Research reports

Effects of herbicides on cellulose decomposition in soil

Ismail Sahid, M.A. Salleh and O. Omar, Faculty of Life Sciences, Universiti Kebangsaan Malaysia, 43600 UKM, Bangi, Malaysia.

Introduction

Organic matter decomposition is one of the most important processes occurring in soil. Any major change in its rate and extent can cause marked practical problems for agriculture. For example, any reduction in decomposition of straw and stubble may result in the accumulation on the soil surface of trash which may harbour plant pests and pathogens (Jeater and McIlvenny 1965, Moore and Thurston 1970). Other implications include the potential transfer of herbicide residues from treated trash to subsequent crops (Jeater and McIlvenny 1965).

Grossbard and Cooper (1974) demonstrated that barley straw sprayed with paraquat (at a rate equivalent to 1.7 kg ha^{-1}) and subsequently buried in soil, decomposed at a markedly slower rate than untreated straw. This is not surprising since Wilkinson and Lucas (1969) previously demonstrated that fungal colonization on potato haulm was reduced following paraquat treatment. When applied to soil, however, this herbicide showed variable effects on cellulose decomposition and number of microbial propagules (Tu and Bollen 1968, 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 naturally occurring cellulosic materials. This paper reports the results of experiments in which an artificial cellulosic substrate was used to investigate the effects of glyphosate and paraquat on cellulose decomposition. Artificial cellulose substrate degradation may resemble the degradation of crude cellulosic waste in the soil, but it may not be exactly analogous because crude cellulose contains other materials besides cellulose that may degrade at different rates.

The rate of cellulose decomposition in soil is affected by many factors such as soil type and climate. As yet little is known about the interaction between herbicides, organic matter decomposition and soil factors. Bearing in mind the importance of the organic matter cycle in soil, especially in light of increasing use of minimum tillage procedures, it is essential that more attention be paid to the side effects of herbicides on organic matter decomposition. This paper examines the effect of two herbicides on the breakdown of cellulose.

Materials and methods

Soil sample and herbicides

Soil samples were obtained from a farm at Universiti Pertanian Malaysia, Serdang, Selangor. They were sifted through a 3 mm sieve and placed in black polythene bags. The soil used was of the type Serdang Series (68% sand, 3% silt, 29% clay, pH 4.1). The cloth, which was specially made for soil burial tests, was obtained from British Textile Technology Group. The plain woven cloth contains 100% cotton yarns in a two-folded form. Further technical details of the cloth can be obtained from the British Textile Technology Group, Manchester, UK.

The paraquat used was supplied under trade name Gramoxone®, containing 200 gm paraquat per litre. Glyphosate was supplied as Roundup®, containing 360 gm glyphosate per litre.

Treatment of the substrates

A single layer of the substrate was sprayed on either side with herbicide at rates equivalent to 0.24 and 0.96 kg ha^{-1} for paraquat, and 2.16 and 8.64 kg ha^{-1} for glyphosate. The substrate was then cut into strips 2 cm × 11 cm and mounted onto glass slides for burial in soil as described by Greaves *et al*. (1978). Five cloth covered slides were placed sideways in the soil in a box. The box was filled with more moist soil using a glass rod to make the soil firm between the slides, thus ensuring good contact between soil and cloth. Ten replicate strips of cloth placed in two boxes of soil were prepared for each treatment. The boxes were then placed in polyethylene bags which were secured in place with elastic bands and then inflated using a compressed air supply. Each box was weighed and incubated at 27°C for up to 8 weeks. The moisture content of the treated and control soils was adjusted to 80% of field capacity.

In another set of experiments, each herbicide was mixed thoroughly with the soil to give final concentrations of 20 and 150 ppm for paraquat and glyphosate respectively, on dry weight basis. Untreated substrate was then buried in the treated soil either immediately or after the treated soil had been kept for 4 weeks at 27°C. The substrate was incubated for 4 or 8 weeks before weight loss was determined.

After incubation the slide-mounted substrate was carefully removed from the soil, and soil particles were gently removed from the cloth using a small artist's brush. The cloth strip was air-dried for 18 hr at 27°C in a desiccator and then weighed. The weight loss was calculated as a percentage of the weight of an initial weight of cloth which had not been buried.

Results

The effects of paraquat and glyphosate on decomposition of cellulosic materials buried in soil immediately following treatment of either the soil or the substrate are shown in Table 1. The results seem to indicate that paraquat reduced the decomposition rate of the substrate. This reduction corresponded with the increase in paraquat concentration and was more pronounced after eight weeks of incubation. Treatment of soil with 20 and 150 ppm of the herbicide reduced the weight loss to 28 and 18% respectively, as opposed to 39% observed in the untreated control after eight weeks of incubation. Similarly, weight loss was reduced to 23

Table 1. Weight loss of substrate (as percentage of initial weight) after 4 and 8 weeks of burial when either substrate or soil were treated with either paraquat or glyphosate ± S.E.

Burial period (weeks)	Herbicide	Treatment of soil (ppm)			Treatment of substrate^A (kg ha^{-1})	
		0	20	150	x	4x
4	Paraquat	13±0.5	12±0.3	10±0.6	11±0.8	6±0.9
	Glyphosate	13±0.5	14±1.8	15±1.0	8±0.3	10±0.1
8	Paraquat	39±1.5	28±1.5	18±1.1	23±1.1	18±1.2
	Glyphosate	39±1.5	46±1.9	44±1.5	50±1.6	51±1.1

^{A} x = 0.24 for paraquat, 2.16 for glyphosate 4x = 0.96 for paraquat, 8.64 for glyphosate

Table 2. Weight loss (as percent of initial weight) of substrates buried in soil preincubated for 4 weeks after treatment with either paraquat or glyphosate ±S.E.

Burial period (weeks)	Herbicide	Treatment of soil (ppm)		
		0	20	150
4	Paraquat	18±0.5	16±0.3	13±0.1
	Glyphosate	18±0.5	17±0.7	20±0.3
8	Paraquat	37±1.1	21±0.4	20±0.3
	Glyphosate	37±1.1	47±1.4	51±1.3

and 18% when the substrate was pretreated with the equivalent of 0.24 and 0.96 kg ha^{-1} of paraquat respectively. In general, however, when the soil or substrate was treated with glyphosate, the rate of decomposition appeared to be enhanced with the exception that decomposition was slightly reduced when the glyphosate-treated substrate was incubated for only four weeks (Table 1).

Incubation of the treated soil for 4 weeks before burial of the substrate did not appear to reduce the inhibitory effects of paraquat on cellulose decomposition in soil (Table 2). The reduction in substrate weight loss, as in the previous experiment, was proportionate to increasing herbicide concentration. However, after eight weeks incubation, no significant further reduction was observed when the amount of paraquat used was increased from 20 to 150 ppm. In the case of glyphosate-treated soil, enhancement of substrate decomposition was again observed. This enhancement was more pronounced when the substrate was incubated for 8 weeks in the treated soil.

Discussion

The results of this study showed that paraquat slightly inhibits cellulose decomposition when applied either directly to the substrate or to the soil. The known antifungal action of paraquat probably explains, in part, the inhibitory effect on the degradation of cellulose. It was reported that paraquat could reduce the decomposition of pure cellulose, calico (Grossbard 1974). This could be related to the fact that paraquat kills cellulolytic fungi which normally colonize the substrate. Paraquat treatment has been shown to inhibit the colonization of potato haulm by saprophytic fungi (Wilkinson and Lucas 1969). Grossbard and Harris (1979) have reported that in pure culture, cellulose-degrading fungus is sensitive to low concentrations of paraquat when applied directly to the cellulosic substrates. It is also known that paraquat is weakly absorbed by cellulose but strongly absorbed to the soil (Damanakis *et al.* 1970). The strong adsorption of the herbicide to soil means that its deleterious effect on soil microbes is reduced. This may explain why the inhibition of cellulose decomposition after the substrate was incubated for 8 weeks was less significant when the herbicide was applied to the soil, as opposed to when it was applied to the substrate. The decomposition of the cellulose was, however redeemed when the treated soil was preincubated followed by a longer period of incubation of the substrate, probably due to such factors as biological and chemical degradation of the herbicide.

The present work also showed that glyphosate has no significant adverse affects on the decay of cellulosic substrate in soil. This agrees with the results of Grossbard and Cooper (1974) who showed that not only did glyphosate fail to inhibit, but actually enhanced degradation of barley straw. However, Ismail *et al.* (1988) showed that glyphosate could decrease decomposition of cellulose in peat soil. It is obvious that factors such as soil type, the time of the year when the soil was collected, storage time and moisture content can influence the response of the cellulolytic soil microflora to this herbicide. These factors may modify the decomposition activity of the microflora and so alter their ability to colonize and degrade cellulosic materials.

Acknowledgements

This work was supported by research grant IRPA 01-07-03-011 from the Ministry of Science, Technology and Environment of Malaysia. The authors express their sincere thanks to Mrs. Alena Sanusi for commenting on the manuscript.

References

Camper, N.D., Moherek, E.A. and Huffman, J. (1973). Changes in microbial populations in paraquat-treated soil. *Weed Research* 13, 231–3.

Damanakis, M., Drennan, D.S.H., Fryer, J.D. and Holly, K. (1970). The adsorption and mobility of paraquat on different soils and soil constituents. *Weed Research* 10, 264–77.

Greaves, M.P., Cooper, S.L., Davies, H.A., Marsh, J.A.P. and Wingfield, G.I. (1978). Methods of analysis for determining the effects of herbicides on soil microorganisms and their activities. Technical Report No. 45. Agriculture Research Council. Weed Research Organization.

Grossbard, E. (1974). The effect of herbicides on the decay of pure cellulose and vegetation. *In* 'Weed Research Organization, Research and Development at Begbroke, part 2'. *Chemistry and Industry* 15, 611–4.

Grossbard, E. and Cooper, S.L. (1974). The decay of cereal straw after spraying with paraquat and glyphosate. Proceedings 12th British Weed Control Conference, 337–43.

Grossbard, E. and Harris, D. (1979). Effects of herbicides on the decay of straw. *In* 'Straw decay and its effect on disposal and utilization'. eds. Grossbard, E. pp. 159–85. (John Wiley & Sons, New York, USA).

Grossbard, E., Marsh, J.A.P. and Wingfield, G.I. (1972). The decay of residues of vegetation and of pure cellulose treated with aminotriazole and paraquat. Proceedings of 11th British Weed Control Conference, 673–9.

Ismail, S., Sukainah, A. and Othman, O. (1988). The effect of paraquat and glyphosate on cellulose decomposition. *Malaysian Applied Biology* 17, 45–8.

Jeater, J.S.L. and McIlvenny, H.C. (1965). Direct drilling of cereals after use of paraquat. *Weed Research* 5, 311–3.

Moore, F.J. and Thurston, J.M. (1970). Interrelationship of fungi, weeds, crops and herbicides. Proceedings of 10th British Weed Control Conference, 920–2.

Szegi, J. (1972). Effect of a few herbicides on the decomposition of cellulose. Proceedings of Symposium on Soil Microbiology, Budapest 11, 349–54.

Tu, C.M. and Bollen, W.B. (1968). Effect of paraquat on microbial activities in soils. *Weed Research* 8, 28–37.

Wilkinson, V. and Lucas, R. L. (1969). Influence of herbicides on the competitive ability of fungi to colonize plant tissues. *New Phytologist* 68, 701–8.