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ALLELOPATHIC EFFECTS OF *PANICUM ANTIDOTALE* RETZ.

Ismat Begum and Farrukh Hussain*

Department of Botany, University of Peshawar, Peshawar.

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Panicum antidotale Retz, besides reducing its own growth, retarded the growth of *Pennisetum americanum* in mixed root cultures. Cold water extracts from inflorescences, shoots and roots; root exudates and soil underneath it not only inhibited its own germination and growth but also that of *Brassica campestris, Cenchrus ciliaris, Lolium multiflorum, Pennisetum americanum, Setaria italica* and *Sorghum almum* in laboratory bioassays. Shoot extract in addition to causing deaths of *Pennisetum americanum* and *Setaria italica,* reduced fresh and dry biomass of the seedlings. Toxicity depended upon the part assayed, test species used and physiological process involved. The grass would not exhibit its benefits as range grass either in mono-or in mixed cultures with the above-mentioned grasses due to allelopathy.

INTRODUCTION

Panicum antidotale Retz is adapted to tropical and subtropical climates with summer rainfall, including Pakistan [21,23]. Many grasses exhibit allelopathy either against themselves or other species [1–5,22]. Naqvi and Muller [19] observed allelopathic effects of *Lolium. Cenchrus* and *Chrysopogon* [2] and *Dichanthium* [7] inhibited germination and growth of test species. *Sorghum vulgare* [8] and *Sorghum almum* [20] reduced germination and growth of susceptible species by phytotoxins. *Imperata cylindrica,* exhibiting phytotoxicity, caused problems in the revegetation of Philippine forest [14].

Khanum [12] and Khanum *et al.* [13] reported phytotoxic effects of *Panicum antidotale* against *Pennisetum* and *Chloris.* However, many points regarding allelopathic mechanisms remain unsolved, therefore, the present investigation was conducted to find allelopathic effects of *Panicum antidotale* against other range grasses.

EXPERIMENTAL PROCEDURE AND RESULTS

Pot Interference Experiment. The interference ability of *Panicum* was tested against *Pennisetum americanum* and its own seedlings following a pot experiment of Dirvi and Hussain [7] Equal sized pots were filled with similar litter-free loamy soil. The roots of the two species were separated by polyethylene sheets, which served as the control; or allowed to mix freely within the pots. Seeds of the interacting species were sown in the first week of July, 1978, and thinning was done on July 23, 1978. Each combination in each treatment had 5 plants of one species in each half of the pot, with 5 replicates. Nutrient deficiency was avoided by providing equal volumes of Hoagland's solution fortnightly. Distilled water was provided to avoid moisture competition. All pots were subjected to uniform environmental conditions and weeded by hand. The experiment was started on July 23, 1978, and terminated after 3 months. Height, fresh and dry weight of each species in each treatment were separately determined.

Height, fresh and dry weight of *Pennisetum americanum* were significantly reduced in mixed root conditions while those of *Panicum* were slightly affected in *Panicum/Pennisetm* combination. *Panicum* retarded its own growth in mixed root condition, suggesting possible self-inhibition (Table 1).

Allelopathic Studies. Four months old *Panicum antidotale* plants were separated into inflorescences, shoots and roots and dried at room temerature (25–30°) in shade. Petri dishes and other glass ware were sterilized at 170° for 4 hr [15]. Powdered grass material (5 g) was soaked in 100 ml double-distilled water for 24 hr and then filtered. The extracts were stored at 5–10° when not used, however they were utilized within a week.

Test species were sown on twice folded Whatman filter paper No. 1 seed beds. Tests were made by soaking the seed beds with extract while control was provided with double distilled water. Petri dishes were sealed with 'parafilm M' to avoid moisutre loss. Germination and radicle growth of 5 replicates, each with 10 seeds, were recorded after 48-hr incubation at 26° unless otherwise stated. This method is referred to as standard filter paper bioassay. Results were

*Now at the Department of Botany, University of Baluchistan, Quetta.

Table 1. Height (cm), fresh and dry weight (g) of the above ground parts of the interacting species in pot experiment.

Observations	Species	Sowing condition	Interfering species	
			Pennisetum americanum	*Panicum antidotale*
Height (cm)	Test species	Root separated (control) ±SD	28.70 5.20	32.30 5.23
		Root mixed ±SD	17.00 4.95	22.10 5.16
		Control (%)	59.23*	68.42*
	Panicum antidotale	Root separated (Control) ±SD	39.90 6.17	30.20 4.92
		Root mixed ±SD	34.30 5.69	21.60 5.77
		Control (%)	85.96	71.52*
Fresh weight (g)	Test species	Root separated ±SD	1.96 0.05	3.25 0.12
		Root mixed ±SD	0.47 0.02	1.13 0.08
		Control (%)	23.97*	34.76*
	Panicum antidotale	Root separated (Control)±SD	3.43 0.06	2.17 0.08
		Root mixed ±SD	2.90 0.05	1.03 0.04
		Control (%)	84.54*	47.46*
Dry weight (g)	Test species	Root separated (Control) ±SD	1.13 0.02	1.40 0.04
		Root mixed ±SD	0.27 0.01	0.53 0.02
		Control (%)	23.89*	37.85*
	Panicum antidotale	Root separated (Control)±SD	1.56 0.03	0.72 0.04
		Root mixed bSD	1.32 0.06	0.40 0.02
		Control	84.61	55.55*

Each value is a mean of 5 replicates, each with 5 plants in each half of the pot. Root separated condition served as the control.
*Significant at P = 0.05

statistically analysed using 'Z' and 't' tests [6].

Aqueous Extract Bioassy. Aqueous shoot extract of *Panicum antidotale* was tested against *Brassica campestris, Cenchrus ciliaris, Lolium multiflorum, Panicum antidotale, Pennisetum americanum, Setaria italica* and *Sorghum almum* using standard filter paper bioassay.

The extract significantly inhibited germination and growth of all the test species. The inhibition varied among the species with an independent affect on germination and radicle growth (Table 2).

Relative Toxicity of Panicum *Parts.* Extracts obtained from inflorescences, shoots (stems and leaves) and roots were tested against the seeds of the afore-mentioned test species in standard filter paper bioassay.

Germination and radicle growth of all the test species were significantly inhibited by the various extracts except germination of *Setaria* in inflorescence and root extracts. The extracts from above ground parts were more inhibitory

Table 2. Effect of aqueous shoot extract of *Panicum antidotale* on germination and radicle growth of test species.

Test species	Control	Test	Control (%)
	Germination (%)		
Brassica campestris	76.00	4.00	5.26*
Cenchrus ciliaris	66.00	3.00	4.54*
Lolium multiflorum	68.00	6.00	8.82*
Panicum antidotale	30.00	6.00	20.00*
Pennisetum americanum	40.00	30.00	75.00*
Setaria italica	94.00	60.00	63.82*
Sorghum almum	28.00	18.00	64.00*
	Radicle growth ±SD (mm)		
Brassica campestris	9.10±1.40	0.38±0.10	4.17†
Cenchrus ciliaris	6.12±1.90	3.06±1.81	50.00*
Lolium multiflorum	4.60±1.94	0.10±0.01	2.10†
Panicum antidotale	1.26±0.10	0.22±0.02	17.46†
Pennisetum americanum	13.44±0.90	1.52±0.65	11.30†
Setaria italica	8.00±2.13	2.16±0.63	27.00†
Sorghum almum	1.54±0.62	0.98±0.08	63.63*

Each value is a mean of 5 replicates, each with 10 seeds.
*Significant at P = 0.05 †Significant at P = 0.01

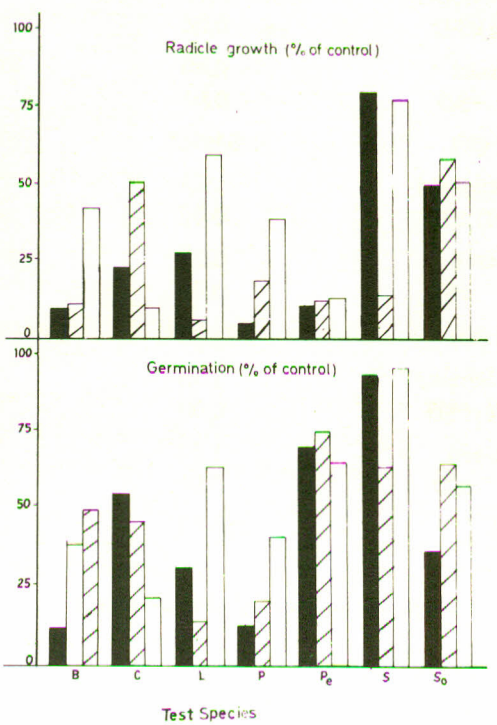

Fig. 1. Germination and radicle growth of test species in aqueous extracts of inflorescences (solid), shoots (hatched) and roots (blank) of *Panicum antidotale*. Values are mean of 5 replicates, each with 10 seeds, expressed as % of their control. All values are significantly different from control at P = 0.05 except with asterisk. (*) B=*Brassica campestris;* C=*Cenchrus ciliaris;* L=*Lolium multiflorum;*P=*Panicum antidotale;* Pe=*Pennisetum americanum* S=*Setaria italica;* So=*Sorghum almum).*

than those from roots (Fig. 1). The effect on germination was less than on the radicle growth. The toxicity of the extracts depended upon the part assayed and species used.

Aqueous Culture Bioassay. Test and control solutions were prepared by mixing equal volumes of shoot extract and distilled water respectively with Hoagland's solution. Roots of 15-day-old uniform vigorous seedlings of *Pennisetum americanum* and *Setaria italica* were thoroughly washed first with tap water followed by distilled water and then transferred singly to 8×1.6 cm sterilized glass vials, each containing 20 ml of either test or control solution.

The vials, plugged with cotton, were wrapped with brown paper to reduce light supply. Ten replicates of each test species were kept under 16 hr photo period and survival recorded for up to 5 days. Fresh and dry weight of seedlings, including the dead ones, were determined at the end.

Survival of *Pennisetum* and *Setaria* was 10 and 75% respectively of the controls on the 3rd day of the treatment (Table 3). Fresh and dry weights of both the test species were significantly reduced by extract (Table 4). Low survival and reduced biomass in the presence of nutrients could be due to water-soluble phytotoxins present in the *Panicum* straw.

Sand Culture Experiment. Equal volumes of washed and sterilized river sand were taken in 8×6 cm pots. Ten seeds of either *Pennisetum americanum* or *Setaria italica* were separately sown in each pot. Test and control solu-

Table 3. Effect of aqueous shoot extract on the survival of 15-day old seedlings of *Pennisetum americanum* and *Setaria italica* in culture solution. Each value is a mean of 10 replicates, each with one seedling.

Test species	Treatments	Observation (day)				
		1	2	3	4	5
Pennisetum americanum	Control	100	100	100	100	100
	Test	80	20	10	10	–
	Control (%)	80	20†	10†	10†	–†
Setaria italica	Control	80	80	80	80	80
	Test	80	70	60	60	50
	Control (%)	100	87.5	75*	75*	62.5*

*Significant at P = 0.05
†Significant at P = 0.01

Table 4. Effect of aqueous shoot extract of *Panicum antidotale* on fresh and dry weight (g) of 15-day old seedlings of *Pennisetum americanum* and *Setaria italica* in culture solution.

Test species	Observation	Control	Test	Control (%)
Pennisetum americanum	Fresh weight	350.87	293.53	83.65*
	±SD	15.45	16.04	
	Dry weight	105.88	87.70	82.82*
	±SD	10.15	9.73	
Setaria italica	Fresh weight	587.19	476.16	81.31*
	±SD	18.44	12.69	
	Dry weight	109.29	91.05	83.31*
	±SD	8.99	10.12	

Each value is a mean of 10 replicates, each with one seedlings including the dead ones after 5 days.
*Significant at P = 0.05

tions, obtained as in the preceding experiment, were used for watering the pots. Germination was recorded after 4 days incubation at 26° and seedlings thinned to 4 per pot. Pots were then transferred to 16 hr photo period at room temperature (25–30°). Fresh and dry weights and moisture contents of the tops of 10 replicates were determined after 3 weeks.

Germination of *Setaria* and fresh and dry biomass and moisture contents of both the test species were significantly inhibited by shoot extract (Table 5), suggesting phytotoxicity of *Panicum* in nutrient rich medium.

Root Exudate Bioassay. Root exudates, collected after Haq and Hussain [11], were tested against *Brassica campestris, Cenchrus ciliaris, Lolium multiflorum, Panicum antidotale, Pennisetum americanum, Setaria italica* and *Sorghum almum* by filter paper bioassay.

Exudates from *Panicum* roots were significantly inhibitory to germination and radicle growth of all the test species, except germination of *Cenchrus,* suggesting its phytotoxicity (Table 6).

Soil Residual Toxicity. Soil from with or without *Panicum,* collected up to 9-cm depth, was used in soil extract and soil-bed bioassays against the aforementioned test species following Hussain *et al.* [10].

Soil extract inhibited germination and radicle growth of all the test species, except germination of *Lolium* and *Pennisetum* (Table 7). All the species except *Pennisetum* exhibited significantly arrested germination and growth on grass soil beds (Table 8).

DISCUSSION

Allelopathy, associated with competition, is an important ecological factor in vegetational composition [16,17]. The reduced growth of test species in interference experiments could not be due simply to competition alone; some

Table 5. Germination (%), fresh and dry weights (mg) and moisture contents (%) of the test species in sand culture experiment.

Test species	Observations	Control	Test	Control (%)
Pennisetum americanum	Germination (%)	87.00	84.00	96.55
	Fresh weight ±SD (mg)	103.29±10.34	23.34± 5.68	22.59*
	Dry weight ±SD (mg)	12.11± 2.12	10.58± 2.43	87.36*
	Moisture contents ±SD (%)	752.93±43.76	120.60±32.60	16.01*
Setaria italica	Germination (%)	82.00	73.00	89.02*
	Fresh weight ±SD (mg)	30.00± 5.65	7.61± 2.82	24.55†
	Dry weight ±SD (mg)	4.56± 1.02	4.94± 1.21	108.33
	Moisture contents ±SD	528.60±29.81	54.93±11.17	10.39†

Germination is mean of 10 replicates, each with 10 seeds while other values are mean of 10 replicates, each with 4 seedlings.
*Significant at P = 0.05
†Significant at P = 0.01

Table 6. Effect of root exudates of *Panicum antidotale* on the germination (%) and radicle growth of test species.

	Germination (%)			Radicle growth (mm)				
	Control	Test	Control (%)	Control	±SD	Test	±SD	Control (%)
Brassica campestris	80.00	73.33	91.66	4.20	0.70	2.26	0.90	53.80*
Cenchrus ciliaris	23.33	10.00	42.86†	1.20	0.40	0.40	0.03	33.33†
Lolium multiflorum	80.00	53.33	66.66*	3.20	0.17	1.60	0.10	50.00*
Pennisetum americanum	93.33	76.66	82.13*	10.96	1.60	7.56	6.90	68.97*
Setaria italica	96.66	83.33	86.20*	22.56	3.00	15.56	6.90	68.97*
Sorghum almum	80.00	23.33	29.16†	4.10	1.00	0.93	0.06	22.68†

Each value is the mean of 3 replicates, each with 10 seeds.
*Significant at P = 0.05
†Significant at P = 0.01

Table 7. Effect of *Panicum antidotale* soil extract on germination (%) and radicle growth (mm) of test species.

Test species	Germination (%)			Radicle growth (mm)				
	Control	Test	Control (%)	Control	±SD	Test	±SD	Control (%)
Brassica campestris	54.00	30.00	55.55†	2.36	0.52	1.10	0.65	46.61†
Cenchrus ciliaris	24.00	4.00	16.60†	1.64	0.01	0.08	0.01	4.87†
Lolium multiflorum	78.00	78.00	100.00	15.24	4.00	11.92	2.30	78.21*
Panicum antidotale	30.00	14.00	46.66†	1.26	0.10	0.50	0.04	39.68†
Pennisetum americanum	100.00	90.00	90.00	12.52	2.40	7.90	2.70	63.09*
Setaria italica	88.00	2.00	2.27†	18.06	1.94	0.04	0.01	00.22†
Sorghum almum	30.00	16.00	53.33*	1.28	0.90	0.76	0.63	59.37*

Each value is a mean of 5 replicates, each with 10 seeds.
*Significant at P = 0.05
†Significant at P = 0.01

Table 8. Germination (%) and radicle growth (mm) of test species in soil bed bioassay.

Test species	Germination (%)			Radicle growth (mm)				
	Control	Test	Control (%)	Control	±SD	Test	±SD	Control (%)
Brassica campestris	88.33	40.00	48.00†	3.80	0.70	1.30	0.60	34.21†
Cenchrus ciliaris	40.00	23.33	58.32	2.63	1.40	1.10	0.50	41.82†
Lolium multiflorum	83.33	20.00	24.00†	10.30	2.40	1.40	0.05	13.59†
Panicum antidotale	53.33	23.33	43.74†	1.36	0.70	0.96	0.02	70.58*
Pennisetum americanum	90.00	90.00	100.00	12.90	3.30	11.30	1.20	87.59
Setaria italica	96.66	83.33	86.20*	18.56	2.50	11.00	1.60	59.26†
Sorghum almum	10.00	3.33	33.33†	0.40	0.50	0.06	0.01	15.00†

Each value is the mean of 3 replicates, each with 10 seeds.
*Significant at P = 0.05
†Significant at P = 0.01

biochemical inhibition mechanism was either partly or wholly involved through roots. *Lolium* [18,19], *Cenchrus* [2], *Dichanthium* [7], tobacco [9] and *Datura* [10] inhibited growth of associated species in mixed root conditions. The results agree with Khanum [12] and Khanum *et al.* [13] who observed retarded growth of *Pennisetum* in mixed root cultures with *Panicum.*

Aqueous extracts from various parts invariably inhibited germination and growth of test species. *Chloris* and *Pennisetum* exhibited retarded germination and growth with *Panicum* shoot extracts [12,13] confirming our results. As with other species [7,9,10,19], the toxicity of *Panicum* depended upon the part assayed and test species used. The inhibitory effects of *Panicum* soil were due to the presence, accumulation and effectivity of toxins against the species. Similarly soil from tobacco; *Datura* [9,10] and *Dichanthium* [7] were phytotoxic. The addition of aqueous extracts to sterilized soil reduced growth of the test species. Toxic root exudates, as oberved in bioassay, were also a source of soil toxicity. The results agree with others in this respect [7,11,19]. In nature the phytotoxins are released during the active growth of *Panicum* as leachates, root exudates, or rain wash and/or during the decay of the litter. These toxins induce soil phytotoxicity on their deposition in soil. The present study revealed that *Panicum antidotale* would not exhibit its benefits as a range grass either in pure or mixed cultures with the other range grasses, owing to allelopathy. Further studies are in progress to identify the toxic principle.

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