Allelopathic Effect of Sorghum Extract and Residues on Selected Crops and Weeds

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수수의 他感作用에 關한 研究

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ABSTRACT

To better understand the allelopathic effect of sorghum(*Sorghum vulgare* L.), the inhibitory activities of water extracts of the stem, leaf and root, and of residues of the stem to major crops and weeds associated with them were evaluated.

The allelopathic activity of sorghum plants was species specific, and depended on source and concentration. Germination, and shoot and root length of all test species were inhibited by the different concentrations of the stem extract. Among the crop species, radish showed the most inhibition, followed by wheat and rice. Maize was the least sensitive species. Of the weed species, *Ipomoea triloba* was most inhibited, followed by *Echinochloa colona* and *Rottboellia cochinchinensis*.

The water extracts of leaves, stems, and roots significantly inhibited germination and seedling growth in *E. colona* and radish. The stem extract gave the greatest inhibitory effect on *E. colona* while all three extracts produced similar response in radish.

In the greenhouse trial, sorghum stem residue placed on the soil surface as mulch significantly inhibited seedling growth in *E. colona* and radish, but not that in rice.

Key words : allelopathy, sorghum

INTRODUCTION

There is no doubt as to the role the chemical method plays in effectively controlling weeds. In judging the efficacy of a method, however, it is important to consider toxicity to non-target organisms and environmental effects.

Recently, the importance of allelopathy in agrcultural practice was recognized, and use of the phenomenon for biological control is accelerating.

Many scientists have reviewed the research on allelopathy and its implication in agriculture,

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especially as it relates to weed control[13,20,21,22]. It is believed that allelopathy can be a potential strategy in weed control.

In bioassay, several crops show promise in inhibiting the growth of certain weed species. The allelopathic potential of sorghum is well documented by Guenzi and McCalia[10], Lehle and Putnam[15], Alsaadawi et al.[1], and Panasiuk et al.[18]. The results show that sorghum reduced weed growth considerably. Aqueous extracts of root, stem, and seed of sorghum inhibited germination of test plants[11]. Einhelling and Rasmussen[7] also reported planting sorghum as cover crop was phytotoxic to seedling growth of weeds in a variety of cropping system. In spite of this, there is little information on the allelophatic effect of sorghum on major crops and weeds associated with them. This experiment was carried out to determine inhibition of the growth of major crops and weeds by aqueous extracts of sorghum plant parts and residues, and to select a sensitive germination bioassy species for use in isolating the most toxic compound.

MATERIALS AND METHODS

Collection and Preparation of Sample

Mature sorghum plants were collected from the International Rice Research Institute experimental farm. Stem, leaf, and root were separated and dried in an oven at 60℃ for 5 days and then ground in a Wiley Mill using 20-mesh screen. Ground samples were stored in bottles at room temperature until they were used.

Plant Species Response to Sorghum Water Extract

Ground sorghum stem was soaked in water for 2 days at the ratio of 0, 5, 10 and 15%(w/v). Twenty seeds of maize, wheat, rice, radish, *E. colona*, *I. triloba*, and *R. cochinchinensis* were placed in vials (5cm in diameter) lined with two Whatman No. 1 filter papers moistened with 5ml of the extract. The germination test was conducted in the temperature-controlled incubator at 30℃ in the presence of light. Percent germination and shoot and root lengths were determined 5 days after treatment.

Phytotoxicity of Sorghum Plant Parts to *E. colona* and Radish.

To determine the part of sorghum plant that gives greatest inhibition, dried sections of stem, leaf, and root were separately ground and water extracts of each plant part at 0, 2.5, 5, 7.5, 10 and 15%(w/v) were prepared. Percent germination and shoot and root length were recored 5 days after treatment. The percent growth inhibition was determined based on germination and root and shoot growth inhibition. *E. colona* and radish were the test species because *E. colona* is a serious weed and radish was most sensitive to water extract in previous experiment. The germination test was conducted as in the preceding section.

Greenhouse study

The greenhouse study investigated the inhibitory effect fo sorghum residues added to soil as a surface mulch at the rate of 0, 0.5, 1, 2, and 3% (w/w). The appropriate amount of residues was placed on the soil surface in each pot, and 20 seeds of rice (IR42), radish, and *E. colona* was planted 0.5cm below the mulch. Germination was recorded 14 days after planting (DAP). After that, the seedlings were thinned to three plants per pot. Shoot and root lengths and dry weight per plant were measurd 30 DAP. The soil used in the greenhouse experiment was clay loam (pH 5.9, CEC 2.5me/100g).

Experimental Design and Analysis of Data

Experiments were laid out in a completely randomized design with four replications. Data were analyszed using single or two-factor analysis. Treatments were compared using Least Significant Differences (LSD).

Table 1. Effect of aqueous extracts of sorghum stem on percent germination and seedling growth of selected crops and weeds.

Test Plant	Concentration (%)	Germination (%)	Growth (mm)	
			Shoot	Root
Crop species				
Maize	0	85.0	57.8	55.1
	5	67.5	10.0	13.7
	10	52.5	6.6	6.7
	15	25.0	5.5	5.0
	LSD 0.05	8.8	11.8	11.9
Wheat	0	62.5	113.0	72.7
	5	58.8	52.7	13.0
	10	0	0	0
	15	0	0	0
	LSD 0.05	18.6	9.1	16.7
Rice	0	78.8	33.1	30.9
	5	55.0	11.8	8.0
	10	25.0	5.8	0
	15	0	0	0
	LSD 0.05	17.3	7.0	6.2
Radish	0	78.8	37.3	35.9
	5	2.5	3.1	4.3
	10	0	0	0
	15	0	0	0
	LSD 0.05	7.6	10.6	13.9
Weeds				
R. cochinchinensis	0	56.2	76.5	75.7
	5	33.5	9.0	9.3
	10	10.0	0.4	0.5
	15	0	0	0
	LSD 0.05	17.1	8.9	9.5
E. colona	0	91.3	28.3	26.6
	5	47.5	6.5	4.8
	10	7.5	0	0.5
	15	0	0	0
	LSD 0.05	19.2	9.2	11.5
I. triloba	0	98.8	62.1	26.8
	5	0	0	0
	10	0	0	0
	15	0	0	0
	LSD 0.05	1.9	4.7	5.3

RESULTS AND DISCUSSION

Plant Species Respose to Sorghum Water Extract

Germination. The effects of aqueous extracts of sorghum stem on the germination and seedling growth of selected crops and weeds are shown in Table 1. Germination of all test species was significantly inhibited, regardless of concentrations. The germination percentage decreased as the extract concentration increased.

Germination of all crop species was inhibited at a 5% concentration. Alhough inhibition in radish and wheat was complete at 10% concentration, inhibition was more marked in radish. At 15%, rice germination was completely inhibited but that of maize was not.

Germination of the weed species was also markedly inhibited at a 5% concentration, and their inhibition was also concentration dependent. Germination of *I. triloba* was completely inhibited even at 5% concentration. The pattern of *E. colona* germination was simillar to that of *R. cochinchinensis*, but *E. colona* germination was lower than that of *R. cochinchinensis* at 5 and 10% concentrations. Germination of *E. colona* and *R. cochinchinensis* was completely inhibited at 15% concentration.

Seedling growth. Shoot and root elongation were also affected by sorghum stem extract. Shoot and root length of all test species were significantly reduced, regardless of concentration (Table 1). However, inhibition of shoot and root length did not markedly differ.

Among the crop species, radish showed the most inhibition, followed by wheat and rice.

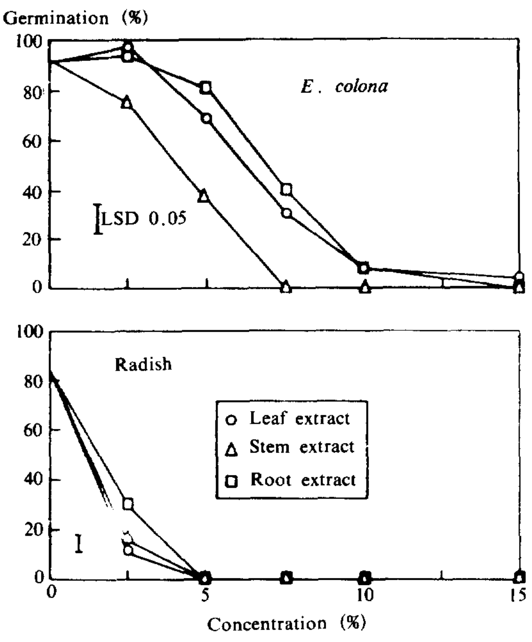

Fig. 1. Effect of water extracts of sorghum plant parts on germination in *E. colona* and radish.

Maize was the least sensitive crop species. Of the weed species, *I. triloba* had the most inhibition, followed by *E. colona* and *R. cochinchinensis*. This reveals an example of species-specific growth-regulating effects of allelochemicals. Overland[17] demonstrated that the inhibitory action of barley varied with test species. Similar differences in response among test species were reported by Bhowmik and Doll[4], Stevens and Tang[24], Gabor and Veatch[9], and Mersie and Singh[16]. Based on this result, radish was selected as bioassay material for crop species. Of the weed species, *I. triloba* was inhibited most by water extract; however, *E. colona* was chosen for bioassay because it is a serious weed in upland conditions. The result demonstrates that sorghum stem extract contains allelopathic substances that inhibit germination and seedling growth of weeds and crops.

Phytotoxicity of Sorghum Plant Parts to *E. colona* and Radish

Germination. The water extracts of sorghum stems, roots, and leaves significantly reduced germination in *E. colona* and radish. The effect of sorghum plant parts on *E. colona* and radish depended on source and concentration (Fig. 1). At the lowest concentration (2.5%), the stem extract, but not the leaf and root extract, significantly reduced *E. colona* germination. As the extract concentration increased, germination was reduced. Germination was completely inhibited by 7.5% stem extract. Root and leaf extracts significantly inhibited germination was not significantly defferent by the plant parts. On the other hand, all three exracts markedly inhibited radish germination even at the lowest concentration of 2.5% (Fig. 4). Stem and leaf extracts had greater inhibitory effect than the root extract are 2.5% but radish germination was inhibited 100% at 5% concentration of all three extracts. These results demonstrate a rate-dependent response of test species to allelochemicals and show that aqueous extracts contain allelochemicals.

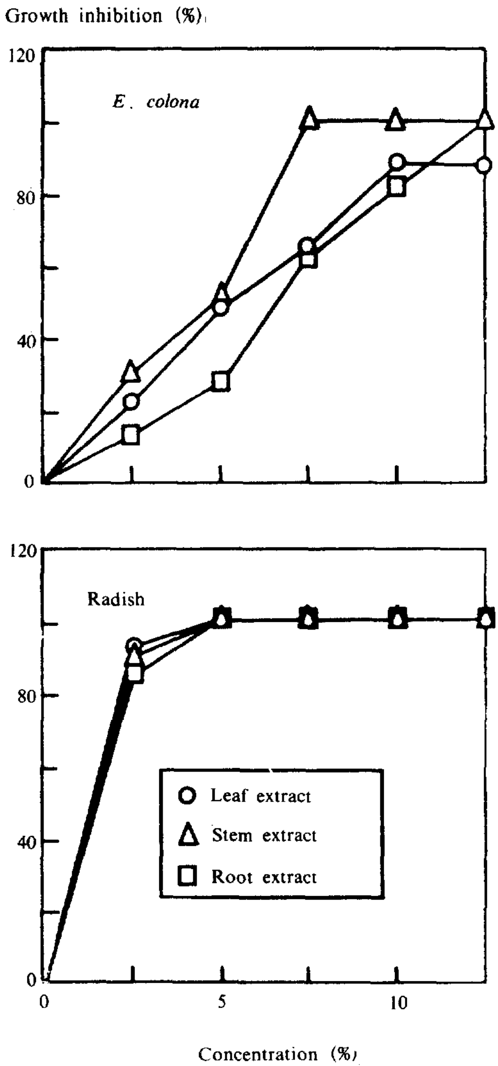

Fig. 4. Percent growth inhibition in *E. colona* and radish treated with varying concentrations of water extracts of sorghum plant parts.

Results are in agreement with previous investigations[4,6,8,12,26,27] that the activity of water extracts from allelopatic weeds was directly related to the extract concentrations. Regardless of extract concentration, percent germination of *E. colona* was generally lower with the stem extract than with other parts. Germination of *E. colona* treated with leaf extracts exhibited the same trend as that treated with root extracts. The differences observed at the lowest concentration of the stem extract and the other parts, which were obtained from the same amounts of the allelopathic compounds than other plant parts of

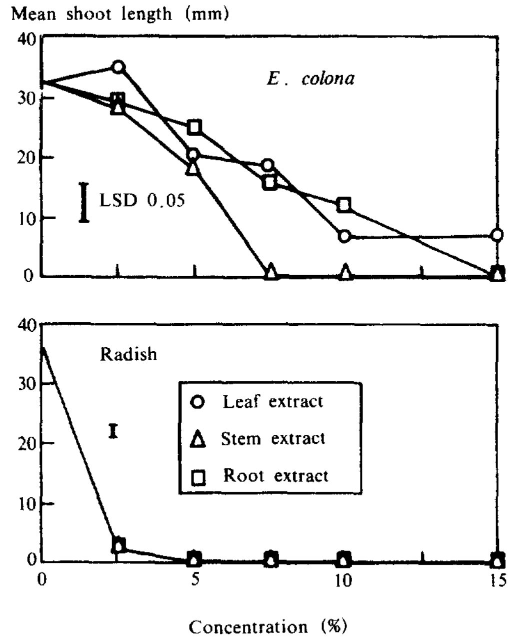

Fig. 2. Effect of water extracts of sorghum plant parts on shoot length in *E. colona* and radish.

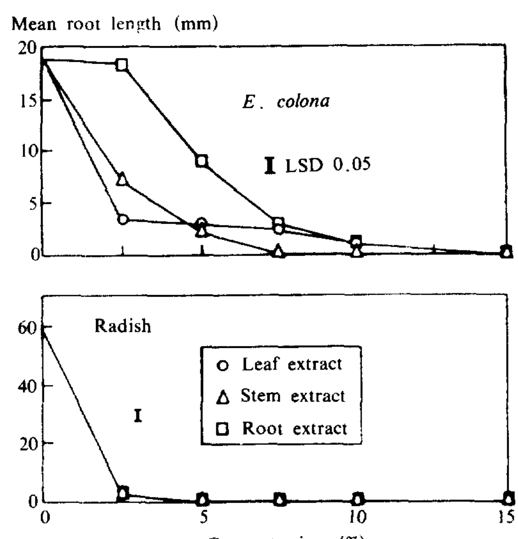

Fig. 3. Effect of water extracts of sorghum plant parts on root length in *E. colona* and radish.

sorghum plants including leaf, stem, root, and seed, but the stem extract has the greatest inhibitory effect on wheat seedling. Root extract of sorghum[*Sorghum bicolor* (L.) Moench.] inhibited seed germination of cress[14] and *A. retroflexus*[1].

Seedling growth. Shoot and root response of *E. colona* and radish were similar to that of germination. Like in percentage germination, shoot and root elongation in *E. colona* and radish significantly reduced as the extract concentration increased (Fig. 2 and 3). The allelochemical could have inhibited seedling growth by at least two mechanisms. The first possible target is cell division. Perhaps, allelochemicals from the sorghum water extract inhibited cell division. Perhaps, allelochemicals from the sorghum water extract inhibited cell division. Avers and Goodwin[2] have shown that various phenolic compounds, one of the largest group of allelochemicals, inhibited root cell division. It is also possible that cell elongation was affected by extracts of sorghum stem. Thomaszewiski and Thiman[25] found many allelochemicals inhibited gibberellin and indoleacetic acid induced growth. These phenomena may account for the results observed in studies with extract.

Overall, all the three parts were inhibitory to germination and seedling growth in *E. colona* and radish but the stem extract was more inhibitory to *E. colona* than either the leaf and root extracts while all three extracts produced similar response in radish (Fig. 4). Thus, water extracts of sorghum plant parts may contain toxic compounds that are nonselective on *E. colona* and radish.

Greenhouse Trial

Germination. Sorghum stem residue placed on the soil surface an a mulch at 1%(w/w) significantly reduced germination in *E. colona* and radish (Table 2). Seed germination was greatly reduced as the amount of stem residues increased. Rice seed germination was not affected by any rate of the mulch.

Seedling growth and dry mass accumulation. Sorghum stem residues reduced shoot length in *E. colona* and radish (Table 2). A similar decrease in root length was observed as the amount of residue rate increased. In contrast, shoot and root elongation in rice was not affected by stem residues. Shoot and root growth in *E. colona* and radish did not differ much. The root, which was in continuous contact with the residue, was exposed to possible toxins released from the decaying sorghum stem. Thus phytotoxicity could occur through two possible mechanisms :

Table 2. Effect of sorghum stem residue applied on the soil surface on the germination, seedling growth and dry weight accmulation of selected species.

Concentration of residue (%)	Test plant		
	E. colona	Radish	Rice
	Percent germination		
0	86	81	46
0.5	85	64	49
1	48	43	54
2	56	45	55
3	52	9	49
LSD 0.05	15	22	ns
	Mean shoot length (cm)		
0	36	11	36
0.5	34	9	30
1	33	9	35
2	28	9	33
3	28	7	32
LSD 0.05	3	2	ns
	Mean root length (cm)		
0	25	11	32
0.5	22	10	28
1	21	10	30
2	19	9	28
3	18	6	28
LSD 0.05	3	2	ns
	Dry weight (mg/plant)		
0	27	35	38
0.5	27	30	29
1	25	26	34
2	15	24	34
3	14	16	31
LSD 0.05	6	8	ns

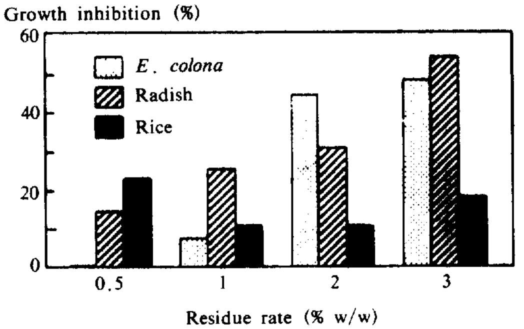

Fig. 5. Percent growth inhibition of test species as affected by the sorghum stem residue.

either allelochemicals were leached directly from residues or they might have been produced by microorganisms during residue decomposition[4].

At the 2%(w/w) rate, stem residues significantly reduced dry mass accumulation of *E. colona* and radish : however, no reduction was observed in rice. The results of this study show that growth of *E. colona* and radish was reduced by sorghum stems while rice was not affected as mesured by all the growth paramters. That many crop residues contain water-extractable phytotoxic compounds has been reported[3,5,11,19,23]. Based on the dry mass accumulation, radish was more inhibited than was *E. colona* (Fig. 5).

In gerneral, *E. colona* and radish growth were strongly inhibited, but rice was not affected by the presence of sorghum stem residues. In *E. colona* and radish, growth reduction was rate dependent and maximum growth inhibition resulted from the highest (3%) residue rate.

摘　要

생물검정 결과 수수에 함유된 타감물질의 억제효과는 공시 식물, 사용부위 및 사용 농도에 따라 다르게 나타났다. 공시 작물 및 잡초 모두가 줄기에서 추출한 물질에 의해 발아 및 생장이 억제되었는데 작물은 무우, 밀, 벼 순으로 억제효과가 있었으며 옥수수에서 억제효과가 가장 적었다. 잡초는 *Ipomoea. triloba*에서 가장 억제효과가 나타났으며 그 다음이 *Echinochloa colona*, *Rottboellia cochinchinensis* 순으로 나타났다.

수수의 부위별로 타감물질의 억제정도를 조사한 결과 *E. colona*에서는 줄기 부위에서 가장 크게 나타났는데 7.5%(w/v)에서 *E. colona*의 생육이 완전히 억제되었으나 잎, 뿌리는 억제효과가 크지 않았다. 무우에서는 줄기, 잎, 뿌리 모두가 비슷하게 억제 작용을 나타냈으며 5%에서 무우의 생육이 완전히 억제되었다.

온실에서 수수 줄기를 이용해서 mulching 실험을 한 결과 줄기의 타감물질이 *E. colona*와 무우에 상당한 억제효과가 있다는 것이 확인이 되었다.

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