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Allelopathic plants: 20. Hairy Beggarticks (*Bidens pilosa* L.)

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CONTENTS

ABSTRACT

Bidens pilosa L. is an annual major weed in warm areas of the world and is serious weed in many crops. In the bioassays and root exudates experiments, it significantly suppressed the growth of test plants. In field experiments, application of its shoots biomass at 2 t ha^{-1} drastically suppressed (80%) the weed density and weed dry weight than hand-weeding and herbicide treatments and completely controlled the emergence of *Rotala indica*, *Commelina diffusa*, *Jussiaea decurrens*. Moreover, rice tiller numbers, panicles and grain were stimulated and yield was enhanced by 20%. Many secondary metabolites (phenolics, polyacetylenes and triterpens) involved in allelopathic action were found in this weed, of these phenylheptatriyne (PHT) and its derivatives amounts were highest in *B. pilosa* oil. Total 23 phenolic compounds [including salicylic acid, vanillin, *p*-hydroxybenzoic acid, *p*-coumaric acid, ferulic acid] were identified and isolated in shoots and roots. Caffeic acid was in highest amount (117.4, 298.7, and 350.3 µg g^{-1} in leaves, stems and roots) followed by pyrocatechin (responsible for phytotoxicity). However, the fate and actual modes of action of these compounds are not well understood, whether these compounds can inhibit emergence of paddy weeds and enhanced the rice yields as well as contributing to its strong invasiveness in nature need to be further studied.

Keywords: Allelochemical, allelopathy, *Bidens pilosa* L., hairy beggarticks, indicator plants, root exudates, weed

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1. INTRODUCTION

Bidens pilosa L. (Asteraceae family) is an annual native to tropical America and widely distributed in tropical and subtropical regions of the world. This genus contains about 280 species and is widespread in both field crops and non crop areas and is one of the world`s worst weed causing losses in crops > 40 countries (14). The genetic name refers to Latin, implied “two tooth”, *bis* means double or two, and *dens* means tooth (20). Because of its fast-growth, strong invasion in plant ecosystems and easy adaptation in warmer regions, it has become most noxious annual weed in several upland crops, soybean and upland rice in Southeast Asia, East Africa etc. (13). This plant has also several medicinal properties (28,31). Present research has reported the phyto-constituents, pharmacological, medicinal applications as well as its phytochemical isolations from this genus.

2. MORPHOLOGY AND ECOLOGY

B. pilosa grows very fast and dominates after the eradication of perennial grasses, and exhibits allelopathic effects on numerous crops (14). It is easily recognized by its elongated burlike achenes that bear recurved or hooked bristles, a device that has insured the plant`s dissemination. The stem grows erect up to 150 cm tall with numerous ridged branches. Its branches and stems are marked with paralled lines or ridges, smooth, green or with brown stripes (14). The tiny inflorescence is a capitulum (congested head of flowers), with yellow centre and white ray petal, the achenes are blackish, narrow, ribbed and sparsely bristled to smooth (20). Leaves are opposite, petioled, pinnate, with 3 to 5 sharply serrated ovate leaflets and slightly hairy (Fig.1). A single plant can produce 3000 to 6000 seeds and many seeds germinate readily at maturity. Optimum temperature for its seed germination is 15- 40^{o}C and seeds remain viable for years and germinate readily, when buried in soil. The 3 to 5 years old seeds show over 80% germination (12,13).

Figure 1. Hairy beggarticks (*B. pilosa* L.)

3. ECONOMIC IMPORTANCE

B. pilosa is used as medicinal plant in many regions of the world, it is useful as cover crop and fodder and source of nectar for honeybees. The entire plant has astringent, diaphoretic and diuretic properties (18). Roots, leaves and seeds possess antibacterial, antidysenteric, anti-inflammatory, antimalarial, antiseptic, anticancer, antipyretic, liver-protective, blood-pressure lowering, and hypoglycemic, diuretic, antidiabetic, hepato-protective effects (29,30). In South Africa, its leaves decoction is used to treat headache, ear infection, kidney problems and flatulence reduction. The leaves extract is used to cure malaria, stomach, and mouth ulcers, diarrhea, hangover and whole plant is taken as a poison antidote (28). In sub-Saharan Africa, fresh or dry shoot and young leaves of *B. pilosa* are sometimes used for human food. In Uganda, the leaves are boiled in sour milk (14). In Australia and Hawaii, the young shoot tips are used to make a tea and the juice-prepared from the leaves is used to treat wounds and ulcers in many countries (20).

4. ALLELOPATHY RESEARCH

4.1. Bioassays

Our research showed that all parts of *B. pilosa*, including leaves, stems and roots of acidic ethyl acetate fraction showed great allelopathic effects against the growth of *Echinochloa crus-galli* and *Raphanus sativus*. The extracts of roots and stems at 100 to 500 ppm showed drastic inhibitory effects (70% to 90%) on the emergence of *E. crus-galli* and *R. sativus*. The suppression against indicator plants was proportional to the applied doses, as the inhibition in emergence of hypocotyls and radicals of *E. crus-galli* and *R. sativus* was up to 90%, respectively. The suppression was less in *E. crus-galli* than in *R. sativus* (10). Some studies had indicated the strong allelopathic influences of *B. pilosa* on crops and weeds. Its leaf and root extracts significantly inhibited the germination and seedling growth of soybean, mungbean, rice, maize, radish, cucumber, lettuce, sorghum, groundnut and bittervine etc (1,5,27,25,32).

4.2. Root exudates experiments

Ten plants of *B. pilosa* (136 days old, 75 days after transplanting) were planted in pots to study the effects of root exudates from the continuous root exudates trapping system in XAD-4 resin (26). After 48 h, its root exudates were collected and applied to *Lactuca sativa*, *Phaseolus vulgaris*, *Zea mays* and *Sorghum bicolor* to examine the phytotoxic effects on their seedling growth. At 14 days after sowing, *B. pilosa* root exudates remarkably inhibited the seedling growth of all tested crops and reduced the leaf area (87%) of *L. sativa* over the control (26). Thus dicotyledons species were more sensitive than monocotyledons. The root exudates of older and larger *B. pilosa* plants were more inhibition to the seedling growth of *L. sativa* and *P. vulgaris* than younger and smaller plants (27). In our recent studies, the root exudates of *B. pilosa* during its early growth stage (20 days exudates on agar culture) caused 70% inhibition in germination, root and shoot length of *Leucaena Leucocephala* followed by 50% inhibition in *E. crus-galli*, *Medicago sativa* and *Oryza sativa,* whereas *B. pilosa* itself was not inhibited (Fig. 2).

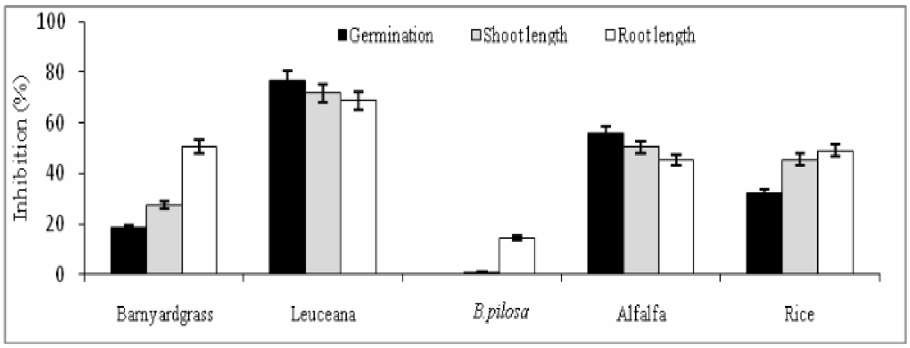

Figure. 2. Allelopathic effects of root exudates of *B. pilosa* on some indicator plants. The bars indicate mean ± standard error, n=3

4.3. Field experiments

To evaluate the actual allelopathic effects of *B. pilosa* on the growth of noxious paddy weeds in field conditions. The aerial parts of *B. pilosa* applied at 2 t ha^{-1} drastically reduced the weeds density (84.9%) and weed dry weight (81.8%) and completely suppressed 3 weeds species (*Rotala indica*, *Commelina diffusa*, *Jussiaea decurrens*). The application of *B. pilosa* biomass showed higher weed suppression than both hand-weeding and herbicide treatments (Table 1) (15). Similar biomass dose of some higher plants [*Ageratum conyzoides*, *Azadirachta indica*, *Euphorbia hirta*, *Galactia pendula*, *Leucaena glauca*, *Melia azedarach*, *Piper methysticum*, *Sophora japonica*, and *Tephrosia candela*] reduced the paddy weeds by 80% (16,18).

4.3.1. Rice growth and rice yield

Plant height of rice was slightly stimulated over the control. However, tiller numbers, panicles and grains of rice were enhanced (11.8% to 16.9%) more than herbicide treatment (5.6% to 7.8%) (Fig. 3) (15). Application of plant materials of *B. pilosa* enhanced the rice yield (20%) than herbicide treatment and was similar to hand-weeding. Thus the application of *B. pilosa* biomass to paddy field significantly suppressed the weed and increased the rice yield. The weed reduction may be due to the release of active phytotoxins (allelochemicals) released from the decomposing *B. pilosa* biomass in soil. Rice growth and rice yield were stimulated may be due to both allelochemicals and nutrient effects from *B. pilosa*. The leaves of higher plants often contain nutrients (P, K, Ca, and Mg), which enhanced the rice growth and yield (16,17).

4.4. Allelochemicals

The *B. pilosa* plant contains many secondary metabolites [phenolics, saponins, flavonoids, flavones glycosides, polyacetylenes, terpens chalcone glucosides, phenylpropanoid glucosides, terpenoids (3,4,28)] and their allelopathic activities are as under:

Table 1. Effects of *B. pilosa* on the growth of paddy weeds

Treatments	Weed species (plant/m²)												Total weed number (plant/m²)	
	A	B	C	D	E	F	G	H	I	J	K	L		
Control	14	4.3	11.3	12.7	5.3	9.7	15.3	3.0	5.3	4.0	32.3	15.1	132.3a	(0.0)
B. pilosa L.	4.3	1.0	1.3	3.3	1.3	-	-	1.3	-	0.7	1.3	5.3	20.0g	(84.9)
Hand-weeding*	1.3	4.0	5.3	2.3	5.7	7.3	-	1.7	4.7	-	23.0	-	55.3bc	(58.4)
Herbicide	10.3	-	5.3	1.7	10.7	1.0	-	-	7.3	-	3.0	6.7	46.0cde	(65.2)
	Weed species (dry weight, g/m²)												Total dry weight (g/m²)	
Control	3.4	1.5	0.6	0.5	0.04	0.8	0.3	0.2	0.5	0.3	1.2	8.0	9.9a	(0.0)
B. pilosa L.	0.1	0.05	0.2	0.5	0.02	-	-	0.2	-	0.02	0.2	0.7	1.8cdef	(81.8)
Hand-weeding	0.04	0.1	0.2	0.4	0.1	0.6	-	0.1	0.8	-	0.7	-	2.8bc	(71.7)
Herbicide	0.2	-	0.4	0.3	0.5	0.01	-	-	0.5	-	0.1	0.2	2.2bcde	(77.8)

With the same letter, values in the parentheses are not significantly different at p<0.05. (-) indicates weed species was not observed. * Hand-weeding was conducted at 15 days after transplanting. Values in the parentheses indicate inhibition over control. A: *Marsilea quardrifolia*, B: *Fimbristylis milliacea*, C: *Leptochloa chinensis*, D: *Cyperus difformis*, E: *Rotala indica*, F: *Sphenoclea zylanica*, G: *Commelina diffusa*, H: *Murdannia keisak*, I: *Jussiaea decurrens*, J: *Dactyloctenium aegyptium*, K: *Brachiaria mutica*, and L: *Monochoria vaginalis*. Source: (15)

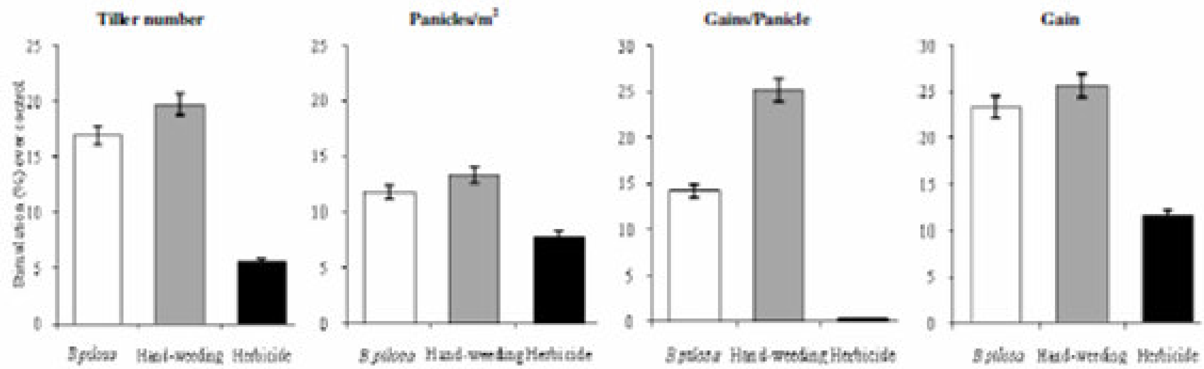

Figure 3. Stimulatory effects of *B. pilosa* on the growth and grain yield of rice. The bars indicate mean ± standard error, n=3 (Source: 15)

4.4.1. Polyacetylenes

Polyacetylenes are naturally occurring hydrocarbon derivatives characterized by one or more acetylenic groups in their structures and are predominantly produced in the roots of Asteraceae (3). The phenylheptatriyne (PHT) (Fig. 4) with potent allelopathic activity was first found in leaf of *B. pilosa* (3,7) and is most studied polyacelylenic compound. Recently, PHT has been also identified and isolated from *B. pilosa* oils by GC, GC-MS and HPLC and is major constituent in all parts of *B. pilosa* (11,23). Among the identified compounds in *B. pilosa*, PHT was in the highest concentration (30% - 48%) in *B. pilosa* oils, followed by 1-phenylhept-5-ena-1,3-diyne found (0.2% - 37.1%) and 7-phenylhept-2-ena-4,6-diynyl acetate (1.3%-22.5%) (23) and these may be involved in phytotoxic action (Table 2). PHT in leaves of *B. alba* also varies in nature and in response to the photoenviroment (6). The other isolated polyacetylens, including 1,2-dihydroxytrideca-3,5,7,9,11-pentayne and its glycoside, 2-β-D-glycopyrasyloxy-1-hydroxytrideca-3,5,7,9,11-tentayne possesses high antimalarial and antibacterial activities, hence, used in Amazone region to treat malaria (4). Several polyacetylenes [*cis*-dehydromatricariaester (*cis*-DMK), lachnophylum ester (LE), matricaria ester (ME), dehydromatricaria lactone, α-terthienyl and thiophene polyacetylenes] isolated from the higher plants are allelopathic (7,24).

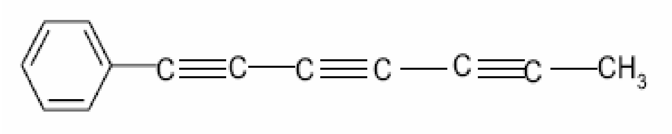

Figure 4. Structure of Phenylheptatriyne (PHT) found in *B. pilosa*.

4.4.2. Phenolics

Phenolic compounds are among of many secondary metabolites which implicated allelopathic activity. The allelopathic activity of simple phenols (benzoic and cinamic acid derivatives flavonoids and tannins) is well documented in literature. The GC-MS and HPLC analyses indicated that 15 phenolic compounds [including salicylic acid, vanillin, *p*-hydroxybenzoic acid, caffeic acid, *p*-coumaric acid, ferulic acid] are present in leaf, stem, root of *B. pilosa*, (11), these are major allelochemicals in nature (2). In all plant parts, caffeic acid content was the highest (117.4, 298.7, and 350.3 µg g^{-1} in the leaves, stems and roots), followed by pyrocatechin (18.5, 32.9, 29.6 µg g^{-1}), and ferulic acid (Fig. 5). Caffeic acid is one of the major allelochemicals in *Leonurus* (19) and possesses allelopathic activity. Most of the detected compounds (*p*-hydrobenzoic acid, vanilic acid, ferulic acid, *p*-coumaric and syringic acid) are the main allelochemicals in nature and also found in some invasive and noxious weeds (2,16,18). In another experiment, 8 phenolic compounds [quercetin 3-Orabinobioside, quercetin 3-O-rutinoside, chlorogenic acid, 3,4-di-O-caffeoylquinic acid, 3,5-di-O-caffeoylquinic acid, 4,5-di-O-caffeoylquinic acid, jacein, and centaurein] were isolated from the fresh whole plant of *B. pilosa* and are responsible for antioxidant action (9).

4.4.3. Terpenoids

Terpenoids are the second largest group after phenolics. Terpenoid natural

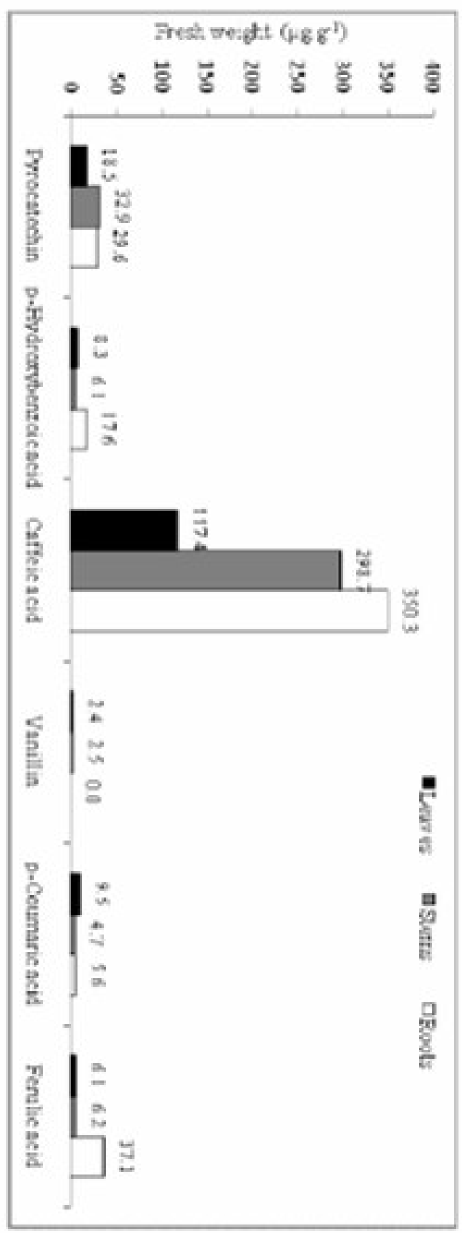

Figure 5. Phenolic compounds content in the aerial parts and roots of *B. pilosa*. Source: (10).

Table 2. Percentage composition of the essential oils of *B. pilosa*

Components	F	L	S	R	Components	F	L	S	R
Acetal	0.09	0.03	-	-	α-Copaene	0.10	0.20	0.10	-
Borneol	-	-	-	0.20	α-Humulene	2.60	0.70	0.90	-
Bornyl acetate	0.18	0.15	0.10	-	Germacrene D	21.1	18.0	7.20	-
Bicyclogermacrene	-	-	0.70	-	Hexadecanol	-	-	0.10	7.10
Caryophyllene oxide	1.03	1.47	1.50	-	Hexadecyl acetate	-	-	-	0.90
cis-3-Hexen-1-ol	-	0.10	-	-	Isoledene	0.47	0.67	-	-
cis-Chrysanthenyl acetate	-	-	-	2.80	Limonene	2.12	0.34	-	0.20
cis-3-Hexenyl acetate	-	0.77	-	-	Linalool	-	0.10	1.40	-
cis-Verbenol	0.80	0.11	-	-	Megastigmatrienone	2.04	5.35	-	-
Diphenylenemethane	1.77	1.94	-	-	*m*-Cymol	0.11	0.08	-	-
Eugenol isobutyrate	-	-	-	0.50	Myrcene	0.10	-	0.10	-
Elixene	0.32	0.25	-	-	Octadecadienol	-	-	0.30	23.80
Ent-spathulenol	0.18	0.33	-	-	Perillene	0.10	-	0.10	-
Epi-cedrol	-	-	-	0.30	Pimaradiene	-	-	0.20	-
Camphene	0.06	0.02	-	-	*p*-Cymen-8-ol	0.35	0.26	-	-
β-Gurjunene	0.24	0.44	-	-	Sabinene	-	-	0.20	0.60
β-Copaene	10.02	1.1	6.4	-	Spathulenol	-	0.30	-	0.10
β-Phellandrene	0.15	0.01	0.60	-	*trans*-Nerolidol	0.13	0.39	-	-
β-Pinene	0.39	0.07	0.20	0.20	*trans*-Verbenol	0.11	-	-	-
β-Myrcene	0.10	0.29	0.10	-	Ylangene	0.13	0.13	-	-
β-*trans*-Ocimene	1.64	0.55	-	-	(-)-b-Cadiene	0.23	0.82	-	-
β-*cis*-Ocimene	1.45	1.46	-	-	A	13.3	13.7	37.1	0.20
β-Bourbonene	0.99	1.10	-	-	1-phenylhepta-1,3,5-triyne	30.7	48.0	37.1	0.20
β-Elemene	0.67	1.00	0.20	0.10	B	0.16	0.82	-	-
β-Caryophyllene	7.50	6.10	7.00	0.10	3-Carene	0.65	-	-	-
β-Cubebene	1.77	2.23	-	-	4-Terpineol	0.41	0.14	-	-
β-Farnesene	0.29	0.72	-	-	C	0.70	0.24	-	-
β-Linalool	0.09	0.43	-	-	D	-	-	1.30	22.5
α-Cadinol	0.20	0.20	0.50	-	(E)-β-ocimene	0.50	-	-	-
α-Caryophyllene	1.00	1.55	-	-	(E)-nerolidol	0.10	0.70	-	-
α-Terpineol	-	-	0.40	-	E	0.25	0.27	-	-
α-Pinene	5.97	0.99	0.6	0.2	**Total identified**	**113.7**	**114.6**	**104.4**	**60.0**

F: Flower; L: Leaf; S: Shoot; R: Root; (-): not detected; A: 1-phenylhept-5-ena-1,3-diyne; B: 2,5,9-Trimethylcycloundeca-4,8 dienone; C: (4E,6Z)-2,6-Dimethyl-2,4,6-octatriene; D: 7-phenylhept-2-ena-4,6-diynyl acetate; E: (+)-Epi-bicyclosesquiphellandrene (Source: 11, 23).

functions are variable [signal molecules, allelochemicals, phytoalexins, pheromones visual pigments, photoprotective agents, memberane constituents and reproductive hormones (21)]. Terpenoids including the volatile terpenes are the major components of essential oils, causing allelopathic interaction among the plants containing volatile allelochemicals (12).

In all parts of *B. pilosa*, 63 compounds have been identified and isolated from its all parts (leaves, stems, roots, flowers and oils). The oils contain 60% to 114.6% of the total components detected (Table 2). Most of the identified compounds [terpenens, thiophenes, and polyacetylenic constituents] are referred as allelochemicals such as β-caryophyllene (0.10% -7.50%) found in all parts of *B. pilosa*, limonene (0.2% - 2.12%), 4-terpineol (0.14% - 0.41%), β-linalool (0.09%- 0.43%), β-pinene (0.07% - 0.39%), α-pinene (0.2% - 5.97%), linalool (0.1% - 0.14%), sabinene (0.2% -0.6%), ugenol isobutyrate (0.5% in root) (Table 2) (11,23).

When the chemical components of essential oil of *B. pilosa* from Japan were compared with that of Argentina, total main components of β-copaene (11.2%), germacrene D (39.5%), 1-phenylhept-5-ena-1,3-diyne (27.0%), α-humulene (3.3%) and 1-phenylhepta-1,3,5-triyne (78.9%) were not found in the essential oil of Japan. Contrarily, the main components from *B. pilosa* of Japan, β-Bourbonene (2.09%), megastigmatrienone (7.39%), and diphenylenemethane (3.71%) were not detected in the plant from Argentina. Many similar essential oils were found in the plant from both areas, however, the percentage composition of essential oils (%) of plant from Japan showed lower than the Argentinan plant. It is known that the phytotoxic components of *B. pilosa* increases in drought and PHT significant varies with geographic and seasonal factors (6,32). These results are consistent with reports of the variations in chemical components of *Mikania micrantha* (22,8). In nature, the production and release of secondary substances by plants are greatly influenced by the environment. It may be suggested that the plants defends themselves through release or increase in their secondary metabolites to adapt with the growing environment and geographical area.

5. CONCLUSIONS

The application of *B. pilosa* shoot biomass in bioassays, root exudates and field experiments, suppressed the weeds growth and significantly enhanced the rice yields. Many compounds (including polyacetylenens, phenolics, terpenens and volatile terpenes) have been identified and isolated. Of these PHT and its derivatives (caffeic acid and some volatile terpenes) were found in high concentrations in this plant and were involved in the allelopathic activity.

6. FUTURE LINES OF RESEARCH

Future research on this weed may be done on following aspects:

(i) Isolation, identification and characterization of phytotoxic substances in *B. pilosa* and in roots exudates at different growth stages and test their allelopathic effects on different weeds should be investigated.

(ii) Determine the mechanism and modes of action of polyacetylenes and its derivatives in the environment and their allelopathic actions during the decomposition of *B. pilosa* in soil.

(iii) Examine phytotoxic substances present in residues, litters and soil-infested with *B. pilosa*. Its materials should be mixed with other allelopathic plants in paddy field to obtain better weed control and higher rice yield. Screening of other *Bidens* ssp. and use them as cover crops, mulches need to be examined.

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