Bull. Environ. Contam. Toxicol. (1989) 43:421–427

Effects of Velvetleaf Plant Residues on Seedling Growth and Soil Microbial Activity

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Decomposing residues from a wide range of plant species often release chemical compounds into the soil environment that inhibit plant growth (Bhowmik and Doll 1982, 1984; Cochran et al. 1977; Drost and Doll 1980; Yackle and Cruse 1983). Soil microorganisms may be involved in production of inhibitory substances from residues through formation of phytotoxic compounds (Guenzi and McCalla 1962). Phytotoxic effects of decomposing giant foxtail (*Setaria faberi* Herrm.) residues on corn seedlings were observed 30 days after planting (Bell and Koeppe 1972). Bioassay of several grass and small grain residues decomposing in the field revealed phytotoxin production following conditions favorable for microbial growth (Colton and Einhellig 1980). The stage of maturity of plant residues also affects the extent of phytotoxicity on seedling growth (Patrick and Koch 1958).

Velvetleaf (*Abutilon theophrasti* Medik.), a major weed species of crops in the midwestern and southern United States, is often present in the field at different stages of maturity during the crop-growing season (Spencer 1984). Whether velvetleaf is allowed to continue throughout the season or is terminated by cultivation or herbicide applications, substantial amounts of plant residues are added to the soil. Decomposition of velvetleaf residues may release substances phytotoxic to crop seedlings. Bhowmik and Doll (1982) found that decomposing velvetleaf residues reduced dry weight accumulation in corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] seedlings in the greenhouse. A later study showed that the phytotoxic effect was independent of any alteration of nutrient uptake patterns (Bhowmik and Doll 1984).

Toxicity of chemicals released into soil by plant residues directly or through decomposition by soil microorganisms and their effects on plant growth has received little attention. The purpose of this study was to assess the toxicity of residues of velvetleaf at different maturity stages incubated in soil on seedling growth of corn, soybean and velvetleaf and on soil microbial respiration. The effects of aqueous extracts of the residues on seedling growth were also investigated.

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MATERIALS AND METHODS

Velvetleaf plants (tops and roots) in vegetative (V5-V7), early reproductive (R4-R5) and late reproductive (R6-R8) stages of maturity (Higgins et al. 1984) were collected during the 1985 growing season at the University of Missouri Agronomy Research Center, 16 km east of Columbia, MO. Samples were air dried for 24 h at 30°C. The residues were ground in a Wiley mill to pass a 2 mm screen. Ground samples were stored at room temperature in sealed plastic bags until use.

A portion of the ground residues (intact tissues) was used to prepare aqueous extracts for chemical analyses and in vitro bioassays. Ground residues (15 g) were placed in 500-ml conical flasks with 300 ml of sterile distilled water. The flasks were shaken for 8 h on an orbital shaker. Extracts were filtered serially through Whatman Nos. 541 and 2 filter paper and were stored refrigerated at 4°C until use.

Residue extracts were analyzed colorimetrically for total soluble phenolic content (Horowitz 1980). Total soluble carbohydrates in the extracts were determined by the anthrone method (Umbreit et al. 1972). Total N in ground residues was determined by Kjeldahl distillation (Bremner and Mulvaney 1982). Total carbon in ground residues was determined by dry combustion of 0.4 g samples in electric furnace at 900°C for 15 min (Nelson and Sommers 1982).

Representative samples from the upper 10 cm of the Ap horizon of a Mexico silt loam soil (Udollic Ochraqualf, fine, montmollinitic, mesic) were air-dried and screened (<2 mm). The soil had an organic matter content of 2.4% (w/w) and a pH of 5.5. Residues were incorporated into the soil at a rate of 1.0 g kg dry soil^{-1}. This rate was chosen based on previous studies of plant response to weed residue rates and is representative of residue amounts occurring in the field (Bhomik and Doll 1982, 1984). Evolution of CO_2 from residue-amended soil and nonamended soils was determined on specified sampling dates during 42 d of incubation using the method of Chahal and Wagner (1965). Data obtained from replicate experiments were calculated and expressed as mg C evolved as CO_2 100 g dry soil^{-1} accumulated over the incubation period.

Five milliliters of residue extract were dispensed on Whatman No. 3 filter paper in sterile petri plates. Five seeds of corn (Pioneer 3377), soybean (Williams 82), or velvetleaf were evenly spaced on the filter paper, and the plates placed in a dark germination chamber at 27°C. The plates were arranged in a randomized complete block design for each plant species with five replications for each residue extract. Filter paper moistened with sterile distilled water served as controls. After four days the plates were removed and % seed germination and radicle lengths were recorded. The experiment was conducted three times.

Mixtures of velvetleaf residues in nonsterile and autoclaved (1.5 h at 121°C) Mexico silt loam soil were prepared as described for the respiration study. Residue-amended soils (460 g) were dispensed into pots and watered to 60% water-holding capacity. Five seeds each of corn and soybean and 10 seeds of velvetleaf were planted 2-cm deep in separate pots and placed in the greenhouse in a randomized complete block design with four replications. At 30 d after planting, plants were removed at the soil surface, dried at 80°C for 48 h and dry weights determined. This study was conducted twice.

RESULTS AND DISCUSSION

Analysis of velvetleaf residue extracts revealed that soluble phenolic content was highest in vegetative residue and lowest in late reproductive residue (Table 1). The largest amount of soluble carbohydrates was also found in vegetative residue. Analysis of residue tissues showed that early and late reproductive residues contained the greatest carbon content. Vegetative residues contained a significantly higher nitrogen content than the reproductive residues. The calculated C:N ratio of residue tissues was 17:1 at the vegetative stage and widened to a maximum of 110:1 at the late reproductive stage.

Vegetative residue extracts significantly inhibited in vitro radicle elongation of all seedlings (Table 2). Radicle elongation of soybean and velvetleaf was also inhibited by early and late reproductive residue extracts. The effect of vegetative extracts on radicle growth may be due in part to the high soluble phenolic content (Table 1). Phenolic compounds have been found to be phytotoxic to seedlings (Paszkowski and Kremer 1988; Rice 1984; Vaughn et al. 1983). Bhowmik and Doll (1982) suggested that allelopathic effects of several weeds on corn and

Table 1. Chemical analyses of velvetleaf residue extracts and intact residue tissues

	Extract		Tissue		
Residue age	Phenolics (mg TAE/l)[a]	Carbohydrates (mg/l)[b]	Carbon (%)	Nitrogen (%)	C:N
Vegetative	94	1500	37.1	2.2	17:1
Early Reproductive	62	840	44.2	0.5	88:1
Late Reproductive	36	580	44.1	0.4	110:1
L.S.D. (0.05)	4	400	2.3	0.2	

[a]mg of tannic acid equivalents
[b]mg of glucose equivalents

Table 2. Effect of velvetleaf residue extracts on radicle length of three seedlings after four days.

Extract	Corn	Soybean	Velvetleaf
	----------(% of control)----------		
Vegetative	36	36	0[a]
Early reproductive	144	54	1
Late reproductive	123	65	1
L.S.D. (0.05)	42	18	—

[a]No radicle growth occurred.

Table 3. Shoot dry weight accumulation in 30-day-old plants grown in soils amended with velvetleaf residues.

Soil treatment	Residue added	Corn	Soybean	Velvetleaf
		---------(mg/plant)----------		
Nonsterile	None	1190	240	300
	Vegetative	1160	230	310
	Early reproductive	620	170	90
	Late reproductive	750	200	90
L.S.D. (0.05)		300	30	40
Autoclaved	None	1320	190	160
	Vegetative	1030	130	120
	Early reproductive	800	100	90
	Late reproductive	640	210	120
L.S.D. (0.05)		280	50	30

soybean growth were due partially to phenolic compounds in residues although these were not determined in their study. Velvetleaf seedlings were highly sensitive to all residue extracts. This autotoxic effect is similar to a previous study that showed inhibition of velvetleaf seedling growth by extracts of velvetleaf seeds (LaCroix and Staniforth 1964). Germination of all species was not affected by any residue extract. Previous studies have also indicated that seedling growth is more sensitive to allelochemicals than is germination (Rice 1984; Yackle and Cruse 1984)

Results of the greenhouse study showed that shoot dry weight accumulation of corn and velvetleaf was inhibited by both early and late reproductive residues while soybean growth was only inhibited

by early reproductive residue in nonsterile soil (Table 3). In autoclaved soil, dry weights of all test species were reduced by all residues except for soybean, which was not affected by late reproductive residue.

Velvetleaf residues incorporated in soil caused an eleven-fold increase in CO_2 evolution compared to soil receiving no residues (Fig. 1). Respiration observed in residue-amended soils decreased in the following order: vegetative > early reproductive > late reproductive residue. This reflects the differences in C:N between the residues and the greater amount of soluble C (carbohydrates) in vegetative residues (Table 1), which is readily available for metabolism. Initial rates of residue decomposition have been shown to be strongly dependent on water soluble components (Rice 1984). Soluble phenolic compounds of reproductive residues were lower than those in vegetative, however, types of phenolics associated with mature residues (tannins, etc.) can markedly decrease decomposition rates (Rice 1984).

Elevated soil microbial respiration indicated that rapid metabolism and, therefore, decomposition of the incorporated residues was occurring. Nonsterile soil amended with vegetative residue exhibited no phytotoxicity toward seedlings, which was likely due to rapid metabolism by soil microorganisms of readily available substrate including the soluble carbohydrate and phenolic fractions (Table 1). It has been previously reported that soluble phytotoxins (e.g. phenolics) can be inactivated by an actively metabolizing soil microbial population (Vaughn et al. 1983). In contrast, vegetative residue in both in vitro and autoclaved soil bioassays exerted phytotoxicity, supporting the involvement of soil microorganisms in inactivation of phytotoxic factors. Also, phytotoxicity of reproductive residues in nonsterile and autoclaved soils may reflect effects both of initially high plant phenolic content (autoclaved soil) that is released into soil over time and formation by soil microorganisms of secondary compounds that were phytotoxic (nonsterile soil). Soybean was not affected by late reproductive residue in nonsterile soil, which may reflect a difference among plant species in susceptibility to phytotoxins from a single source (Bhowmik and Doll 1982). This may also explain the stimulation in growth of corn by reproductive residue extracts observed in in vitro bioassays (Table 2). Disparities between in vitro bioassays and greenhouse tests have been reported (Colton and Einhellig 1980; Yackle and Cruse 1984) and indicates that soluble residue components may contribute little in the soil environment.

The results provide indirect evidence that vegetative residues of velvetleaf may not affect seedling growth in soil due to inactivation of potential phytotoxic compounds by soil microorganisms. However, incorporation of velvetleaf residues in reproductive stages of development may affect plant growth because of higher phenolic content and formation of secondary phytotoxins through

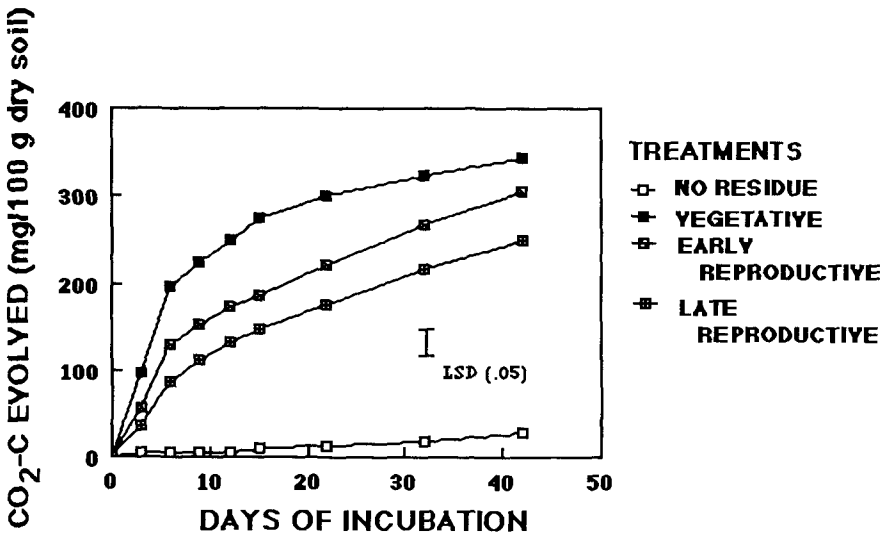

Figure 1. Total carbon released as CO_2 from soil amended with velvetleaf residues during incubation.

microbial metabolism. Practical implications are apparent in cropping systems where weed residues are incorporated in soil prior to or at planting.

Acknowledgments. This paper is a joint contribution of USDA-ARS and Department of Agronomy, University of Missouri. Missouri Agricultural Experiment Station Journal Series No. 10613.

REFERENCES

Bell DT, Koeppe DE (1972) Noncompetitive effects of giant foxtail on the growth of corn. Agron J 64:321-325

Bhowmik PC, Doll JD (1982) Corn and soybean response to allelopathic effects of weed and crop residues. Agron J 74:601-606

Bhowmik PC, Doll JD (1984) Allelopathic effects of annual weed residues on growth and nutrient uptake of corn and soybeans. Agron J 76:383-388

Bremner JM, Mulvaney CS (1982) Total Nitrogen. In: Page AL (ed) Methods of Soil Analysis, part 2. American Society of Agronomy, Madison, Wisconsin, p.594

Chahal DL, Wagner GH (1965) Decomposition of organic matter in Sanborn Field soils amended with C^{14} glucoce. Soil Sci 100:96-103

Cochran VL, Elliott LF, Papendick RI (1977) The production of phytotoxins from surface crop residues. Soil Sci Soc Am J 41:903-909

Colton CE, Einhellig FA (1980) Allelopathic mechanisms of velvetleaf (*Abutilon theophrasti* Medic. Malvaceae) on soybean. Am J Bot 67:1407-1413

Drost DC, Doll JD (1980) The allelopathic effect of yellow nutsedge (*Cyperus esculentus*) on corn (*Zea mays*) and soybean (*Glycine max*). Weed Sci 28:229-233

Guenzi WD, McCalla TM (1962) Inhibition of germination and seedling development by crop residues. Soil Sci Soc Am Proc 26:456-459

Higgins RA, Staniforth DW, Pedigo LP (1984) Effect of weed density and defoliated and undefoliated soybean (*Glycine max*) on velvetleaf (*Abutilon theophrasti*) development. Weed Sci 32:511-519

Horowitz W (1980) Tannin. In: Horowitz W (ed) Official Methods of Analysis of the Association of Official Analytical Chemists. A.O.A.C., Washington D.C., p. 158

LaCroix LJ, Staniforth DW (1964) Seed dormancy in velvetleaf. Weeds 12:161-174

Nelson DW, Sommers LE (1982) Total Carbon, Organic Carbon, and Organic Matter. In: Page AL (ed) Methods of Soil Analysis, part 2. American Society of Agronomy, Madison, Wisconsin, p. 539

Paszkowski WL, Kremer RJ (1988) Biological activity and tentative identification of flavonoid components in velvetleaf (*Abutilon theophrasti*) seed coats. J Chem Ecol 14:1573-1582

Patrick ZA, Koch LW (1958) Inhibition of respiration, germination and growth by substances arising during decomposition of certain plant residues in the soil. Can J Bot 36:621-647

Reinertsen SA, Elliott LF, Cochran VL, Campbell GL (1984) Role of available carbon and nitrogen in determining the rate of wheat straw decomposition. Soil Biol Biochem 16:459-464

Rice EL (1984) Allelopathy. Academic Press, New York

Spencer NR (1984) Velvetleaf, *Abutilon theophrasti* (Malvaceae), history and economic impact in the United States. Econ Bot 38:407-416.

Umbreit WW, Burris RH, Stauffer, JF (1972) Manometric and Biochemical Techniques. Burgess Publ. Co., Minneapolis, Minnesota

Vaughn D, Sparling GP, Ord BG (1983) Amelioration of the phytotoxicity of phenolic acids by some microbes. Soil Biol Biochem 15:613-614

Yackle GA, Cruse RM (1983) Corn plant residue age and placement effects on early corn growth. Can J Plant Sci 63:871-877

Yackle GA, Cruse RM (1984) Effect of fresh and decomposing corn plant extracts on corn seedling development. Soil Sci Soc Am J 48:1143-1146

Received September 26, 1988; accepted April 19, 1989.