1× of aqueous extracts from *B. oleracea* and *B. campestris* waste leaves, and *V. cracca* and *O. sativa* straw was the strongest, with *RI* of −0.71, −0.63, −0.62 and −0.61 respectively. And 5× of aqueous extracts from *O. sativa* straw was also characterized with rather strong inhibition against *GI* of *A. adenophora*, with *RI* of −0.51.

3.1.2. The impacts of water-soluble materials of donor on the single index for the seedlings growth of A. adenophora

The statistics results of single tested index for the seedlings growth simulation experiment were shown in Table 2. It showed aqueous extracts from 7 crops straw (residue) were characterized with universal impacts on the single index for the seedlings growth of *A. adenophora* as shown in Table 2.

From Table 2, it can be seen that 1× of aqueous extracts from 7 crops straw (residue) were characterized with significant inhibitions against *RL* of *A. adenophora*, with *RI* between −0.77 and −0.36, and 1× of aqueous extracts from *V. cracca* straw, *B. campestris* and *B. oleracea* waste leaves and *P. sativum* straw were characterized with the strongest inhibition, with *RI* of −0.77, −0.68, −0.47, and −0.42 respectively. Similarly, 5× of aqueous extracts from *V. cracca* straw, *B. campestris* waste leaves, *P. sativum* straw and *O. sativa* straw were also featured with rather strong inhibitions against *RL*, with *RI* of −0.45, −0.41, −0.33 and −0.32 respectively. By contrast, 1× of aqueous extracts from the crops straw (residue) (excluding *P. sativum* straw) were all characterized with inhibitions against *HL*, with *RI* between −0.37 and −0.02, while 1× of aqueous extracts from *V. cracca* straw were characterized with the strongest inhibition, with *RI* of −0.37.

3.2. The synthetic effect of water-soluble materials of donor on the multi-index for seeds germination and seedlings growth of A. adenophora

3.2.1. The synthetic effect of water-soluble materials of donor on the bi-index for seeds germination of A. adenophora

The statistics of synthetic effect index (SEI_1) for seeds germination simulation were shown in Fig. 1. It showed that aqueous extracts from 7 crops straw (residue) were characterized with a certain synthetic effect on the bi-index for seeds germination of *A. adenophora* as shown in Fig. 1.

From Fig. 1, it also showed that on the concentration level of 1×, aqueous extracts from 7 crops straw (residue) all showed strong synthetic inhibitory effect on *GR* and *GI* of *A. adenophora*, with SEI_1 between −0.60 and −0.28, and aqueous extracts from *B. oleracea* waste leaves and *O. sativa* straw were featured with the strongest inhibition, with SEI_1 of −0.60 and −0.55 respectively; on the concentration level of 5×, aqueous extracts from *O. sativa* straw and *T. aestivum* straw showed rather strong inhibition against *GR* and *GI* of *A. adenophora*, with SEI_1 of −0.42 and −0.31 respectively; and on the concentration level of 25×, aqueous extracts from *O. sativa* straw and *T. aestivum* straw also showed rather strong inhibition against *GR* and *GI* of *A. adenophora*, with SEI_1 of −0.27 and −0.18, respectively. Thus, the high concentration (1×) of aqueous extracts from

Table 2
The impacts of aqueous extracts from several crops straw (residue) on single index for *A. adenophora* seedling growth. *Note*: Different letters (same letters) stand for significant difference (no significant difference) when $p = 0.05$ and significant difference at $p = 0.01$.

Donor materials	Aqueous extracts	Radicle length (*RL*)		Hypocotyl length (*HL*)	
		Mean ± *SE* (cm)	RI_3	*Mean* ± *SE* (cm)	RI_4
O. sativa straw	1×	2.04 ± 1.83a	**−0.36**	6.06 ± 3.19a	**−0.02**
	5×	2.19 ± 1.30a	**−0.32**	6.32 ± 3.51a	0.02
	25×	2.69 ± 2.01b	−0.16	8.16 ± 3.65b	0.24
	CK	3.20 ± 2.13c	0.00	6.19 ± 2.85a	0.00
Z. mays straw	1×	1.95 ± 1.06a	**−0.39**	6.72 ± 3.71a	**−0.21**
	5×	2.44 ± 1.55b	−0.24	7.22 ± 3.46a	−0.15
	25×	3.12 ± 1.31c	−0.02	9.32 ± 2.70c	0.09
	CK	3.19 ± 1.50c	0.00	8.46 ± 3.16b	0.00
T. aestivum straw	1×	1.63 ± 0.99a	**−0.41**	6.11 ± 2.69a	**−0.16**
	5×	2.33 ± 1.32b	−0.16	6.31 ± 2.56a	−0.13
	25×	2.45 ± 1.62b	−0.12	6.72 ± 3.10b	−0.07
	CK	2.78 ± 1.53c	0.00	7.26 ± 3.13c	0.00
B. campestris leaves	1×	1.09 ± 0.94a	**−0.68**	4.74 ± 2.34a	**−0.20**
	5×	1.99 ± 1.13b	**−0.41**	7.71 ± 3.30b	0.23
	25×	2.67 ± 1.51b	−0.21	9.16 ± 3.84c	0.35
	CK	3.37 ± 1.52c	0.00	5.92 ± 2.18a	0.00
B. oleracea leaves	1×	0.94 ± 0.87a	**−0.47**	4.21 ± 2.60a	**−0.20**
	5×	1.37 ± 1.08b	−0.23	7.61 ± 4.43c	0.31
	25×	1.60 ± 1.22c	−0.10	8.22 ± 4.09c	0.36
	CK	1.78 ± 1.55c	0.00	5.24 ± 3.00b	0.00
P. sativum straw	1×	2.11 ± 1.39a	**−0.42**	7.23 ± 2.88b	0.10
	5×	2.45 ± 1.64b	**−0.33**	7.42 ± 3.12b	0.12
	25×	3.35 ± 1.87c	−0.08	8.11 ± 3.53c	0.20
	CK	3.64 ± 2.22c	0.00	6.52 ± 2.60a	0.00
V. cracca straw	1×	0.87 ± 1.01a	**−0.77**	5.10 ± 2.86a	**−0.37**
	5×	2.11 ± 1.26b	**−0.45**	8.21 ± 3.75b	0.01
	25×	3.22 ± 1.37c	−0.16	9.06 ± 3.79c	0.10
	CK	3.85 ± 1.89c	0.00	8.13 ± 2.88b	0.00

B. oleracea waste leaves, and three concentrations (1×, 5×, 25×) of aqueous extracts from *O. sativa* straw and *T. aestivum* straw could be chosen as ideal biological materials for the control over the seeds germination of *A. adenophora*.

3.2.2. *The synthetic effect of water-soluble materials of donor on the bi-index for seedlings growth of A. adenophora*

The statistics of synthetic effect index (SEI_2) for seedlings growth simulation were shown in Fig. 2. It showed that aqueous extracts from 7 crops straw (residue) were characterized with a certain synthetic effect on the bi-index for seedlings growth of *A. adenophora* as shown in Fig. 2.

From Fig. 2, it also showed that on the concentration level of 1×, aqueous extracts from 7 crops straw (residue) all brought about strong synthetic inhibitory effects on *RL* and *HL* of *A. adenophora*, with SEI_2 between −0.57 and −0.16, and aqueous extracts from *V. cracca* straw and *B. campestris* waste leaves were featured with the strongest inhibition, with SEI_2 of −0.57 and −0.44 respectively; on the concentration level of 5×, aqueous extracts from *V. cracca* straw, *Z. mays* straw, *T. aestivum* straw and *O. sativa* straw were characterized with rather strong inhibition against *RL* and *HL* of *A. adenophora*, with SEI_2 of −0.22, −0.20, −0.15 and −0.15 respectively; and on the concentration level of 25×, just aqueous extracts from *T. aestivum* straw produced rather strong inhibitory effect on *RL* and *HL* of *A. adenophora*, with SEI_1 of −0.10. Thus, the high and moderate concentration (1× and 5×) of aqueous extracts from *V. cracca* straw, high concentration (1×) of aqueous extracts from *B. campestris* waste leaves, and moderate and low concentrations (5× and 25×) of aqueous extracts from *T. aestivum* straw could be selected as ideal biological materials for the control over the seedlings growth of *A. adenophora*.

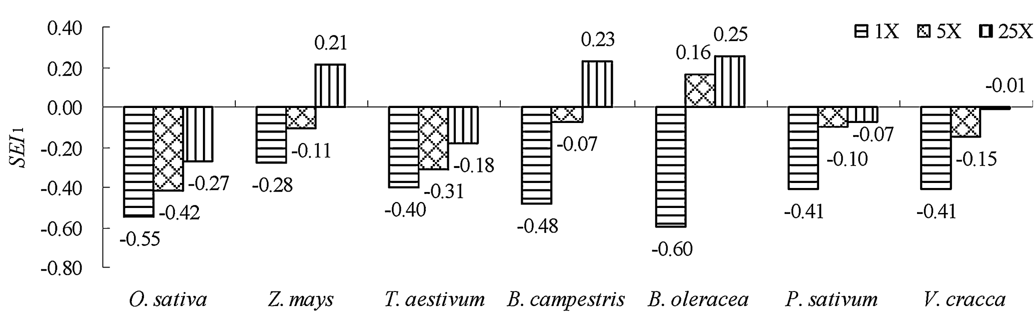

Fig. 1. The synthetic effects of aqueous extracts from several crops straw (residue) on *A. adenophora* seed germination *Note*: $SEI_1 = (RI_1 + RI_2)/2$.

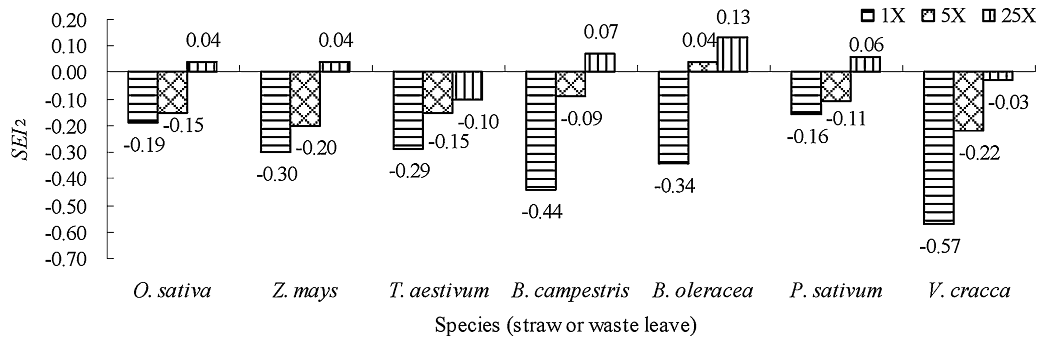

Fig. 2. The synthetic effects of aqueous extracts from several crops straw (residue) on *A. adenophora* seedling growth. *Note*: $SEI_2 = (RI_3 + RI_4)/2$.

3.2.3. The synthetic effect of water-soluble materials of donor on the multi-index for seeds germination and seedlings growth of A. adenophora

The statistics of all-round synthetic effect index (*SEI*) for seeds germination and seedlings growth simulation were shown in Fig. 3. It showed that aqueous extracts from 7 crops straw (residue) were characterized with a certain synthetic effect on seeds germination and seedlings growth of *A. adenophora* as shown in Fig. 3.

From Fig. 3, it also showed that on the concentration level of 1×, aqueous extracts from 7 crops straw (residue) were all characterized with strong synthetic inhibitory effects on *GR*, *GI*, *RL* and *HL* of *A. adenophora*, with *SEI* between −0.49 and −0.29, among them, aqueous extracts from *V. cracca* straw, *B. oleracea* waste leaves and *B. campestris* waste leaves showed the strongest inhibition, with *SEI* of −0.49, −0.47 and −0.46 respectively; on the concentration level of 5×, aqueous extracts from *O. sativa* straw and *T. aestivum* straw showed rather strong inhibitions against *GR*, *GI*, *RL* and *HL* of *A. adenophora*, with *SEI* of −0.28 and −0.23 respectively; and on the concentration level of 25×, aqueous extracts from *O. sativa* straw and *T. aestivum* straw had rather strong inhibitions against *GR*, *GI*, *RL* and *HL* of *A. adenophora*, with *SEI* of −0.12 and −0.14. Thus, the high concentration (1×) of aqueous extracts from *V. cracca* straw, *B. oleracea* waste leaves and *B. campestris* waste leaves, and three concentration (1×, 5×, 25×) of aqueous extracts from *O. sativa* straw and *T. aestivum* straw could be chosen as ideal biological materials for the control over seeds germination and seedlings growth of *A. adenophora*.

4. Discussion

4.1. Agriculture waste (residue) resources and environmental sustainable development

At present, the research on agriculture waste (residue) resources is featured with diverse development and trends. Take crops straw for example, it is not only valuable in improvement of soil properties and crop production (Shi et al., 2010; Tejada et al., 2008; Kasteel et al., 2007; Liu et al., 2006; Kumar and Goh, 2000), composted fertilizer (Lim et al., 2012), forage processing, biofuel production (Tian et al., 2013; Sun et al., 2010; Rasmussen et al., 2010; Han et al., 2009), and industrial utilization (Suzuki et al., 2007), but also in the research potential and utilizing prospects in the field of agricultural pests management (Cao et al., 2010; Han et al., 2010; Ma et al., 2013), environmental pollution abatement (Liu et al., 2012; Chen et al., 2008; Chen and Yuan, 2011; Jones et al., 2011), etc. (Duan et al., 2012; Woolf et al., 2010). For example Liu et al. (2012) discovered that *Hordeum vulgare* straw, *O. sativa* straw and *T. aestivum* straw greatly inhibited the growth of *Microcystis aeruginosa*, and the inhibition increased with the increase in straw addition and with the development of *M. aeruginosa*, moreover, the inhibitory effect was possibly due to allelopathic materials such as organic acid, phenols with methyl, alcohol and ketone, which were from the decomposition of the crops straw in aerobiotic context. Study by Cao et al. (2010) indicated that the introduction of *T. aestivum* straw could inhibit the growth of *Meloidogyne* spp. When the additive amount was 2 N (4.16 g/kg), the inhibitory effect on *Meloidogyne* spp. was the strongest, with inhibition rate of 94.0%. Ma et al. (2013) found that aqueous extracts from aboveground and underground part of some corn hybrids had the potential to induce suicide germination of root parasitic weed sunflower broomrape (*Orobanche cumana*). Such researches provided a certain theoretical guidance and technological support for the utilization of agriculture waste (residue) resources. In this paper, the authors found that water soluble materials from several commonly seen crops straw (residue) along Dianchi Lake had a certain bioactivity against the seeds germination and seedlings growth of *A. adenophora*, thus it is expected to provide a new development field and technological idea for the research and utilization of agriculture waste (residue) resources, which would be of great value and importance for the regional agriculture sustainable development and eco-environment protection.

4.2. Prevention and control over invasive weeds and regional biodiversity protection

It is well known that biological invasion had direct impacts on and threats against native species survival and reproduction (Stinson et al., 2006; Kasenene, 2007; Mangla et al., 2008), regional biodiversity protection (Cui et al., 2011; Wang et al., 2010; Zhou et al., 2009a,b), ecological safety maintenance (Wang et al., 2013; Li et al., 2013, 2009), and environment health and development (Balasubramanian et al., 2013; Zhang et al., 2013; Zhou et al., 2009a,b), which has become a global ecological environment issue (Celesti-Grapow et al., 2010; Li et al., 2009; Pritekel et al., 2006). How to effectively control and scientifically manage the invasive species has become an important issue and a great challenge for biologists and environment protectionist. In this paper, *A. adenophora*, a vicious weed worldwide, with strong productivity at a fast spreading rate, has widely distributed and spread over Yunnan, Guizhou, Sichuan, Chongqing, Guangxi, Tibet and Taiwan, with an annual speed of 20 km to spread further east and north (Wang and Wang, 2006), which has been classified as the No. 1 invasive species in China. Its invasion has brought about soil quality change (Niu et al., 2007; Callaway et al., 2004), local species degradation (Niu et al., 2007; Stinson et al., 2006), biodiversity decreasing (Wang et al., 2010; Pritekel et al., 2006) and great economic loss (Xu et al., 2006; Zhu et al., 2005) in the invaded regions. At present, there is no technological way to effectively prevent, control and eliminate such weed (Wan et al., 2010). The traditional technologies to prevent and eliminate invasive weeds, i.e., physical, chemical, and biological ways, had its own strength and weakness. However,

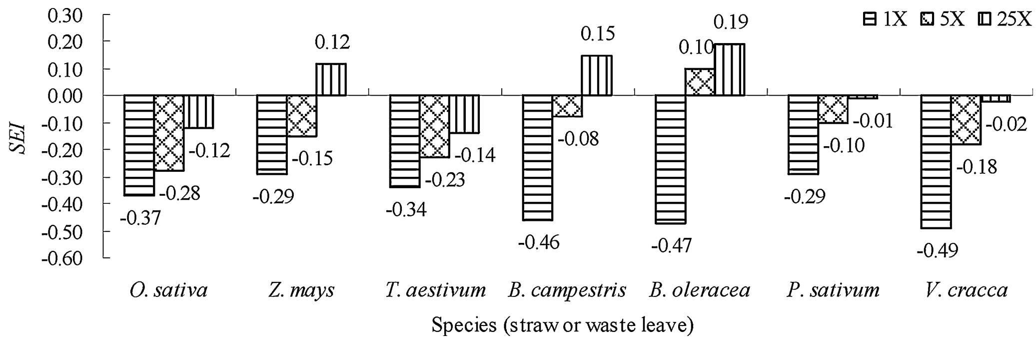

Fig. 3. The synthetic effects of aqueous extracts from several crops straw (residue) on *A. adenophora* seed germination and seedling growth. *Note*: $SEI = (RI_1 + RI_2 + RI_3 + RI_4)/4$.

based on the consideration that in the process of weeds prevention and elimination, a second environment pollution should be avoided and regional biodiversity should be emphasized, in this paper, it is aimed to select biological materials for the prevention and elimination of *A. adenophora* from crops straw (residue), the results showed that the water soluble materials of some commonly seen crops straw (residue) could effectively inhibit the seeds germination and seedling growth of *A. adenophora*, indicating that these could be developed as ideal biological materials for the prevention and elimination of invasive weeds.

4.3. Some scientific issues and research focus in the future

The study in this paper is just a preliminary trial, thus some problems would be inevitable to be left behind, e.g., which active chemicals in the crops straw (residue) dominated or participated in the influential impacts on the seeds germination and seedlings growth of *A. adenophora*? Under the stress from water soluble materials of crops straw (residue), what changes in physiological metabolism have taken place, and what is the in-depth mechanism then? In the context of outdoors or natural environment, would the disturbance and its impacting mechanism from the water soluble materials of crops straw (residue) on *A. adenophora* be the same to that in the indoors experiment? And the list can go on. Without doubt, such problems would be important scientific issues worth in-depth research in the future.

5. Conclusions

Based on the analysis above, the results of this study were determined as follows:

(a) Aqueous extracts from 7 crops straw (residue) were produced different effects on the single index for seeds germination and seedlings growth, e.g., the high concentration (1×) of aqueous extracts from *B. oleracea* waste leaves and *O. sativa* straw showed the strongest inhibition against *GR* of *A. adenophora*; 1× of aqueous extracts from *B. oleracea* waste leaves, *B. campestris* waste leaves, *V. cracca* straw and *O. sativa* straw showed the strongest inhibition against *GI* of *A. adenophora*; 1× of aqueous extracts from *V. cracca* straw, *B. campestris* waste leaves, *B. oleracea* waste leaves, and *P. sativum* straw showed the strongest inhibition against *RL* of *A. adenophora*; and 1× of aqueous extracts from *V. cracca* straw showed the strongest inhibition against *HL* of *A. adenophora*.

(b) Aqueous extracts from 7 crops straw (residue) had different synthetic effects on the bi-index (*GR* and *GI*) for seeds germination of *A. adenophora*. The high concentration (1×) of aqueous extracts from *B. oleracea* waste leaves, *O. sativa* straw and *T. aestivum* straw showed rather strong inhibitions against *GR* and *GI* of *A. adenophora*, which could be chosen as ideal biological materials for the control over seeds germination of *A. adenophora*.

(c) Aqueous extracts from 7 crops straw (residue) were characterized with different synthetic effects on the bi-index (*RL* and *HL*) for seedlings growth of *A. adenophora*. The high and moderate concentrations (1× and 5×) of aqueous extracts from *V. cracca* straw, the high concentrations (1×) of aqueous extracts from *B. campestris* waste leaves, and the moderate and low concentrations (5× and 25×) of aqueous extracts from *T. aestivum* straw showed rather strong inhibitions against *RL* and *HL* of *A. adenophora*, which could be selected as ideal biological materials for the control over seedlings growth of *A. adenophora*.

(d) Aqueous extracts from 7 crops straw (residue) exerted different synthetic effects on the multi-index (*GR*, *GI*, *RL* and *HL*) for seeds germination and seedlings growth of *A. adenophora*. The high concentrations (1× and 5×) of aqueous extracts from *V. cracca* straw, *B. oleracea* waste leaves and *B. campestris* waste leaves, and three concentrations (1×, 5× and 25×) of aqueous extracts from *O. sativa* straw and *T. aestivum* straw showed rather strong inhibitions against *GR*, *GI*, *RL* and *HL* of *A. adenophora*, which could be selected as ideal biological materials for the control over seeds germination and seedlings growth of *A. adenophora*.

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