Bull. Environm. Contam. Toxicol. 25, 706-712 (1980)

Effects of Chlorpropham, Chlortoluron and Isoproturon on Respiration and Transformation of Nitrogen in Two Soils

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The effect of herbicides on soil microbial activities and microorganisms has been investigated extensively (GREAVES et al. 1976). As described earlier (MARSH et al. 1977; DAVIES & MARSH, 1977) this work is important because of the possible effect the use of herbicides may have on soil fertility. This paper describes some of the effects of chlorpropham, chlortoluron and isoproturon on carbon dioxide evolution from, and transformation of nitrogen in, two soils.

MATERIALS AND METHODS

Soils and herbicides

The soils used came from arable (Boddington Barn) and permanent grass (Triangle) fields at the Weed Research Organization (WRO). Some of their characteristics are given in Table 1.

TABLE 1

Soil characteristics

	SOIL	
	Boddington Barn	Triangle
Soil classification	Sandy loam to Sandy clay loam	Sandy loam
pH (in water)	6.7	5.8
Available P, μgP g^{-1} dry soil	14.2	3.4
Total N, %	0.19	0.35
Organic C, %	1.8	4.0
NH_4^+-N, μgN g^{-1} dry soil	1.7	7.8
NO_3^--N, μgN g^{-1} dry soil	145.0	55.0
CEC, mEq/100g	24	43
Clay, %	18	16
Silt, %	16	18
Fine sand, %	34	40
Coarse sand, %	32	26
Field capacity, % H_2O	16.6	27.0

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The herbicides tested were:-

Chlorpropham (isopropyl N-(3-chlorophenyl) carbamate), as an emulsifiable concentrate containing 400 g a.i. litre^{-1} (Farmon CIPC 40, Farm Protection Ltd., Uppingham, Leicestershire).

Chlortoluron (N -(3-chloro-4-methylphenyl)-N,N-dimethylurea), as a wettable powder containing 80% w/w a.i. (Dicurane 80 WP, Ciba-Geigy (UK) Ltd., Agrochemical Division, Cambridge).

Isoproturon (N'-(4-isopropylphenyl)-N,N-dimethylurea), as a wettable powder containing 75% w/w a.i. (Arelon, Hoechst U.K. Ltd., Agricultural Department, Hounslow, Middlesex).

Experimental details

Moist soil was treated with herbicide to give a mean final concentration of 100 ppm active ingredient calculated on an oven dry basis. Treated and control soils were adjusted to field capacity by spraying on deionized water. Two 3kg replicates were prepared and these soils incubated in polyethylene bags at 23^{o}C for 30 weeks. Methods used for the application of the herbicides, incubation for CO_2 evolution and analysis of mineral nitrogen content have been described previously by GREAVES et al. (1978). Soil samples (50g) for measurement of mineral nitrogen were taken directly from the polyethylene bags 0, 1, 3, 5 and 9 weeks after herbicide application. These and samples (50g) taken every 6 weeks for residue analyses were stored at -15^{o}C until analysed.

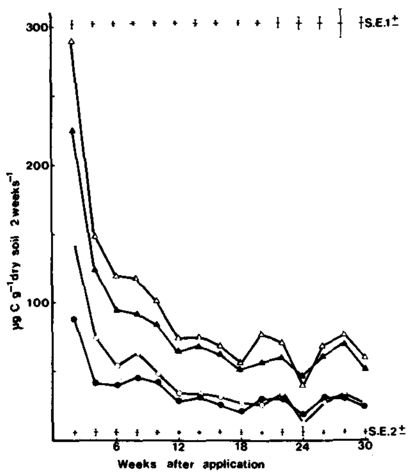
Herbicide residues were measured using the methods described by BYAST et al. (1977).

RESULTS

Chlorpropham

Carbon dioxide evolution from chlorpropham-treated soils was higher than from the control soils, although the differences became smaller during the latter half of the experiment (Fig. 1).

The effect of the herbicide on nitrogen transformation in the two soils differed. In Boddington Barn soil there was some indication of inhibition of nitrification for the first 3 weeks of incubation (Table 2) but at the same time stimulation of mineralization of nitrogen occurred (Fig. 2). In Triangle soil, however, there was inhibition of both nitrification and mineralization of nitrogen for the first 5 weeks (Table 2, Fig. 2). No nitrite was detected in the control or any of the herbicide-treated soils used in this experiment.



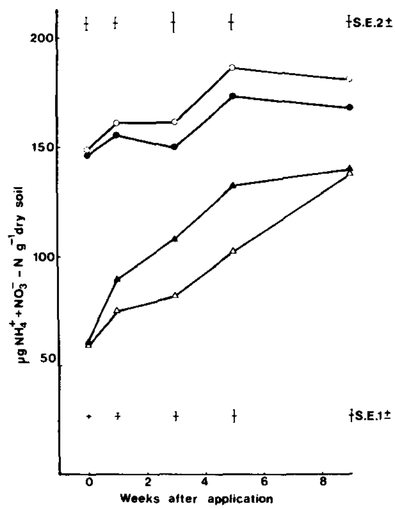


Fig. 1. The effect of chlorpropham on CO_2 output of 2 soils.

Fig. 2. The effect of chlorpropham on mineralization of nitrogen in 2 soils.

Triangle soil:

▲, control; △, chlorpropham; S.E.1, standard errors.

Boddington Barn soil:

●, control; ○, chlorpropham; S.E.2, standard errors.

TABLE 2

The effect of herbicides at 100 ppm on NH_4^+-N in soil

Soil	Treatment	Weeks of incubation 0	1	3	5	9
		µg NH_4^+-N g^{-1} dry soil				
Boddington Barn	control	1.7	<1.0	<1.0	1.3	1.2
	chlorpropham	2.0	7.0	4.5	1.1	2.1
	chlortoluron	1.7	1.7	1.3	2.7	1.8
	isoproturon	1.6	<1.0	1.1	2.1	1.6
	S.E. ±	0.57	0.29	0.41	0.45	0.38
Triangle	control	7.8	2.4	2.5	1.2	2.9
	chlorpropham	8.1	13.7	21.7	20.9	2.6
	chlortoluron	7.3	10.7	5.2	5.0	6.7
	isoproturon	8.0	6.8	3.8	3.4	3.9
	S.E.±	0.37	0.22	0.42	0.31	0.48

Chlorpropham degraded rapidly in both soils during the first 6 weeks after application, but the rate then declined and after 30 weeks, 5% of the original amount applied could still be detected.

Chlortoluron

Treatment of both soils with chlortoluron caused a small stimulation of CO_2 evolution above the control level for most of the incubation period (Fig. 3). This herbicide also stimulated nitrogen mineralization, the effect occurring sooner in Boddington Barn soil than in Triangle soil (Fig. 4). Nitrification was not reduced in Boddington Barn soil, however, in Triangle soil there was a small inhibition (Table 2).

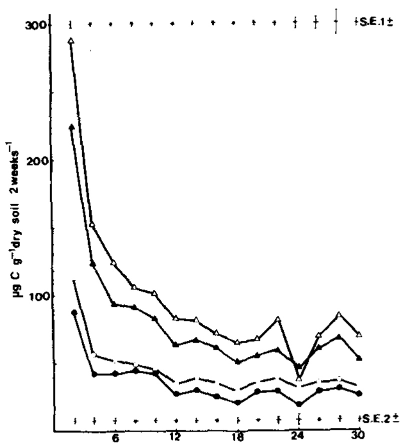


Fig. 3. The effect of chlortoluron on CO_2 output of 2 soils.

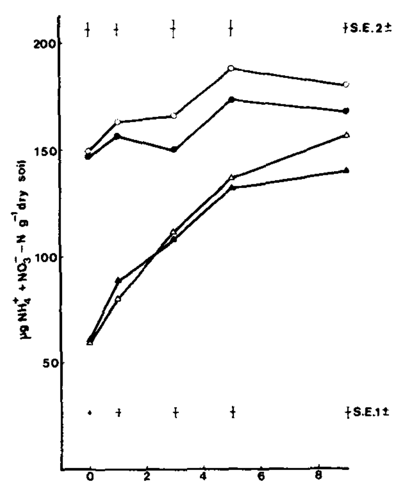


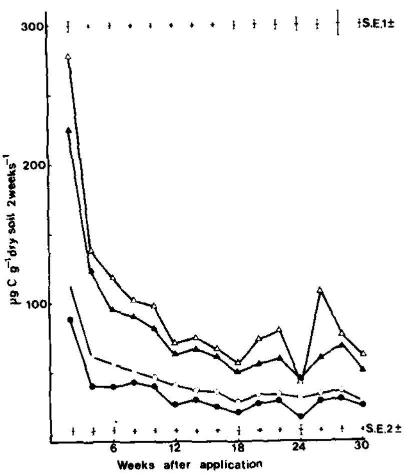
Fig. 4. The effect of chlortoluron on mineralization of nitrogen in 2 soils.

Triangle soil:
▲, control; △, chlortoluron; S.E.1, standard errors.
Boddington Barn soil:
●, control; ○, chlortoluron; S.E.2, standard errors.

Chlortoluron degraded slowly in both soils, 48% and 38% of that applied remaining in Boddington Barn and Triangle soils respectively after 30 weeks. The formation of a metabolite of chlortoluron was indicated by the presence of a second peak on the chromatograph. This has been tentatively identified as N-(3-chloro-4-methylphenyl)-N-methylurea, a known metabolite of chlortoluron (BYAST, T.H. personal communication).

Isoproturon increased CO_2 output of both soils above their control levels for most of the 30 week incubation period (Fig. 5). Mineralization of nitrogen was increased by this herbicide in both soils, but as with chlortoluron this effect occurred sooner in Boddington Barn soil (Fig. 6). There was a small effect on nitrification in Triangle soil (Table 2).

Residue analyses showed that isoproturon degraded at a similar rate in both soils with approximately 10% remaining in each soil after 30 weeks.



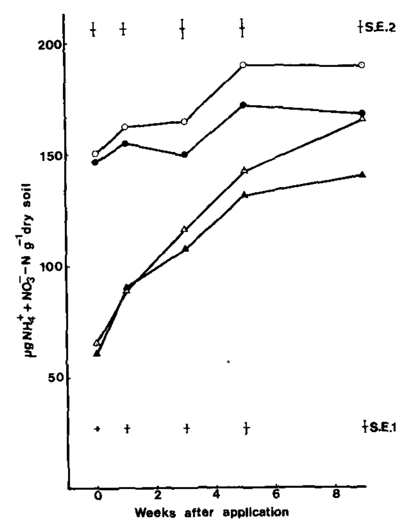


Fig. 5. The effect of isoproturon on CO_2 output of 2 soils.

Fig. 6. The effect of isoproturon on mineralization of nitrogen in 2 soils.

Triangle soil:

▲, control; △, isoproturon; S.E.1, standard errors.

Boddington Barn soil:

●, control; ○, isoproturon; S.E.2, standard errors.

DISCUSSION

Stimulation of CO_2 evolution following herbicide application to soil at rates higher than those used for normal field application has been observed for phenylcarbamates (TEATER et al. 1958; BARTHA, et al. 1967) and substituted ureas (GROSSBARD & MARSH 1974). The duration of this stimulation was usually only for the first few weeks and was sometimes followed by inhibition. In a short term experiment MATSUGUCHI & ISHIZAWA (1969) also obtained stimulation of CO_2 production over a range of concentrations of chlorpropham, but it was preceded by a period of inhibition. The work reported here shows an immediate stimulation which is maintained for much longer than described by other authors (TEATER et al. 1958; BARTHA et al. 1967; GROSSBARD & MARSH 1974). It is interesting that although chlortoluron was more persistent than chlorpropham and isoproturon they all increased CO_2 output. This agrees with GROSSBARD's (1976) view that increases in CO_2 output are not due entirely to carbon released by breakdown of the herbicide. Possibly the components of formulation may provide a readily available source of nutrients for the microorganisms resulting in either a proliferation of microbial numbers or an increase in their metabolic activity.

A temporary inhibition of nitrification by chlorpropham and chlortoluron was obtained in Triangle soil but not in Boddington Barn soil. Inhibition of nitrification by high concentrations of chlorpropham has been reported previously (TEATER et al. 1958; BARTHA et al. 1967; MATSUGUCHI & ISHIZAWA 1969). There has been less work published on isoproturon and chlortoluron, although REICHLOVÁ (1975) did show some reduction of nitrification both at normal and ten times field rates of chlortoluron. The absence of any inhibition in Boddington Barn soil may be related to the pH and organic matter content of the soil as discussed previously by DAVIES & MARSH (1977) and MARSH & DAVIES (1977).

Mineralization of nitrogen was affected differently by chlorpropham in these soils, being inhibited in Triangle soil, but stimulated in Boddington Barn soil. Similar variations in response of microorganisms to herbicides in these soils have been noted previously (DAVIES & MARSH 1977; MARSH & DAVIES 1977). Chlortoluron and isoproturon increased mineralization of nitrogen in both soils compared with controls. An increase in mineral nitrogen production has also been obtained with chlortoluron at normal and 10-fold field rates by REICHLOVÁ (1975). Such increases occur with other herbicides and possible explanations are discussed by MARSH et al. (1977).

The results published here indicate that, if used as recommended, these herbicides will not have effects, on either of the microbial activities tested, which will be of agricultural importance. However, the differences in effects observed on the two soils suggest that it is important to test the effects of herbicides on microorganisms in soils with different characteristics if the herbicide is likely to be used in a wide range of soils.

ACKNOWLEDGEMENTS

We wish to thank Dr. K. Holly and Dr. E. Grossbard for help and advice throughout this work, Mr. B.O. Bartlett and Mrs. S. Ridge of the joint Letcombe/WRO Statistics Section for statistical analyses, Mr. T.H. Byast and Mr. E.G. Cotterill of WRO Chemistry Section for residue analyses, Miss C.J. Standell for technical assistance and the manufacturers for supplying the herbicides.

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