Dissipation of Thiobencarb Concentration in Soil Solution under an Upland Field Condition and Its Herbicidal Activity*

Yasuhiro Yogo**, Do-Jin Lee***, Katsuichiro Kobayashi*** and Hiroshi Sugiyama**

Abstract: An emulsifiable concentrate of thiobencarb, S-(4-chlorobenzyl) diethylthiocarbamate (active ingredient: 50%, Saturn®), was applied at 15 kg a.i./ha to an upland field just after sorghum (*Sorghum bicolor*) sowing. Thiobencarb concentration in soil solution and centrifuged soil began to decrease 7 days after application (DAA) in 0-5 cm from the soil surface. The ratio of thiobencarb concentration between the soil solution and the centrifuged soil was about 2% at 0 DAA and decreased to ca. 0.4% at 11 DAA. Sorghum growth was suppressed within 2 weeks in the field. In the laboratory, sorghum sensitivity to thiobencarb was closely related to the initial concentration in the soil solution of 0-1 cm from the soil surface, in which most thiobencarb was distributed. Consequently, it was supposed that herbicidal activity of soil-applied thiobencarb on sorghum was largely dominated by the initial concentration in soil solution in the soil surface under an upland field condition.

Key words: thiobencarb, soil solution, upland field condition, herbicidal activity

Introduction

Numerous laboratory and field studies on herbicides in soil solution have been reported under upland conditions. Laboratory studies^{1~3,6,10,13,14} have focused on adsorption/desorption characteristics in relation to soil moisture, and adsorption/desorption balance were found to be affected by physicochemical characteristics of each chemical and soil characteristic. Some laboratory⁸⁾ and field studies⁹⁾ sought to clarify the relationship between the herbicide in soil solution and its efficacy, however, only limited information is still available to apply their relationship to practical weed control. Our previous field studies on pendimethalin (*N*-(1-ethylpropyl)-2,6-dinitro-3,4-xylidine)¹¹⁾ and metolachlor (2-chloro-2'-ethyl-*N*-(2-methoxy-1-methylethyl)-6'-methylacetanilide)¹²⁾ using water extraction method suggested that the herbicidal activity in an upland condition was closely related to water-soluble ingredients, but not to water-insoluble or acetone-soluble ingredients. We^{4,7)} also found that the herbicidal activity and the mobility of soil-applied thenylchlor (2-chloro-*N*-(3-methoxy-2-thienylmethyl)-2',6'-dimethylacetanilide) was dominated by its concentration in soil solution, which depended on the adsorption/desorption balance, by introducing a double centrifugation tube to separate the soil solution⁹⁾. These studies, however, were conducted only under water saturated conditions and the herbicide was incorporated into

* A part of this study was presented at the 34th Annual Meeting of the Weed Science of Japan in April, 1995.

** National Agricultural Research Center (NARC), Tsukuba, Ibaraki 305, Japan.

*** Institute of Applied Biochemistry, University of Tsukuba, Ibaraki 305, Japan.

(Received July 13, 1995)

soil *in vitro*.

Thiobencarb, *S*-(4-chlorobenzyl) diethyl-thiocarbamate, is widely used in paddy and upland fields in Japan as a pre-emergence soil-applied herbicide against annual monocotyledonous and dicotyledonous weeds. The objective of this work was to elucidate the dissipation of thiobencarb in soil solution under an upland field condition in relation to its herbicidal activity; laboratory studies were conducted to analyze above relationship in detail.

Materials and Methods

Field study

The trial was conducted during 1994 in an upland field of the National Agricultural Research Center (Kannondai, Tsukuba, light-colored andosol, total carbon: 3.29%, total nitrogen: 0.29%, phosphate adsorption coefficient: 2,241, cation exchange capacity: 19.0 me/100 g, clay content: 12.0%). Sorghum (*Sorghum bicolor*), which is relatively sensitive to thiobencarb and selected as an indicator plant for this study, was sowed in 50 cm long rows 5 cm apart, at a depth of 3 cm on May 20th, 1994. On the same day, an emulsifiable concentrate of thiobencarb, *S*-(4-chlorobenzyl) diethyl-thiocarbamate (active ingredient: 50%, Saturn®), was applied at 5 and 15 kg a.i./ha with a CO₂-pressurized boom sprayer (3 kg/cm², flat fan nozzle, spray volume: 100 ml/m²). Soil was sampled at 0-5 cm depth at 0, 3, 5, 7, 11, 20, 32, 46 and 62 days after application, and stored in a deep freezer (-20°C) immediately after sampling until further analysis.

Sorghum growth was also periodically evaluated on plant height, top fresh weight, emergence rate and leaf development. Each treatment was conducted in six replications.

Extraction and determination of thiobencarb

The sampled soil was divided into soil solution and centrifuged soil by centrifugation with stainless double tubes as described⁴⁾. Thiobencarb in the soil solution and the centrifuged soil was extracted and prepared for further analysis by a method similar to that used for thenylchlor⁴⁾. The amount of thiobencarb in the prepared solution was determined by gas chromatography (HP-5890) with NP-FID using a glass column packed with 2% OV-101 on 100-120 mesh chromosorb W operating at 200°C. The carrier gas was nitrogen, air and hydrogen at 25, 100, 3.5 ml/min, respectively. The detector and injection port was held at 300 and 280 °C, respectively. The detectable limit of thiobencarb was 0.05 ppm and recoveries from the centrifuged-soil and soil solution exceeded 90%.

Thiobencarb distribution in soil layer in laboratory study

Since thin layer soil sampling was difficult in the field trial, the vertical distribution of thiobencarb at application was simulated in a greenhouse. Four plastic rings (10 cm in diameter, 1 cm of high) were piled up and fastened with Parafilm® (American National Can). The moisture of air-dried Kannondai soil was adjusted by distilled water to about 33% (liquid/total, w/w). The soil was then placed in the rings and put in the greenhouse at 25 to 28°C. The soil layers were separated 3 hours after thiobencarb spraying at 5, 15 kg a.i./ha with the same spray equipment as used in the field study. Thiobencarb was extracted from each soil layer, and the amount was determined as described above.

Sorghum sensitivity to thiobencarb with water culture

Ten g of sea sand (20-35 mesh) was put into glass vials (25 mm diameter, 70 mm high), and

Fig. 1. Changes in thiobencarb concentration in soil solution and centrifuged soil over period of time.

3.5 ml of thiobencarb solution was applied at a given concentration. Three sorghum seeds were then put onto the sea sand and covered by 8 additional grams of the sand. Shoot length of sorghum was measured 5 days after application.

Each treatment of soil layer and sensitivity was performed with three replicates.

Results and Discussion

Dissipation of thiobencarb under upland field condition

The soil moisture (liquid/total, w/w) at sampling was 33.9, 33.4, 32.0, 48.3, 41.1, 38.7, 39.8, 33.1, and 33.8% at 0, 3, 5, 7, 11, 20, 32, 46, and 62 days after application (DAA), respectively, and the precipitation during the trial is shown in Figure 1A, B and Figure 2. In the

Fig. 2. Change in the ratio of thiobencarb concentration between soil solution (A) and centrifuged soil (B) over period of time.

0–5 cm soil sampling at 15 kg a.i./ha of thiobencarb application, the concentration in the soil solution and the centrifuged soil at application was about 4×10^{-6} M and 2×10^{-4} M, respectively (Figure 1A, B). Most of the thiobencarb was distributed in the centrifuged soil, and the ratio of thiobencarb concentration between the soil solution and the centrifuged soil was about 2% at application (Figure 2). The concentration in the solution and the centrifuged soil began to decrease greatly 7 DAA, and the concentration at 11 DAA was about 4% and 17% of the initial concentration, respectively (Figure 1A, B). The herbicide concentration in soil solution thus decreased with time^{1,8,11,12,14}). This study supported earlier results, although the chemicals were different from those used in previous studies. The above ratio also decreased to ca. 0.4% at 11 DAA, and then ratio gradually increased to about 2% at 62 DAA. Decrease in the ratio is assumed to be explained by 1) the high soil adsorption coefficient of thiobencarb, resulting in the decrease of concentration in soil solution as the dissipation of total chemical amount in soil^{6,13}), and 2) herbicide micro-movement into a more adsorptive site or condition in soil, corresponding to a lower concentration

Table 1. Vertical distribution of thiobencarb in soil just after application.

Thiobencarb distribution in soil	Soil layer (cm)	Concentration ($\times 10^{-5}$ M)	
		5*	15*
Soil solution (A)	0-1	2.4	7.3
	1-2	trace	trace
Centrifuged soil (B)	0-1	41.8	154
	1-2	trace	trace
Ratio (A/B, %)	0-1	5.7	4.7
	1-2	—	—

*: Application dosage (kg a.i./ha)

in soil solution¹⁾; the increase tendency at 20 DAA or later, however, could not be explained.

Such changes in time course were also observed when applied at 5 kg a.i./ha, although the data at 20 DAA and later were below the detectable limit of thiobencarb (data not shown).

Vertical distribution of thiobencarb just after application

Most of the thiobencarb was distributed in the 0-1 cm soil surface layer, and the concentration in soil solution (7.3×10^{-5} M) was almost 20 times that of the 0-5 cm soil in the field (Figure 1, Table 1), although the concentration in centrifuged soil was about 8 times that in the field. In general, highly adsorp-

tive chemicals were substantially and rapidly adsorbed by the soil, most of them within 1 day, followed by subsequent slow adsorption, which may affect further decrease of the chemical concentration in soil solution¹⁾. It is assumed that such a large portion of thiobencarb was distributed in soil solution in 0-1 cm soil surface at application, because the initial adsorption process was not terminated within 3 hours, and free thiobencarb in the field trial was diluted and adsorbed to other soil particles in deeper layers by mixing.

Sorghum response to thiobencarb in soil in the field and in water culture

Sorghum growth was suppressed in the field applied with thiobencarb at 5 or 15 kg a.i./ha within 2 weeks, and then recovered gradually in respect to plant height, top fresh weight, and leaf development (Table 2). In the laboratory, a 50% and an 80% inhibitory dose of thiobencarb was 1×10^{-5} M and 8×10^{-5} M in water culture, respectively (Figure 3), approximately identical with the initial concentration in the soil solution 0-1 cm from the soil surface (7.3×10^{-5} M).

Consequently, it was supposed that the effect of thiobencarb on sorghum was largely dominated by the initial concentration of the

Table 2. Effect of thiobencarb on sorghum growth in upland field condition.

	Dosage (kg a.i./ha)	Plant height (mm)				TFW*/plot (g)				TFW/plant (mg)				Leaf stage		Emergence rate (%)	
		14	28	46	61	14	28	46	61	14	28	46	61	14	28	14	28
Growth rate (/day)**	0	3.6	5.3	19.2	51.2	0.2	0.4	8.7	76.4	8.9	20	496	4803	0.15	1.8	1.4	-0.2
	5	2.3	4.4	14.9	53.8	0.1	0.2	6.7	66.2	7.2	11	462	5035	0.15	0.20	1.0	-0.2
	15	1.4	1.6	8.6	45.3	0.1	0.0	2.6	32.9	5.3	7	288	3085	0.10	0.18	0.6	-0.4
Inhibition (%)	5	36	25	23	6	27	50	25	15	20	39	8	-3	2	-3	30	37
	15	60	66	65	36	45	78	77	62	41	58	55	42	31	14	56	79

*: TFW=Top Fresh Weight

** : The growth response was calculated as follows ("n" means number of evaluation timings) :
[evaluation data (n) - evaluation data (n-1)] / interval between n and n-1 (days)

Fig. 3. Sensitivity of sorghum to thiobencarb in water culture.

herbicide in soil solution in the surface soil under an upland condition. This study confirms that the herbicide concentration in soil solution can be a more precise indicator of herbicide efficacy than total herbicide amount in soil, although further studies are needed to apply this to practical weed control, especially as it relates to soil sampling in the field, different soil types/conditions, and different chemicals under field conditions.

Acknowledgements: The authors are grateful to Kumiai Chemical Co. Ltd. for providing Saturn® emulsifiable concentrate and thiobencarb technical.

References

- 1) Gaillardon, P., F. Fauconnet, P. Jamet, G. Soulas and R. Calvet 1991. Study of diuron in soil solution by means of a novel simple technique using glass microfibre filters. *Weed Res.* **31**, 357-366.
- 2) Goetz, A.J., G. Wehtje, R.H. Walker and B. Harjek 1986. Soil solution and mobility characterization of imazaquin. *Weed Sci.* **34**, 788-793.
- 3) Green, R.E. and S.R. Obien 1969. Herbicide equilibrium in soil in relation to soil water content. *Weed Sci.* **17**, 514-519.
- 4) Kobayashi, K., M. Onoe and H. Sugiyama 1994. Thenylchlor concentration in soil water and its herbicidal activity. *Weed Res., Japan* **39**, 160-164.
- 5) Lambert, S.M. 1966. The influence of soil-moisture content on herbicidal response. *Weeds* **14**, 273-275.
- 6) Malik, N. and D.S.H. Drennan 1989. Adsorption-desorption equilibria of 14 C-fluridone at low solution concentrations and soil: water ratios. *Can. J. Soil Sci.* **69**, 567-577.
- 7) Onoe M., D.J. Lee, K. Kobayashi and H. Sugiyama 1995. Herbicidal activity of soil-applied thenylchlor and its mobility in two paddy soils. *Weed Res., Japan* **40**, 75-79.
- 8) Patterson, M.G., G.A. Buchanan, R.H. Warker and R.M. Patterson 1982. Fluometoron in soil solution as an indicator of its efficacy in three soils. *Weed Sci.* **30**, 688-691.
- 9) Seto, M. 1980. Rate of CO_2 evolution from soil in relation to content of soil water and amount of dissolved organic carbon in soil solution. *Japanese J. Ecol.* **30**, 385-391.
- 10) Smith, C.N. and R.F. Carsel 1986. A stainless-steel soil solution sampler for monitoring pesticides in the vadose zone. *Soil Sci. Soc. Am. J.* **50**, 263-265.
- 11) Sugiyama H., K. Komamiya and K. Kobayashi 1990. Changes in the concentration of residues of pendimethalin applied to soil and effect on plant growth (in Japanese with English Summary). *Weed Res., Japan* **35**, 122-128.
- 12) Sugiyama H. and K. Kobayashi 1993. Herbicidal activity and residual states of metolachlor in upland soil. *Weed Res., Japan* **38**, 300-306.
- 13) Streibig, J.C. 1982. Relationship between soil-applied pyrazon and content in soil solution. *Weed Sci.* **30**, 527-531.
- 14) Wolt, J.D., G.N. Rhodes, J.G. Graveel, E.M. Glosauer, M.K. Amin and P.L. Church 1989. Activity of lazaquin in soil solution as affected by incorporated wheat (*Triticum aestivum*) Straw. *Weed Sci.* **37**, 254-258.

畑圃場におけるチオベンカーブの土壤溶液中濃度の消長と殺草活性

與語靖洋*・李 度鎮**・小林勝一郎**・杉山 浩*

摘 要

畑圃場におけるチオベンカーブの土壤中の消長について、二重遠心管を用いた遠心分離法により、土壤溶液および遠心残渣土（遠心土）に分け、存在形態の経時的变化および殺草活性との関連性について検討した。チオベンカーブ（50% 乳剤）15 kg a.i./ha 処理において、本剤の大半が遠心土中に存在しており（Fig. 1）、両者の分配比（土壤溶液中濃度/遠心土中濃度）は処理当日においては約 2% であった。土壤溶液および遠心土中濃度は、処理 7 日後から急激に減少し始め、その後さらに減少した。また分配比は、処理 7 日後から減少し始めたもの

の、処理 20 日後から処理時程度まで増加した（Fig. 2）。室内実験では、散布処理したチオベンカーブは、土壤表層 1 cm 以内にそのほとんどが分布し、土壤溶液中濃度は圃場試験において 5 cm 深で採取した場合に比べ、20 倍近くであった（Table 1）。一方、チオベンカーブのソルガムに対する影響については、処理後 2 週間以内に全ての調査項目において生育阻害が観察されたが、その後生存個体では、葉齢に続いて草丈・新鮮重が回復したことから、処理後 2 週間以内の作用がその後の生育に強く影響していることが明らかとなった（Table 2）。水耕法でのソルガムのチオベンカーブ感受性の結果（Fig. 3）も合わせて考えると、土壤表層（1 cm 以内）における処理 1 週間以内の土壤溶液中の薬剤濃度がソルガムに対する生育抑制効果に大きく関与していると推測される。

キーワード：チオベンカーブ、土壤溶液、畑圃場、殺草活性

* 農業研究センター

** 筑波大学応用生物化学系