Pertanika J. Sci. & Technol. 3(1):45-50(1995)
ISSN: 0128-7680

Effects of Metolachlor, Oxyfluorfen and Picloram on Cellulose Decomposition in a Peat Soil under Laboratory Conditions

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Received 17 June 1993

ABSTRAK

Kesan tiga herbisid iaitu metolachlor, picloram dan oxyfluorfen ke atas pereputan selulosa dalam tanah gambut telah dikaji di dalam makmal. Herbisid tersebut telah disembur kepada bahan selulosa sebelum ditanam atau digaul dalam tanah. Substrat yang telah disembur dengan herbisid sebelum ditanam menyebabkan kadar pereputan yang berkurangan dengan jelas berbanding dengan kadar pereputan di dalam tanah yang digaul dengan racun. Tanah yang telah diperlakukan dengan herbisid dan dieram selama 4 minggu sebelum ditanam telah meningkatkan sedikit kadar pereputan selulosa selepas 6 dan 12 minggu pengeraman.

ABSTRACT

The effects of the three herbicides, metolachlor, picloram and oxyfluorfen on cellulose decomposition were studied in a peat soil in laboratory experiments. The herbicides were either sprayed on to cellulose substrate before burial or incorporated directly into the soil. The herbicides applied directly to the substrates before burial reduced the decomposition of the substrate more than those applied to the soil. Pre-incubation of the treated soil for 4 weeks before burial slightly increased the decomposition rate after 6 or 12 weeks of incubation.

Keywords: cellulose decomposition, metolachlor, oxyfluorfen, picloram

INTRODUCTION

The decomposition of crop residues and soil organic matter is an essential part of the nutrient cycling process in soil. Organic matter in the soil is decomposed primarily through microbial processes. The importance of the microflora responsible for this degradation is considerable because their activity determines the accumulation of plant debris on the soil surface. Herbicides come into contact with crop residues during spraying and/or after incorporation of treated crop residues into the soil. However, the presence of herbicide residues on dead plants may alter their decomposition rate. Herbicide application may delay cellulose decomposition, an important process in the degradation of organic matter in general. Wilkinson and

Lucas (1969), for example, demonstrated that colonization of cellulose fungi on potato haulm was reduced following paraquat treatment. When applied to soil, however, this herbicide showed variable effects on cellulose decomposition and the number of microbial propagules (Grossbard *et al.* 1972; Szegi 1972; Camper *et al.* 1973).

In studies on cellulose decomposition, artificial substrates such as cotton cloth or filter paper are usually used because they are easier to handle and results are more reproducible than those obtained with natural cellulose materials. This paper reports the results of experiments in which an artificial cellulose substrate was used to investigate the effects of three herbicides, metolachlor, oxyfluorfen and picloram, on cellulose decomposition in a peat soil.

MATERIALS AND METHODS

Soil, Cellulose Material and Herbicides

The peat soil used was taken from the experimental plot of the MARDI Research Station, Jalan Kebun, Kelang, Selangor. The soil contained 43.7% sand, 11.7% silt, and 44.6% clay, and had 55% organic carbon and a pH of 4.9. The soil was collected to a depth of 10 cm, sifted through a 3-mm sieve and placed in black polyethylene bags before use. The cellulose substrate (100% cellulose, specially made for soil burial tests) was obtained from the British Textile Technology Group.

The herbicides tested were metolachlor as Dual™: active ingredient 720 g/l of 2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide; oxyfluorfen as Goal™: active ingredient 264 g/l of 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene; and picloram as Tordon™: active ingredient 240 g/l of 4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid.

Direct Herbicide Treatment of the Substrate

A single layer of the substrate was sprayed with herbicide at a spraying volume of 45 ml/m^2. The concentrations used were the recommended rate and four times the recommended rate (Table 1). As the control, a substrate was sprayed with an equal volume of water. The substrate was then cut into strips 2 cm by 11 cm, and each strip was mounted on a glass slide for burial in soil as described by Greaves *et al.* (1978). Five substrate-covered slides of each concentration of each herbicide were placed, separately, sideways in the soil in a box. The box was filled with more moist peat soil to give a final weight of 700 g; a glass rod was used to make the soil firm between the slides to ensure good contact between the soil and substrate. The boxes were then placed in polyethylene bags, which were secured with elastic bands, and then inflated with compressed air. Each box was weighed and incubated at 27°C for 6 or 12 weeks. The moisture content of the treated and control soils was maintained at 50% of the field capacity.

TABLE 1
Application rates of herbicides on substrate

Herbicides	Recommended rate	Four times recommended rate
	kg/ha	
Metolachlor	1.08	4.32
Oxyfluorfen	0.39	1.56
Picloram	2.00	8.00

Herbicide Treatment of the Soil

In another experiment, each herbicide was mixed thoroughly with the soil to give final concentrations of 20 p.p.m. (equivalent to 2 kg ai/ha) and 150 p.p.m. (15 kg ai/ha) for each herbicide on a dry weight basis. For the control, soil was sprayed with an equal volume of distilled water. The untreated substrate, mounted on glass slides, was then buried in the treated and control soils either immediately or after the soil had been kept for 4 weeks at ambient temperature. The substrates were incubated for another 6 and 12 weeks before weight loss was determined.

The moisture content of the soil was checked weekly and maintained at 50% field capacity during the incubation period by adding water. After 6 or 12 weeks of incubation, the slide-mounted substrate was carefully removed from the soil, and soil particles gently removed from the substrate using a small brush. The weight loss was determined and expressed as a percentage of the weight of an identical piece of substrate which had not been buried. The data were presented as averages of five replications for each concentration of each herbicide.

RESULTS AND DISCUSSION

The results of these experiments showed that all herbicides at the recommended, or four times the recommended, rate reduced cellulose decomposition when applied directly to the substrate (Table 2). A greater reduction in decomposition rate was observed at the higher concentration. Metolachlor and oxyfluorfen applied at four times the recommended rate reduced cellulose decomposition by 82% and 92% of untreated control, respectively, after 6 weeks of burial. After six weeks, less inhibition (reduced by 58% of untreated control) was shown by picloram, at the higher concentration, sprayed on substrate. At the same concentration, the decomposition was reduced by 56% of untreated control after 12 weeks of burial.

TABLE 2
Weight loss (as percentage of initial weight) of substrates treated with metolachlor, oxyfluorfen or picloram after 6 and 12 weeks of burial in a peat soil.

Herbicide (kg/ha)	Incubation Period	
	6 weeks	12 weeks
	%	
Untreated control	17.9 + 0.21	35.2 + 0.47
Metolachlor		
1.08	8.9 + 0.33	20.8 + 0.42
4.32	3.1 + 0.22	14.3 + 0.31
Oxyfluorfen		
0.39	4.6 + 0.41	15.5 + 0.34
1.56	1.5 + 0.21	11.8 + 0.26
Picloram		
2.00	8.6 + 0.52	17.6 + 0.58
8.00	7.4 + 0.11	15.3 + 0.70

The effects of metolachlor, oxyfluorfen and picloram on the decomposition of cellulose materials buried immediately or after pre-incubation of treated soil are shown in Table 3. In general, the degree of inhibition increased at the higher concentration of herbicide. Substrate buried in the soil immediately after soil treatment with the herbicide showed a slower decomposition of cellulose materials than when treated soil had been pre-incubated.

Incubation of the soil for 4 weeks before burial of the substrate only slightly alleviated the inhibitory effects of the herbicide on decomposition. At 150 p.p.m. of oxyfluorfen, the decomposition was reduced by 46% of untreated control in pre-incubated soil compared to 48% in soil without pre-incubation after 6 weeks of incubation. Factors such as breakdown or adsorption of herbicide during the 4-week incubation period prior to the addition of the substrate may account for the decreased effects of the herbicides. It has been reported that the half-life of metolachlor and atrazine in soil under laboratory conditions is 22 and 35 days, respectively (Singh *et al.* 1990; Ismail and Wei 1993). At 150 p.p.m., oxyfluorfen and picloram caused greater inhibition of decomposition, regardless of incubation period, than metolachlor. During 4 weeks of incubation, metolachlor lost its residual activity due to adsorption by soil particles faster than the other two herbicides, consequently reducing its effect on cellulose-acting microorganisms (Ismail and Yap 1994).

TABLE 3
Weight loss (as percentage of initial weight) of substrates buried in soil treated with metolachlor, oxyfluorfen or picloram either immediately after treatment or after 4 weeks of pre-incubation in a peat soil.

Herbicide (kg/ha)	Without pre-incubation		4 weeks incubation	
	6 weeks	12 weeks	6 weeks	12 weeks
	%			
Untreated control	17.9 ± 0.21	35.2 ± 0.47	25.0 ± 0.27	38.9 ± 0.32
Metolachlor				
20	13.8 ± 0.58	29.4 ± 0.32	24.4 ± 0.32	37.9 ± 0.33
150	11.6 ± 0.16	25.7 ± 0.94	16.6 ± 0.28	28.1 ± 0.21
Oxyfluorfen				
20	12.2 ± 0.25	26.6 ± 0.36	20.4 ± 0.23	34.9 ± 0.25
150	9.3 ± 0.26	18.8 ± 0.56	14.7 ± 0.21	23.2 ± 0.27
Picloram				
20	ND	29.0 ± 2.40	24.2 ± 2.10	37.2 ± 0.20
150	ND	26.4 ± 1.00	14.6 ± 2.60	23.6 ± 1.00

The results of this study showed that picloram and oxyfluorfen had deleterious effects on cellulose decomposition when applied directly to the substrate, at rates higher than those recommended. The presence of herbicide residue on the substrate may reduce the colonization of cellulose-acting fungi (Wilkinson and Lucas 1969). Ismail and Mamat (1992) observed that fungal numbers (*Aspergillus, Penicillium* and *Chaetomium*) isolated from the substrate treated with picloram at the highest concentration decreased significantly. When herbicides were applied to soil, however, their effect was not as great as when applied directly to the substrate.

The application of herbicide to soil may change both quantitatively and qualitatively the microbial populations in the soil (Camper *et al.* 1973; Wardle and Parkinson 1990). Other herbicides such as atrazine, as reported by Raju and Rangaswari (1971), cause a temporary decline in soil microbial numbers. The decrease in cellulolytic propagules may have occurred as a result of the death of susceptible species, leaving resistant strains to dominate the population. These strains could then increase steadily after a few days of treatment in the pre-incubated soil. The rate of cellulose decomposition and the interactions between cellulose, microflora and herbicide are greatly influenced by such edaphic factors as soil type, soil moisture and pH.

Besides the inherent characteristics of the compounds, methods of herbicide application may also influence the decomposition of cellulose in soil. Among these factors, organic content of the soil plays an important role in determining the residual activity of the herbicide. Most herbicides are readily adsorbed on soils with higher organic matter content, possibly reducing their effect on soil microorganisms (Rahman *et al.* 1978). This could perhaps explain the slight increase in decomposition observed in pre-incubated soil treated with any of these herbicides.

ACKNOWLEDGMENTS

This work was supported by a research grant IRPA 01-07-03-011 from Ministry of Science, Technology and Environment of Malaysia.

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