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Research Article

The Allelopathic Effects of Humus Soil from *Betula platyphylla* and *Quercus liaotungensis* on Undergrowth Medicinal Species in the Qiaoshan Area

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Abstract: In this research, eleven medicinal species were planted in pots containing humus horizon soils collected from *Betula platyphylla* and *Quercus liaotungensis* woodlands in the Qiaoshan Area in the Loess Plateau. The seed germination, seedlings growth and physiological indexes of medicinal species were measured and the allelopathic effects of humus horizon soil on medicinal species were studied. The results showed that the humus soil of *B. platyphylla* woodland showed obvious allelopathic inhibitory effects on *Achyranthes bidentata*, *Bupleurum chinense*, *Glycyrrhiza uralensis* and *Arisaema heterophyllum*, followed by *Astragalus membranaceus*, *Isatis tinctoria*, *Belamcanda chinensis* and *Polygala tenuifolia*. The humus soil of *Q. liaotungensis* woodland showed remarkable all elopathic inhibitory effects on *A. membranaceus*, *A. bidentata* and *I. tinctoria*, followed by *P. tenuifolia*, *B. chinense*, *A. heterophyllum* and *G. uralensis*. Based on our results, these medicinal plants were not recommended to be planted in *B. platyphylla* and *Q. liaotungensis* forests, or they could be planted after intermediate cuttings of forests and removing of litters, in order to impair the allelopathic inhibitory effects of tree species on the medicinal plants.

Keywords: Allelopathy, *Betula platyphylla*, litter, medicinal plants, *Quercus liaotungensis*

INTRODUCTION

Betula platyphylla and *Quercus liaotungensis* are two kinds of the widely planted broad-leaved tree species in Qiaoshan Area of the Loess Plateau, China. However, most pure forests of these species have presented problems such as growth declination, difficult regeneration and soil degradation, thus they were need to be reformed (Gao *et al*., 2013). Forming compound ecosystem is a promising way to solve these problems (Chen and Zhao, 2000).

Complex plantation of tree and medicinal plants can increase the utilization rate of land and soil fertility, improve the physical structure of soil, accelerate trees growth and enhance the economic benefits (Du, 2013). Harmonious interspecific relationship is a key term for forming complex ecosystem, which includes the communion of the light, heat, water and nutrients resources. Allelopathic inhibition is one of the most important factors damaging the interspecific relationship (Bogatk *et al*., 2006), while only a few studies were conducted to investigate the allelopathy in complex ecosystems of tree and medicinal plants. In addition, previous studies mainly investigated allelopathic effects by treating receiver plants (or their seeds) using the water extracts (or leaching solutions) of donor plants (or their litters) and soil and assessing the allelopathic effects based on the obtained data of germination, growth and physiological indicators (Li *et al*., 2013a). However, these methods might cause extremely high concentrations of allelochemicals (Li *et al*., 2013b). Moreover, the transformation processes of allelochemicals in soil were not considered, while most allelochemicals can affect receiver plants after being decomposed, polymerized, transformed and diluted in soil. Hence, using humus soil of pure forests as the source of allelochemicals for testing might be a better approach to study the practical allelopathic effects of tree species on medicinal plants.

Our previous studies had showed that the humus soils from *B. platyphylla* and *Q. liaotungensis* pure forests had remarkable allelopathic inhibitory effects on the growth of *Medicago sativa* and *Amorpha fruticosa* (Huang *et al*., 2014). Hence, the humus soils from typical of *B. platyphylla* and *Q. liaotungensis* pure forests of the hilly area of the Loess Plateau was collected and used as cultivating media for a pot cultivation experiment of 11 medicinal plant species

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which were commonly planted in this area. The germination, seedling growth and physiological indicators of medicinal plants were continuously detected for analyzing the allelopathic effects of tree species on medicinal plants, aiming to provide scientific basis for the reformation of pure forests and the screening of suitable inter-planting species or inter-planting pattern of tree and medicinal species.

MATERIALS AND METHODS

Humus soil sampling: Soil was sampled from the pure forests in Shuanglong Plantation, which is located in Qiaoshan Area, Huangling County, China, with an average annual precipitation of 630.9 mm, an average annual temperature of 9.4°C and a relative humidity of 64% and a frost-free period of 150 day. The soil here was classified as Grey forest soils. Two sample plots with a size of 20×20 m were established within the pure forests of *B. platyphylla* and *Q. liaotungensis* with the same site conditions, respectively and 5 quadrats were uniformly established within each sample plot. The soil of the humus layer (0-10 cm) within quadrats was collected and uniformly mixed after getting rid of the sundries. With the same methods, soil from tree-free waste grassland was sampled for Control testing (CK). The collected fresh soil samples were passed through a 5 mm sieve to reserve.

Seeds preparation of medicinal plants: Eleven kinds of commonly planted medicinal plants were studied in this research, including *Bupleurum chinense*, *Glycyrrhiza uralensis*, *Astragalus membranaceus*, *Isatis tinctoria*, *Saposhnikovia divaricate*, *Platycodon grandiflorus*, *Polygala tenuifolia*, *Achyranthes bidentata*, *Angelica dahurica*, *Belamcanda chinensis* and *Arisaema heterophyllum*. Current-year seeds of these species were bought from local seed company. The plump seeds with uniform size without any pests infected were used for germination and pot cultivation tests (the germination rates of these seeds were over 85% in a pre-testing, thus they were eligible for the following tests).

Pot cultivation experiments: The germination tests were conducted in the rainproof installations. Each kind of homogenized soil sample was divided into 99 subsamples with a weight of 3 kg and placed into cultivation pots (height: 15.5 cm, diameter: 16.6 cm). One hundred of prepared seeds of each medicinal plant species were sowed in a pot uniformly and covered with soil (the soil thickness is 2.5 times of the diameter of the seeds). The combination of a kind of soil and a kind of seed species was defined as a treatment and repeated for 3 times. After sowing, distilled water was added into pots to adjust the soil moisture to 60% of the field water holding capacity. During the cultivation period, water was added every three days according to the water losses and the environmental conditions (such as soil humidity, light and air temperature) were kept consistent for every pot. In order to avoid the self-toxic effects caused by the high destiny of seedlings, during the germination and growth testing, seedlings were randomly pulled out. When doing this, the remaining seedlings were kept uniformly distributed in the pot and approximately 15 seedlings were remained for the final determinations of biomass and other indicators.

Indexes determination: The nutrient contents of soil were determined by the following methods: alkaline N content was measured by alkaline hydrolysis diffusion method; available P by a UV-Vis spectrophotometer; available K by a flame photometer.

Germination indicators: The date of starting germination experiments was defined as the first day and the quantity of germinated seeds were counted every day until there were no more germinated seeds. The germination rates were calculated and the germination indexes were obtained by Eq. (1):

$$GI = \sum (Gt/Dt) \quad (1)$$

In which,
GI = Germination index
Gt = The quantity of germinated seeds
Dt = The corresponding germination time for Gt

Growth indicators: At the end of growth period of the medicinal plants (90-120 day after germination), the whole plants were harvested and the shoot height, root length were measured. After being rinsed and oven dried at 65°C, the biomasses of shoot/root/whole plants per pot were determined.

Physiological indicators: Physiological properties were determined in middle of June. Chlorophyll contents (Chl) were determined by spectrophotometry method and Catalase Activity (CAT) by titration method, Peroxidase activity (POD) by guaiacol colorimetric method and Malondialdehyde contents (MDA) by thiobarbituric acid method.

Data processing: SPSS 20.0 were employed for the data processing. A t-test method was used for testing the differences of indexes (germination, growth and physiological indicators) between treatments and CK ($\alpha = 0.05$). The allelopathic response indexes RI were obtained by Eq. (2):

$$RI = T/C - 1 \quad (2)$$

In which, T was the values obtained in treatments and C was the values obtained in Control testing (CK). A positive RI indicated the allelopathic promoting effects and a negative one showed inhibition. The absolute values of RI indicated the degree of effects.

The *RI* values of every indicators of each kind of plant species were then submitted to SPSS 20.0 and analyzed using an integrated principal component analysis method and the integrated principal component values *F* obtained were used to assess the comprehensive allelopathic effects of humus soil on medicinal plants. A positive *F* indicated the allelopathic promoting effects and the negative ones showed inhibition.

RESULTS

Soil fertility of humus forest soil and wasteland (CK): Relative to CK soil, soil samples from *B. platyphylla* and *Q. liaotungensis* forests showed significant higher contents of organic matters, alkaline N, available P and available K (Table 1).

Table 1: Soil fertility of humus forest soil of *B. platyphylla*, *Q. liaotungensis* forests and wasteland (CK)

Types of litter	Organic matter (g/kg)	Available N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)
CK	24.09	51.59	6.73	81.31
B.p.	37.32*	59.45*	14.42*	159.92*
Q.l.	35.62*	59.93*	7.38*	125.40*

*: Indicated significant differences between experimental value and control value at 0.05 level; The same below

Allelopathic effects of humus soil from pure forests on germination of medicinal plants: The allelopathic effects of humus soil from pure forests on germination of medicinal plants were assessed according to two indicators: germination rate and germination index. Relative to be sowed in tree-free waste grassland soil, the germination rates of *B. chinense*, *A. dahurica*, *A. heterophyllum*, *B. chinensis* and *S. divaricata* were significantly ($p<0.05$) decreased by 29.00-76.00% in humus soil from *B. platyphylla* pure forest (Table 2) and the germination indexes of *B. chinense*, *B. chinensis*, *P. grandiflorus*, *S. divaricata* and *A. dahurica* were significantly decreased by 20.00-83.00%, among which *S. divaricata* was mostly inhibited.

The germination rates of *I. tinctoria*, *B. chinense*, *P. grandiflorus*, *A. dahurica*, *A. heterophyllum*, *B. chinensis* and *S. divaricata* were significantly ($p<0.05$) decreased by 23.00-78.00% in humus soil from *Q. liaotungensis* pure forest (Table 2) and the germination indexes of *P. grandiflorus*, *A. dahurica*, *B. chinensis* and *S. divaricata* were significantly decreased by 27.00-62.00%, among which *S. divaricata* was mostly inhibited.

Allelopathic effects of humus soil from pure forests on seedling growth of medicinal plants: Relative to be planted in tree-free waste grassland soil, *I. tinctoria* and *A. membranaceus* showed significant ($p<0.05$) decreases in shoot height (26 and 42% decreased, Table 3) in the soil from *B. platyphylla* pure forest. The root lengths of *A. membranaceus*, *I. tinctoria* and *A. bidentata* were significantly decreased by 24-40%. The root dry weight of *B. chinensis* was significantly decreased by 33%.

G. uralensis, *I. tinctoria*, *A. membranaceus* and *A. bidentata* showed significant ($p<0.05$) decreases in shoot height (34-57% decreased, Table 3) in the soil from *Q. liaotungensis* pure forest. The root lengths of *A. bidentata*, *A. membranaceus* and *I. tinctoria* were significantly decreased by 33-57%. The root dry weights of *B. chinensis*, *S. divaricata*, *P. grandiflorus*, *A. heterophyllum*, *A. bidentata* and *P. tenuifolia* were significantly decreased by 42-68%. The shoot dry weights of *P. grandiflorus*, *A. heterophyllum*, *A. membranaceus*, *P. tenuifolia*, *A. bidentata* and *I. tinctoria* were significantly decreased by 39-64%.

Allelopathic effects of humus soil from pure forests on physiological properties of medicinal plants: Relative to be planted in tree-free waste grassland soil, *A. dahurica*, *A. heterophyllum* and *A. bidentata* showed significant ($p<0.05$) decreases in Chla content (34, 45 and 64% decreased, respectively Table 4), *G. uralensis*, *A. bidentata*, *A. heterophyllum* and *A. dahurica* showed significant ($p<0.05$) decreases in Chlb content (37, 38, 40 and 70% decreased, respectively Table 4) in the soil from *B. platyphylla* pure forest. Relative to be planted in tree-free waste grassland soil, *I. tinctoria* and *A. membranaceus* showed significant ($p<0.05$) decreases in Chla content (24 and 39% decreased, Table 4), *B. chinense*, *I. tinctoria*, *A. membranaceus* and *G. uralensis* showed significant ($p<0.05$) decreases in Chlb content (43, 46, 54 and 54% decreased, respectively Table 4) in the soil from *Q. liaotungensis* pure forest.

The CAT activity of *S. divaricate*, *G. uralensis*, *P. grandiflorus* and *A. dahurica* were significantly decreased by 51-83% in the soil from *B. platyphylla* pure forest. The CAT activity of *G. Uralensis*, *P. grandiflorus* and *A. dahurica* were significantly decreased by 43-81% in the soil from *Q. liaotungensis* pure forest.

The POD activity of *B. chinense* was significantly decreased by 42% in the soil from *B. platyphylla* pure forest and that of *A. dahurica* was significantly decreased by 67% in the soil from *Q. liaotungensis* pure forest.

A. bidentata, *B. chinense*, *G. uralensis* and *A. heterophyllum* showed significant ($p<0.05$) increases in MDA content (52, 132, 146 and 185% increased, respectively) in the soil from *B. platyphylla* pure forest. *A. membranaceus*, *A. heterophyllum*, *G. uralensis* and *P. tenuifolia* showed significant ($p<0.05$) increases in MDA content (51, 73, 90 and 241% increased, respectively) in the soil from *Q. liaotungensis* pure forest.

Table 2: Seed germination indexes of medicinal plants potted with humus forest soil of *B. platyphylla* and *Q. liaotungensis*

Test index	Treatment		B.ce.	G.u.	A.m.	I.t.	S.d.	P.g.	P.t.	A.b.	A.d.	B.cs.	A.h.
GR/%	Wasteland	C	8.17	11.46	12.56	23.05	18.91	16.00	8.67	7.87	9.12	7.91	17.24
	B.p.	T	5.76*	11.16	15.22	19.81	4.48*	12.88	14.11*	11.55	4.99*	3.91*	8.91*
		RI	-0.29	-0.03	0.21	-0.14	-0.76	-0.20	0.63	0.47	-0.45	-0.51	-0.48
	Q.l.	T	5.83*	14.00	16.15*	17.80*	4.07*	10.16*	10.45	11.93*	5.82*	2.81*	9.76*
		RI	-0.29	0.22	0.29	-0.23	-0.78	-0.36	0.20	0.52	-0.36	-0.64	-0.43
GI	Wasteland	C	15.00	38.00	43.33	70.67	48.33	42.33	19.67	40.00	26.00	27.00	32.00
	B.p.	T	12.00*	35.00	38.33	70.00	19.33*	30.33*	23.33	61.00*	4.33*	21.00*	26.00
		RI	-0.20	-0.08	-0.12	-0.01	-0.60	-0.28	0.19	0.53	-0.83	-0.22	-0.19
	Q.l.	T	15.00	33.33	55.67	69.67	18.33*	31.00	27.67*	59.33*	18.33*	12.33*	26.00
		RI	0.00	-0.12	0.28	-0.01	-0.62	-0.27*	0.41	0.48	-0.29	-0.54	-0.19

B.ce.: *Bupleurum chinense*; G.u.: *Glycyrrhiza uralensis*; A.m.: *Astragalus membranaceus*; I.t.: *Isatis tinctoria*; S.d.: *Saposhnikovia divaricata*; P.g.: *Platycodon grandiflorus*; P.t.: *Polygala tenuifolia*; A.b.: *Achyranthes bidentata*; A.d.: *Angelica dahurica*; B.cs.: *Belamcanda chinensis*; A.h.: *Arisaema heterophyllum*; B.p.: *Betula platyphylla*; Q.l.: *Quercus liaotungensis*; The same below

Table 3: Seeding growth indexes of medicinal plants potted with humus forest soil of *B. platyphylla* and *Q. liaotungensis*

Test index	Treatment		B.ce.	G.u.	A.m.	I.t.	S.d.	P.g.	P.t.	A.b.	A.d.	B.cs.	A.h.
Shoot height cm	Wasteland	C	18.92	18.98	33.58	17.93	15.26	6.75	15.52	11.85	8.00	19.88	10.62
	B.p.	T	19.10	16.65	19.57*	13.24*	19.67*	15.12*	19.88	12.18	12.39*	22.47	13.67*
		RI	0.01	-0.12	-0.42	-0.26	0.29	1.24	0.28	0.03	0.55	0.13	0.29
	Q.l.	T	16.05	12.56*	15.57*	8.84*	18.56	6.71	13.47	5.13*	15.33*	17.26	8.88
		RI	-0.15	-0.34	-0.54	-0.51	0.22	-0.01	-0.13	-0.57	0.92	-0.13	-0.16
Root length cm	Wasteland	C	19.27	20.21	34.98	22.62	16.81	7.80	17.88	11.82	10.05	23.37	14.00
	B.p.	T	22.02	17.47	26.57*	14.20*	22.69*	16.14*	21.62	7.14*	21.63*	26.80	15.52
		RI	0.14	-0.14	-0.24	-0.37	0.35	1.07	0.21	-0.40	1.15	0.15	0.11
	Q.l.	T	17.11	16.43	21.19*	9.83*	17.90	6.76	15.72	7.93*	18.38*	18.81	13.75
		RI	-0.11	-0.19	-0.39	-0.57	0.06	-0.13	-0.12	-0.33	0.83	-0.20	-0.02
Root dry weight g	Wasteland	C	0.04	0.06	0.03	0.02	0.06	0.08	0.05	0.04	0.01	0.34	0.32
	B.p.	T	0.05	0.12*	0.15*	0.03	0.05	0.20*	0.06	0.06*	0.35*	0.25*	0.37
		RI	0.43	1.02	3.89	0.30	-0.20	1.43	0.32	0.46	24.21	-0.26	0.16
	Q.l.	T	0.03	0.09*	0.06*	0.02	0.03*	0.05*	0.02*	0.02*	0.05*	0.20*	0.14*
		RI	-0.14	0.40	0.81	-0.12	-0.44	-0.46	-0.68	-0.65	2.89	-0.42	-0.56
Shoot dry weight g	Wasteland	C	0.11	0.10	0.09	0.24	0.07	0.08	0.10	0.09	0.03	0.17	0.07
	B.p.	T	0.22*	0.14*	0.13*	0.20	0.14*	0.15*	0.14	0.11	0.32*	0.24	0.08
		RI	0.92	0.40	0.35	-0.15	0.90	0.82	0.45	0.26	8.48	0.40	0.23
	Q.l.	T	0.08	0.07	0.05*	0.09*	0.08	0.05*	0.05*	0.04*	0.11*	0.12	0.04*
		RI	-0.27	-0.29	-0.47	-0.64	0.14	-0.39	-0.51	-0.52	2.23	-0.29	-0.42

Table 4: Physical indexes of medicinal plants potted with humus forest soil of *B. platyphylla* and *Q. liaotungensis*

Test index	Treatment		B.ce.	G.u.	A.m.	I.t.	S.d.	P.g.	P.t.	A.b.	A.d.	B.cs.	A.h.
Chl a content mg/g	Wasteland	C	2.62	1.38	1.18	1.05	0.85	0.87	1.15	0.84	1.28	1.12	1.43
	B.p.	T	2.25	1.20	1.10	0.92	0.88	0.99	1.21	0.30*	0.84*	1.17	0.79*
		RI	-0.14	-0.12	-0.06	-0.12	0.04	0.14	0.06	-0.64	-0.34	0.05	-0.45
	Q.l.	T	1.98	1.32	0.72*	0.80*	0.89	0.98	1.17	0.73	1.11	1.10	1.09
		RI	-0.24	-0.04	-0.39	-0.24	0.05	0.12	0.02	-0.13	-0.13	-0.01	-0.24
Chl b content mg/g	Wasteland	C	0.71	0.50	0.29	0.37	0.16	0.17	0.20	0.25	0.58	0.34	0.24
	B.p.	T	0.53	0.31*	0.27	0.30	0.17	0.19	0.24	0.16*	0.18*	0.21	0.14*
		RI	-0.26	-0.37	-0.07	-0.19	0.10	0.15	0.23	-0.38	-0.70	-0.37	-0.40
	Q.l.	T	0.40*	0.63	0.13*	0.20*	0.17	0.32*	0.22	0.21	0.26*	0.41	0.22
		RI	-0.43	0.27	-0.54	-0.46	0.07	0.93	0.15	-0.15	-0.54	0.23	-0.08
CAT activity mg/g/min	Wasteland	C	3.89	2.83	2.02	1.66	2.61	2.18	1.79	1.81	6.33	1.83	1.99
	B.p.	T	3.42	1.08*	1.84	1.76	1.27*	0.39*	4.92*	2.77	1.10*	4.23*	2.03
		RI	-0.12	-0.62	-0.09	0.06	-0.51	-0.82	1.74	0.53	-0.83	1.32	0.02
	Q.l.	T	4.86	1.61*	1.56	2.06	2.69	1.03*	3.20*	2.18	1.22*	4.56*	2.84*
		RI	0.25	-0.43	-0.22	0.24	0.03	-0.53	0.78	0.21	-0.81	1.49	0.43
POD activity U/g·min	Wasteland	C	1.89	2.76	2.01	3.24	1.12	0.54	3.82	1.31	3.25	0.63	9.25
	B.p.	T	1.10*	3.15	2.30	4.39	1.55*	1.27*	3.32	1.33	3.91	0.55	9.72
		RI	-0.42	0.14	0.15	0.35	0.39	1.36	-0.13	0.02	0.20	-0.14	0.05
	Q.l.	T	1.58	4.33*	2.00	3.49	1.07	0.75*	3.63	1.80	1.07*	2.57	10.09
		RI	-0.16	0.57	0.00	0.08	-0.04	0.40	-0.05	0.38	-0.67	3.05	0.09
MDA content mg/g	Wasteland	C	11.37	1.51	2.74	2.21	1.53	0.19	3.55	1.91	12.84	1.06	0.61
	B.p.	T	26.32*	3.72*	2.64	1.33*	1.54	0.22	3.59	2.89*	9.73	1.01	1.74*
		RI	1.32	1.46	-0.04	-0.40	0.01	0.12	0.01	0.52	-0.24	-0.05	1.85
	Q.l.	T	10.72	2.87*	4.14*	1.20*	1.44	0.23	12.10*	2.03	5.15*	0.59	1.06*
		RI	-0.06	0.90	0.51	-0.46	-0.06	0.19	2.41	0.06	-0.60	-0.45	0.73

Integrated allelopathic effects of humus soil from pure forests on physiological properties of medicinal plants: To assess the integrated allelopathic effects of humus soil from pure forests on physiological properties of medicinal plants, the obtained *RI* values of germination rate, germination index, shoot height, root length, shoot dry weight, root dry weight, contents of Chl a, Chl b and MDA and activities of CAT and POD were submitted to SPSS 20.0 for principal component analysis (as the higher content of MDA indicated the

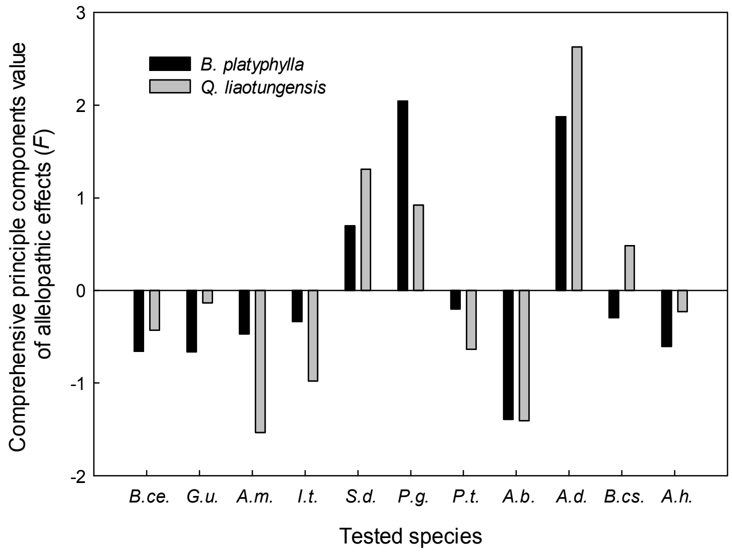

Fig. 1: Comprehensive principal components value of allelopathic effects of humus forest soil of *B. platyphylla* and *Q. liaotungensis* on medicinal plants

inhibitory effects, thus the *RI* values of MDA were converted into reciprocals). The obtained models of comprehensive principal components value (*F*) were presented in Eq. (3) and (4) and the *F* values were given in Fig. 1:

$$F_{B.p.} = 0.448F_1 + 0.288F_2 + 0.156F_3 + 0.108F_4 \quad (3)$$

$$F_{Q.l.} = 0.506F_1 + 0.323F_2 + 0.171F_3 \quad (4)$$

The results revealed that humus soil from *B. platyphylla* pure forest showed the most obvious inhibitory effects on *A. bidentata*, followed by *G. uralensis*, *B. chinense*, *A. heterophyllum*, *A. membranaceus*, *I. tinctoria*, *B. chinensis* and *P. tenuifolia*, while it showed the most obvious promoting effects on *P. grandiflorus* and *A. dahurica*, followed by *S. divaricata*. Humus soil from *Q. liaotungensis* pure forest showed the most obvious inhibitory effects on *A. bidentata*, *A. membranaceus* and *I. tinctoria*, followed by *P. tenuifolia*, *B. chinense*, *A. heterophyllum* and *G. uralensis*, while it showed the most obvious promoting effects on *A. dahurica* and *S. divaricata*, followed by *P. grandiflorus* and *B. chinensis*.

DISCUSSION

Our results indicated that both of the humus soil from *B. platyphylla* and *Q. liaotungensis* pure forests significantly inhibited the seeds germination of *A. dahurica*, *B. chinensis* and *S. divaricate*, which was similar with the findings of Li *et al*. (2011). Amylase plays an important role in the metabolic activity of seed germination (Li *et al*., 2011), while the allelochemicals in humus soil might inhibit the composition and activities of many enzymes, thus the inhibition of humus soil on medicinal plants germination might be caused by the inhibitory effects of allelochemicals on amylase activity. In addition, allelochemicals can lead to the alteration in the permeability and function of biomembrane and consequently inhibit seed germination. For instance, Liu *et al*. (2013) stated that water extracts of leguminous forage can destroy the bio-membrane system of *Lolium multiflorum* to some extent and cause decreases in seed activities.

Simultaneously, allelochemicals can hinder the division and elongation of plant cells (Li *et al*., 2002), destroy their organelle (Kaur *et al*., 2005) and control the growth and differentiation of cells and consequently affect the shoot/root length and the accumulation of biomass. In addition, allelopathy can affect the enzyme activities and hormone contents in plants and thus inhibit the growth and developments of plants. As an example, Soltys *et al*. (2011) stated that the water extracts of *Hevea brasiliensis* leaves can disturb the hormone balance in plant tissue, cause decrease in IAA contents, but increase the ABA contents.

Allelopathy inhibited not only the germination and seedling growth of medicinal plants, but also the physiological properties of them. For instance, humus soil from *B. platyphylla* forest significantly decrease the Chla and Chl b contents of *A. dahurica*, *A. heterophyllum* and *A. bidentata*. Humus soil from *Q. liaotungensis* forest also decreased those of *I. tinctoria* and *A. membranaceus*, which were in line with the findings of Zhou *et al*. (2009) and Yu *et al*. (2006). Previous studies had stated that allelochemicals can destroy the cytomembrane system and chloroplasta (Einhellig and Rasmussen, 1979; Wu *et al*., 2004), that might respond for the decreases in Chla and Chl b contents. The Reactive Oxygen Species (ROS) contents will be sharply increased under adversity conditions, large amounts of ROS will lead to death of plant cells or damages of cytomembrane and cause accumulations of MDA (Payton *et al*., 2001; Wang *et al*., 2011). Our results indicated that humus soil from *Q. liaotungensis* forest could lead to increases in POD and CAT activities, while the allelochemicals might also accelerate the protective enzyme activities and increase the ability of transforming ROS to innoxious substances of plants, thus the significant increase in MDA contents was not observed, which was supported by the findings of Ding *et al*. (2007).

CONCLUSION

Humus soil from *B. platyphylla* forest showed integrated allelopathic inhibitory effects on *A. bidentata*, *G. uralensis*, *B. chinense*, *A. heterophyllum*, *A. membranaceus*, *I. tinctoria*, *B. chinensis* and *P. tenuifolia*, these medicinal plants should be avoid being planted in *B. platyphylla* forests. Humus soil from *Q. liaotungensis* forest showed integrated allelopathic inhibitory effects on *A. bidentata*, *A. membranaceus*, *I. tinctoria*, *P. tenuifolia*, *B. chinense*, *A. heterophyllum* and *G. uralensis*, these medicinal plants should be avoid being planted in *Q. liaotungensis* forests.

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