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ALLELOPATHIC EFFECTS OF *PARTHENIUM HYSTEROPHORUS* L.

III. INHIBITORY EFFECTS OF THE WEED RESIDUE

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KEY WORDS

Allelopathy Branching Inhibition Leaching Legumes Nodulation Parthenium Tillering Weed residues Yield

SUMMARY

Growth toxins are released to the soil through leaching and during decay from the air-dried parts of *Parthenium hysterophorus* L. The dry leaves mixed to the soil inhibit nodulation and growth in legumes, branching in tomato (*Lycopersicum esculentum* L. cv. 'Pusa Ruby'), plant height and tillering in ragi (*Eleusine coracana* Gaertn. cv. 'Poorna'), and yield in bean (*Phaseolus vulgaris* L. cv. 'Burpees Stringless'), cowpea (*Vigna sinensis* L.), tomato and ragi, but have stimulatory effect on bajra (*Pennisetum typhoideum* Rich cv. 'H.B.1'). The inhibitors released to the substratum remain active for about thirty days.

INTRODUCTION

A survey of the area infested by *Parthenium hysterophorus* L., an exotic weed which has spread throughout India like wild fire revealed that the weed formed pure stands and the bareground beneath the stand was studded with dry leaves and cypsella of the plant. While clearing the infested areas of the weed which included arable lands also, the usual practice was to cut only the aerial parts slightly above the ground level and heap or leave them as such for several days. The material dried up on the spot shedding further large amount of leaf and cypsella to the soil. In many arable situations the weed apart from being left on the cultivated fields was also ploughed back into the soil while preparing the land for cultivation. Earlier studies in our laboratory revealed the presence of water soluble inhibitory substances in the receptacles and cypsella of the weed[18]. Hence, in the present trial studies were undertaken to test if the inhibitors

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remained active in all the dry parts of the weed and if so, to test the effect of incorporation of different parts of the weed to soil on the growth of crops planted in such media.

MATERIALS AND METHODS

Extent of inhibition due to dry parts

Two g each of the dry root, stem, leaf, inflorescence and cypsella of Parthenium collected from the natural stand of the weed were surface sterilised with 0.1% mercuric chloride, thoroughly washed with distilled water and soaked in 32 ml of distilled water at 10°C for 72 h. The leachate obtained was filtered through Whatman No. 1 filter paper and the filtrate was tested on the growth of wheat (*Triticum aestivum* L. cv. 'UP 301') seedlings in 9 cm petridishes on blotters moistened with 2.5 ml of leachate from different parts under laboratory light conditions, in five replications. During the experimental period the mean maximum and minimum temperatures were 28 and 20°C respectively and mean relative humidity 56%. The length and dry weight of coleoptile and root and dry weight of grain remaining attached to the 72 h old seedlings were recorded. Osmotic potential (following Janardhan *et al.*[8]) and the electric conductivity (using Toshniwal conductivity bridge type CL01.02A) of the different leachates were determined.

Field trials on the effect of mixing Parthenium leaf and root material to the soil on crop growth

Bean (*Phaseolus vulgaris* L. cv. 'Burpees Stringless'), cowpea (*Vigna sinensis* L.) tomato (*Lycopersicum esculentum* L. cv. 'Pusa Ruby'), ragi (*Eleusine coracana* Gaertn. cv. 'Poorna') and bajra (*Pennisetum typhoideum* Rich. cv. 'H.B.1') were the crops tested in the field trials.

Initial two trials were conducted with 50 × 60 cm plots replicated five times following randomised block design. Based on the leaf shed under natural conditions (333 kg/ha) 100 g of air-dried leaves were mixed to each plot. Confirmatory trials for all the crops were run with 1.5 × 3 m plots with four rows of test plants in each.

The soil was sandy loam with a moisture holding capacity of 32%, pH ranging from 8.0–8.5, and mean carbon content of 0.67%, phosphorus and potash content 25 and 195 kg/ha, respectively. Application of compost manure and fertilisers was made according to the recommendation made by the Directorate of Agriculture, Karnataka. The number of trials, the period of experimentation and weather conditions that prevailed during the period are given in Table 1.

Effect of incorporation of Parthenium roots into the soil was tested only in the case of bean. Based on the density of root material of the weed in nature, 65 g of root was added to 50 × 60 cm plots.

a. *Trials on bean and cow pea*

In trials with bean, 12 seeds were sown in each plot so as to maintain 6 plants per plot at an inter plant distance of 20 cm and inter row distance of 25 cm. With cow pea eight seeds were sown in each plot to maintain four plants at an inter plant distance of 30 cm and inter row distance of 40 cm. Two split doses of NPK at the rate of 25, 40 and 30 kg/ha were applied. The plots were irrigated immediately after fertilization and once in two days there after, maintaining soil moisture level at 45%. The success of germination was noted and performance of 20 day old seedlings of bean and 40 day old seedlings of cow pea were studied for nodule number, their fresh and dry weight and the dry weight of shoot and root. In the subsequent two sets of trials with bean and cow pea conducted as above, the

Table 1. Weather conditions that prevailed during the field trials on the influence of leaf and root material of *Parthenium hysterophorus* L. on the growth of different crops

Crops tested	Trial number	Number of days	Mean temperature		Mean relative humidity (%)	Total rainfall during the period (cm)
			Minimum	Maximum		
I set						
Bean and cowpea	I	25	21	30	60	18
	II	40	18	28	65	23
II set						
Bean	I	65	20	29	55	15
	II	68	18	28	65	27
Cowpea	I	126	18	27	65	30
	II	131	18	27	65	30
Tomato	I	119	16	28	60	10
	II	135	18	32	65	18
	III	126	18	33	55	40
Bajra and ragi	I	125	18	29	65	10
	II	123	18	33	55	23
	III	136	18	27	65	30

plants were studied for flowering and yield. pH of the leaf mixed soil was determined 7 and 15 days after mixing the leaf material, using Toshniwal pH meter following Piper[17].

b. *Growth of bean seedlings at different pH values*

Bean seedlings were raised in pots containing garden soil whose initial pH was adjusted to 8.3 using alkaline tap water. The control pH was initially adjusted to 7. The mean maximum and minimum temperature during the experimental period were 28 and 20°C and the mean relative humidity 50%.

c. *Trials with tomato*

25 day old seedlings of tomato raised in nursery bed were transplantes to plots maintaining four plants in each. Compost manure at the rate of 15 cart loads/ha were added at the time of transplantation and NPK at the rate of 50 kg/ha each, a week hence. The number of branches produced, time taken for flowering and the final yield were recorded.

d. *Trials with ragi and bajra*

30 day old seedlings of ragi and bajra raised separately in nursery bed were transplanted to plots maintaining nine plants in each. Compost manure at the rate of 15 cart loads/ha was added and a week hence. NPK was added at the rate of 125, 75 and 37 kg/ha respectively in three split doses. The number of tillers produced and total grain yield in test species were determined.

Life of the inhibitors

The duration for which the inhibitors are retained in the leaf material when mixed to the soil and also the life of the inhibitors leached to the substratum were determined as follows:

Ten g of Parthenium leaf material was mixed to 500 g of garden soil in polythene bags of 15 cm diameter and 20 cm depth kept exposed to natural conditions. The moisture content was maintained throughout at 32%. During the experimental period the mean maximum and minimum temperature were 28 and 18°C and mean relative humidity 60%. There was no rainfall during the experiment. On the 7, 15 and 30th day, the leaf material was seperated from the soil and the soil as well as the leaf litter were leached in distilled water for 72 h at 10°C at the ratio 1 : 5 and 1 : 16 w/v respectively and the leachates were tested on the growth of wheat seedlings as mentioned under the first experiment.

Table 2. Effect of aqueous leachate of different parts of *Parthenium hysterophorus* L. on 72 h growth of wheat (*Triticum aestivum* var. 'UP 301') seedlings

	Coleoptile			Root system			
	Length (cm)	Fresh weight (mg)	Dry weight (mg)	Seminal root length (cm)	Fresh weight (mg)	Dry weight (mg)	Grain dry weight (mg)
Distilled water (Control)	3.2 (0.3)	10.3 (0.3)	3.6 (0.5)	6.0 (0.5)	12.5 (1.5)	4.4 (0.5)	57 (4.0)
Root	2.2^{++} (0.3)	7.5^{++} (0.8)	2.36^{++} (0.3)	3.6^{++} (0.5)	10.5^{++} (2.5)	3.2^{++} (0.6)	68^{++} (3.0)
Stem	2.5^{++} (0.2)	6.7^{++} (0.8)	2.7^{++} (0.4)	2.5^{+} (0.6)	7.5^{++} (0.5)	2.4^{+} (0.8)	78^{++} (3.0)
Leaf							
Aseptic condition	0.6^{+} (0.02)	2.4^{+} (0.5)	0.78^{+} (0.5)	1.2^{+} (0.05)	4.3^{+} (0.5)	1.4^{+} (0.05)	82^{++} (4.0)
Non-sterile medium	0.6^{+} (0.02)	2.5^{+} (0.5)	0.76^{+} (0.5)	1.0^{+} (0.03)	4.5^{+} (0.5)	1.4^{+} (0.04)	83^{++} (4.0)
Inflorescence	1.0^{+} (0.03)	2.8^{+} (0.5)	0.8^{+} (0.05)	1.3^{+} (0.03)	3.5^{+} (0.5)	1.12^{+} (0.05)	82^{++} (4.0)
Seed	2.3 (0.03)	3.5 (0.05)	1.04 (0.05)	4.1 (0.3)	6.2 (0.3)	1.8 (0.05)	60 (2.5)

Figures in parentheses refer to standard error.

$^{+}$, $^{++}$ Significantly different from the control respectively at 0.01, 0.05 level or better.

RESULTS

Results of the forgoing experiments reveal that even dried parts of Parthenium retain the inhibitors. Leaves and inflorescence contain the highest amounts of inhibitors followed by seed, stem and root (Table 2). Osmotic potential of the leaf and root leachate were -6.2 and -3.1 bar and electrical conductivity 0.16×10^{-2} and 0.31×10^{-3} mhos respectively. Field trials with leaf and root mixed soil revealed that leaf material caused greater inhibition than the root material in trials on bean (Table 3). In leaf mixed soil emergence was inhibited significantly in bean and cow pea. With other crops as the seedlings were transplanted to the plots, germination could not be studied. The nodulation, shoot and root dry weight of 20 day old bean and 40 day old cow pea plants were inhibited significantly. (Table 3). Addition of leaf material to the soil changed the pH from 7.5 to 8.3. But the performance of test bean plants grown in soil with the pH adjusted to 8.3 did not show any significant difference from that grown at pH 7 (Table 4). Branching in tomato, height and tillering in ragi were reduced

Table 3. Emergence, nodulation and root and shoot growth in bean (*Phaseolus vulgaris* L. var. 'Burpees Stringless') and cowpea (*Vigna sinensis* L. garden variety) in plots mixed with air-dried leaf/root material of *Parthenium hysterophorus* L.

Test species and growth medium	Seed germination per plot	Nodule number	Nodule fresh weight (mg)	Nodule dry weight (mg)	Root dry weight (mg)	Shoot dry weight
Bean						
Control	10	32	880	29	440	12
	(1.0)	(9.0)	(22)	(5.5)	(0.05)	(2.0)
Leaf-mixed soil	6*	9*	210*	8*	360	8*
	(1.5)	(1.5)	(19)	(0.5)	(0.08)	(2.2)
Root mixed soil	8**	19*	310*	11*	400**	9**
	(1.5)	(2.0)	(20)	(0.5)	(0.02)	(2.5)
Cowpea						
Control	10	23	620	19	150	15
	(1.5)	(6.0)	(23)	(3.0)	(0.5)	(0.6)
Leaf-mixed soil	5*	8	180*	7*	109**	12**
	(0.5)	(3.0)	(19)	(2.0)	(0.5)	(1.2)

Figures in parentheses refer to standard error.
*, ** Significantly different from the control respectively at 0.01, 0.05 level or better.
Post emergence growth parameters were studied with 20 day-old plants of bean and 40 day-old plants of cowpea.

Table 4. Nodulation root and shoot growth in 20 day-old bean (*Phaseolus vulgaris* L. var. 'Burpees Stringless') grown in soil adjusted to two different pH values

pH of the growth medium	Nodule number	Nodule fresh weight (mg)	Nodule dry weight (mg)	Root dry weight (g)	Shoot dry weight (g)
7.0*	20	300	10.0	0.35	8.6
	(3.2)	(25)	(2)	(0.06)	(0.85)
8.3**	18	295	10.5	0.33	9.0
	(4.2)	(20)	(2.1)	(0.04)	(0.92)

* and ** pH values respectively of the control soil and that mixed with leaf material of *Parthenium hysterophorus* L.
Figures in parentheses refer to standard error.
Differences in growth parameters at the two pH values not significant.

Table 5. Yield of bean (*Phaseolus vulgaris* L. var. 'Burpees Stringless') and cowpea (*Vigna sinensis* garden variety) grown in soil mixed with leaf and root material of *Parthenium hysterophorus* L.

Test species and treatment	Yield per plot (g)			
	I	II	III	Average of I, II, III
Bean				
Control	200	386	226	269
	(35)	(25)	(25)	(76.3)
Leaf mixed soil	163+	200+	200+	186+
	(18)	(23)	(17)	(17)
Control	200	304	302	275
	(620)	(18)	(19)	(37)
Root mixed soil	200+	286+	286+	264+
	(22)	(34)	(35)	(36.6)
Cowpea				
Control	204	284	212	233
	(25)	(32)	(25)	(33)
Leaf mixed soil	190+	209+	180+	193+
	(18)	(20)	(30)	(10.6)

I, II, III are trial numbers.
Figures in parentheses refer to standard error.
+ Significantly different from the control at 0.05 level or better.

Table 6. Branching and yield in tomato (*Lycopersicum esculentum* Mill. var. 'Pusa Ruby') grown in plots mixed with leaf material of *Parthenium hysterophorus* L.

	Trials			
	I	II	III	Average of I, II, III
Number of branches per plant				
Control	7 (0.5)	6.5 (0.5)	6.8 (0.8)	6 (0.66)
Treatment	3.5$^+$ (0.5)	4.0$^+$ (0.03)	5.0$^+$ (0.3)	4$^+$ (0.5)
Yield (g) per plot				
Control	300 (15)	750 (35)	306 (25.0)	452 (199)
Treatment	139$^+$ (11.5)	369$^+$ (25)	274$^+$ (20.5)	277$^+$ (61)

Figures in parentheses refer to standard error.
$^+$ Significantly different from the control at 0.01 level or better.

considerably (Tables 6 and 7). There was no delay in flowering in any of the species tested. But the yield was reduced to varying degrees (Tables 5, 6 and 7). In bajra there was increase in plant height, tiller production and yield. Data in Table 8 show that up to 15 days from time of storing leaves in soil, their inhibitor content gradually reduced and that of soil increased. However, by 30 days both the litter and soil medium had lost their inhibitors.

DISCUSSION

Data of the experiments presented above reveal that the inhibitors which remain active in the dry parts of the weed are either rain-leached or released during their decomposition in soil. In Parthenium infested area large amount of dry leaf material, inflorescence and seed are shed to the ground. After harvesting the crop, the land is usually left fallow till the next growing season. During this interval, Pathenium plants grow in abundance and when these dry up, their stems get broken and lie scattered on the ground. Usually the land is tilled after one or two showers. By this time, the showers would have leached large quantity of inhibitors from the dry aerial parts of the weed and this would obviously hinder the normal growth of crops.

Table 7. Height tiller production and yield of ragi (*Eleusine coracana* (L.) Gaertn var. 'Poorna') and bajra (*Pennisetum typhoideum* Rich. var. 'H.B. I' grown in soil mixed with leaf material of *Parthenium hysterophorus* L.)

Test crop	Trial number	Height (cm)		Number of tillers/plant		Yield/plot (g)	
		c	t	c	t	c	t
Ragi	I	48 (5.2)	45 (4.6)	16 (2.6)	9 (1.2)	61 (3.5)	56 (5.2)
	II	58 (5.0)	53+ (6.0)	16 (2.5)	12+ (2.0)	73 (6.2)	38+ (4.4)
	III	38 (4.8)	36 (3.6)	14 (2.2)	9+ (7.5)	62 (5.2)	32+ (4.2)
	Mean	48 (6.6)	44+ (6.0)	15 (0.8)	10+ (1.1)	65 (5.1)	38+ (11.7)
Bajra	I	60 (5.5)	53+ (6.0)	8 (3.5)	11+ (2.5)	40 (4.5)	50+ (4.5)
	II	45 (3.5)	53+ (4.3)	17 (3.5)	14+ (3.5)	40 (3.5)	49+ (4.4)
	III	40 (4.5)	45 (4.0)	90 (2.5)	12+ (2.0)	40 (4.0)	48+ (3.9)
	Mean	50 (8.3)	52 (2.8)	11 (3.3)	12 (1.0)	40 (0.2)	49 (0.5)

Figures in parentheses refers to standard error.
+ Significantly different from the control at 0.01 level or better.

Inhibitory effects of decomposing weed material in soil on the growth of weeds[1,3,9,19,20,21,22], crop residue on growth of other crops [4,5,6,7,10,11,13,14,15,16] are extensively evidenced in literature. Air dried leaf or root of Parthenium mixed to soil reduced nodulation, plant growth and yield in bean and cow pea significantly. Though this effect could be suspected to be due to change in soil pH brought about by the treatment, that this has not been the case is clearly borne out by the data presented in Table 4. Rice[20] reported the inhibition of nodulation in inoculated legumes caused by plant residues of *Ambrosia psilostachya*, *Euphorbia supina* and *Helianthus annuus*. Inhibition in yield of legumes of the present study can be related to the inhibition of nodulation. Thus, observed invasion of many leguminous crops by Parthenium might

Table 8. Growth of 72 h-old wheat (*Triticum aestivum* var. 'UP 301') seedlings as influenced by air-dried leaf material of *Parthenium hysterophorus* L. left in soil for different durations

Growth medium	day 0				7 days				15 days				30 days			
	Total length of root system (cm)	Per cent of control	Length of coleoptile (cm)	Per cent of control	Total length of root system (cm)	Per cent of control	Length of coleoptile (cm)	Per cent of control	Total length of root system (cm)	Per cent of control	Length of coleoptile (cm)	Per cent of control	Total length of root system (cm)	Per cent of control	Length of coleoptile (cm)	Per cent of control
Distilled water (control)	20 (2.0)	–	4.1 (0.3)	–	20.0 (2.0)	–	4.1 (0.3)	–	20 (2.0)	–	4.1 (0.3)	–	20 (2.0)	–	4.1 (0.3)	–
Leachate of leaf litter of different age	4.3^{+} (0.5)	21.5	0.3^{+} (0.02)	7.3	14.4^{++} (0.8)	72.0	3.0^{++} (0.5)	73.2	18.0^{++} (2.0)	90.0	3.2^{++} (0.5)	78.1	18.5^{++} (2.0)	92.5	4.0 (0.5)	97.6
Control soil not mixed with leaf)	16.5 (2.0)	–	4.2 (1.2)	–	16.5 (2.0)	–	4.2 (1.2)	–	16.5 (2.0)	–	4.2 (1.2)	–	16.5 (2.0)	–	4.2 (1.2)	–
Soil after being in contact with leaf material for different durations	–	–	–	–	10.2^{+} (0.8)	61.8	2.5^{+} (0.8)	59.5	12.0^{++} (2.0)	72.7	2.8^{++} (0.5)	66.7	16.0 (0.5)	97.0	4.0 (0.2)	95.2

Figures in parentheses refer to standard error.

$^{+}$, $^{++}$ Significantly different from the control respectively at 0.01 and 0.05 level or better.

affect the yield of these drastically and hence have serious impact on agriculture. Inhibition of emergence in case of bean and cow pea, the reduction in the plant height, branching and yield of tomato and decreased tillering and yield in ragi in Parthenium leaf mixed soil under field conditions, speak of the adverse effects of ploughing back the weed material into the soil. Bell and Koeppe[2] suggested that in view of the allelopathic effects, incorporation of weed material into the soil may constitute a poor agronomic practice.

The promotory effect of Parthenium residue on growth and yield of bajra is interesting enough to deserve further investigation. This type of differential response was also noted with *Ambrosia psilostachya* which inhibited growth of *Andropogon ternarius* but stimulated *Aristida oligantha*, *Bromus japonicus*, *Haplopapus ciliatus* and *Rudbeckia hirta*[12].

Parthenium leaves mixed to the soil lose their inhibitors almost completely by about 30 days though the soil in contact with the leaves showed evidence for the occurrence of inhibitors in sufficiently high quantity when tested after a fortnight of the treatment. Microorganisms might have broken down the inhibitors in the soil as well as in the litter by about 30 days and hence the lack of significant inhibition. However, it has been reported that during the decomposition of plant residue in soil more toxic substance may be produced[5,6], toxicity depending upon the conditions maintained in the soil[14]. Heavy soils characterised by poor aeration, excessive moisture and relatively low temperature produced more toxic substances. Patrick and Koch[14] also found that the soil flooded for 3–5 days with plant residue proved highly toxic. It is possible that under the conditions described by these workers, the inhibitory effect of Parthenium residue might become more severe. Notwithstanding the observation that the inhibitors released from Parthenium residue to the soil become ineffective by about 30 days, different test species grown in Parthenium leaf mixed soil showed significant reduction in yield. This may be explained as either a carry over effect of growth inhibition caused in the early stages or as due to probable changes in the composition of micro flora induced in the substratum by the toxins which must have cast their effect on the plant at a later stage.

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