J. Pesticide Sci. **10**, 211–216 (1985)

Original Article

Flowable Formulation of Selective Herbicide S-3552

Fumio HORIDE, Hiroshi FUYAMA, Ryo YOSHIDA and Kozo TSUJI

Pesticides Research Laboratory, Takarazuka Research Center, Sumitomo Chemical Co., Ltd., Konohana-ku, Osaka 554, Japan

(Received October 27, 1984)

Flowable formulation containing melt crystal of S-3552 gave good physico-chemical properties, especially lower viscosity, while the one containing recrystallized material showed high viscosity. Herbicidal activity of S-3552 flowable formulation is almost the same or little inferior to that of EC formulation. Addition of specified surfactant to flowable formulation itself or its spray liquid improved herbicidal activity of S-3552 flowable formulation. Addition of the surfactant to the formulation caused remarkable crystal growth after storage, which was supposed to be due to Ostwald ripening. S-3552 flowable formulation has characteristics such as lower irritation on mucous membrane and lower acute oral toxicity in mouse than EC formulation.

INTRODUCTION

S-3552 [*N'*-4-(4-methylphenethyloxy)phenyl-*N*-methoxy-*N*-methylurea] is a foliar application herbicide invented by Sumitomo Chemical Co., Ltd. Chemical structure is shown in the previous paper.[1)]

S-3552 shows excellent herbicidal activity against troublesome broadleaf weeds in soybean and high soybean selectivity by post-emergence foliar application.[2–5)]

High content EC formulation of S-3552 is formulated with difficulty due to low solubility of S-3552 in xylene and cyclohexanone *etc.* which are usually used for EC formulation as solvents. However, it has been reported in an earlier paper that S-3552 30 EC could be formulated by using phenol as a co-solvent.[1)] On the other hand, aqueous flowable (FL) formulation (Suspension Concentrate) which has recently been given attention, has characteristics of non inflammability, lower irritation and lower toxicity due to no or less amount of organic solvents in comparison with EC formulation. FL formulation also has characteristics of no dustiness at the time of dilution, is easy to measure for dilution and has generally high biological activity due to smaller particle size of active ingredient in comparison with WP formulation. This paper presents the results of research work on S-3552 FL formulation.

EXPERIMENTAL

1. Materials

S-3552 was synthesized in the Pesticide Synthetic Section, Pesticides Research Laboratory, Takarazuka Research Center, Sumitomo Chemical Co., Ltd. Auxiliary materials used for formulation were of technical grade, and water used for formulation was distilled and deionized.

2. Methods

2.1 Preparation of recrystallized material and melt crystal

a. Recrystallized material

One part of crude S-3552 was dissolved in one part of toluene at 50 to 60°C. About six parts of *n*-hexane was added into the solution drop by drop and the solution was cooled to 5°C which resulted in precipitation of S-3552 crystal. The crystal was washed with chilled

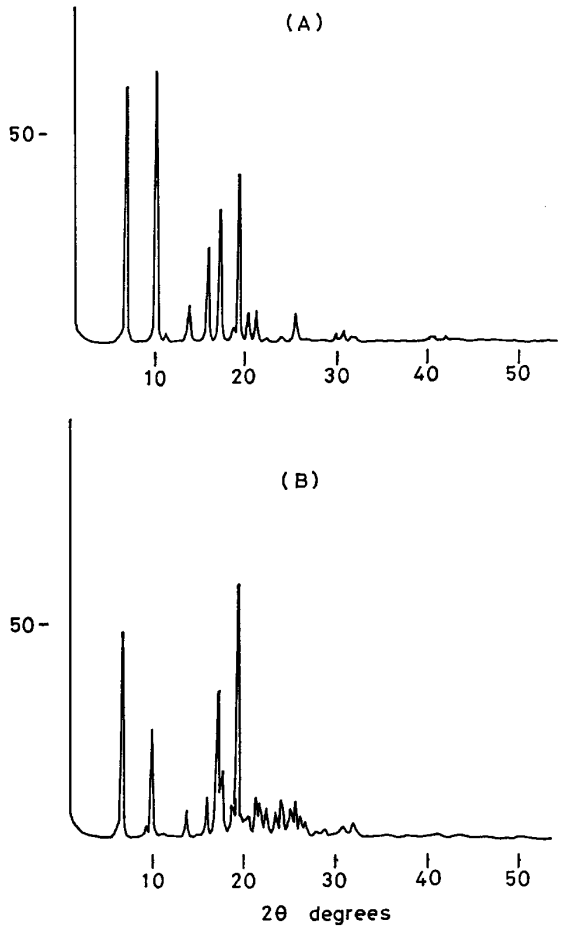

Fig. 1 X-ray diffraction patterns of S-3552. (A): recrystallized material, (B): melt crystal.

mixed solvent of toluene and *n*-hexane and the solvent was removed under reduced pressure to obtain recrystallized material.

b. Melt crystal

S-3552 was melted by heating at about 90°C for 15 min. After cooling the melt to room temperature, the lump of the material was crushed by a hammer, followed by further pulverization by a juice mixer to obtain powder under 20 mesh. X-ray diffraction pattern of the melt crystal is slightly different from that of recrystallized material, as shown in Fig. 1. Therefore crystal form of the melt crystal seems to be slightly different from that of recrystallized material.

2.2 Formulation of FL (400 g scale)

Correct amounts of S-3552, dispersing agent and water were added to a vessel (1000 ml) of the sand mill (Igarashi Co., Ltd.) and wet-grinded with glass beads (1 mmϕ, one and quarter of the dispersing liquid) for 2 hr. Particle size distribution of S-3552 does not change significantly even if S-3552 is wet-grinded for a much longer time. S-3552 FL formulation was obtained by the addition of a thickener to the wet-grinded dispersing liquid after separating the glass beads.

2.3 Determination of particle size distribution

Particle size distribution was determined by means of coulter counter (Coulter Electronics) and centrifugal particle size analyzer CP-2 (Shimadzu).

2.4 X-ray diffraction

Shimadzu DX-5A (DP-51) was used for this study.

2.5 Herbicidal activity test

Herbicidal activity tests were carried out by the method described in an earlier paper.[1)]

RESULTS AND DISCUSSION

1. Formulation

S-3552 is generally obtained by recrystallization with organic solvents such as toluene and *n*-hexane and is needle crystal having a melting point of 82–83°C. FL formulation is generally formulated by wet-grinding using glass beads, but, in the case of needle crystal, pulverizability of the material is not very good. FL formulation which has a mean diameter of particles less than 3 μm measured by a coulter counter and a centrifugal particle size analyzer could be formulated but a large amount of needle crystal particles larger than 10 μm in length are observed by microscope. This difference seems to be caused by the fact that particle size distribution obtained by these methods is based on the assumption of the spherical shape particles.

As for physico-chemical properties of S-3552 20% FL formulation using recrystallized material, viscosity of the formulation became high (*ca.* 7000 cps), which could be attributed to the structural viscosity of the needle crystal. Therefore low viscosity FL formulation of S-3552 content higher than 25% is hard to be formulated. In order to formulate FL formulation of low viscosity, effect of preparation method of S-3552 technical material on physicochemical properties of FL formulation was studied. Instead of the recrystallized material, melt crystal was used. By using the melt crystals, pulverizability by the sand mill and

Table 1 Properties of S-3552 20% and 40% FL formulations.

Items	40 FL	20 FL
Viscosity[a] (cps)	2100	2000
Average diameter (μm)	2.5	2.4
Accelerated storage stability a.i. content (%)		
Initial	41.6	21.0
40°C, 1 M	41.4	21.0
50°C, 1 M	41.0	20.9
Dispersion stability		
Initial	Uniform	Uniform
40°C, 1 M	Uniform	Uniform
50°C, 1 M	Uniform	Uniform

[a] B-type viscometer, No. 2 rotor, 6 rpm.

high viscosity due to the structural viscosity were improved. Viscosity was reduced to 2100 cps, and moreover 40% FL could be readily formulated. Properties of the formulation using melt crystal are shown in Table 1.

2. Biological Efficacy

Herbicidal activity of FL formulation is superior to that of WP formulation, as described in the earlier paper.[1] The difference of the activities between FL and WP is thought to be due to the difference of particle size of S-3552. FL formulation has smaller particle size than WP formulation. Average particle sizes of FL and WP are about 2.5 μm and 5 μm, respectively, and as will be shown later for FL formulation, smaller particles will give better herbicidal activity.

Herbicidal activity of FL formulation is almost the same or slightly less than that of EC formulation, as described in the earlier paper.[1] This difference may be caused by difference in penetration of S-3552 *via* cuticular layer of the weed leaves. In the case of EC, S-3552 is in emulsion after dilution, and particle size will be smaller, even if crystals appear after spraying. Surfactants and/or solvents play an important role in the physical state of S-3552, which could have an effect on penetration. In practice, the addition of 10% of specified surfactant such as polyoxyethylene alkylaryl ether into the S-3552 20% FL increases herbicidal activity, as shown in Table 2.[6]

In this case, herbicidal activity of FL formulation is almost the same or slightly less than that of EC formulation and especially, under the wet condition such as the summer season in Japan, FL formulation shows almost the same herbicidal activity as EC formulation. But addition of the surfactant caused crystal growth, as described in the next section. On the other hand, the addition of the surfactant into the spray liquid of S-3552 FL also increased herbicidal activity. Therefore it is clear that the addition of the surfactant into the spray liquid of S-3552 FL avoids the crystal growth of S-3552 and increases herbicidal activity.

The relationship between the particle size and herbicidal activity of S-3552 FL was studied using particles with average diameter of 2.5 μm and 4.0 μm. S-3552 FL which contained smaller particles showed higher herbicidal activity, as shown in Table 3. Therefore it is clear that smaller particles are desirable for herbicidal activity.

Table 2 Effect of the surfactant on herbicidal activity of S-3552 20% FL formulation (S-3552/surfactant=20/10).

Surfactant	Dose of A.I. (kg/ha)	Morning-glory	Velvet-leaf	Large crabgrass	Barnyard grass
None	0.25	3	4	0	0
	0.5	4	5	1	0
	1.0	5	5	2	2
Polyoxyethylene (10 mol) alkylarylether	0.25	4	5	2	2
	0.5	5	5	3	3
	1.0	5	5	4	3

5: complete kill–0: no effect.

Table 3 Effect of particle size on herbicidal activity of S-3552 20% FL formulations.

Particle size	Dose of A.I. (kg/ha)	Morning-glory	Velvet-leaf	Large crabgrass	Barnyard grass
Average diameter (2.5 μm)	0.25	4	4	0	0
	0.5	5	5	1	0
	1.0	5	5	2	2
Average diameter (4.0 μm)	0.25	3	4	0	0
	0.5	4	5	0	0
	1.0	5	5	1	1

5: complete kill–0: no effect.

Table 4 Number of particles (%) in each classified particle size before and after storage at 40°C for 7 days.

Particle size (μm)	Recrystallized material		Melt crystal	
	Before storage	After storage	Before storage	After storage
<1.6	41.3	23.1	33.8	41.5
1.6–2.0	35.7	23.9	25.5	31.8
2.0–2.5	17.4	21.5	19.5	17.6
2.5–3.2	4.5	15.7	12.4	6.7
3.2–4.0	0.8	10.1	6.4	2.0
4.0–5.0	0.1	4.3	2.0	0.4
5.0–6.4	—	1.1	0.4	0.1
>6.4	—	0.2	—	—

3. *Crystal Growth*

When polyoxyethylene (6–15 mol) alkylarylether was added to the FL formulation, remarkable crystal growth was observed after storage at 40°C for 14 days, as shown in Fig. 2. As for crystal growth rate, a little difference was observed between recrystallized material and melt crystal, and crystal growth of recrystallized material was slightly faster than that of the latter one. Table 4 shows number of particles in each classified particle size measured by a coulter counter before and after storage at 40°C. In the case of melt crystal, apparent numbers of smaller particles less than 2.0 μm increases after storage at 40°C, and in this case needle crystal was observed, as shown in Fig. 3. This phenomenon may be due to the change in crystal shape. Needle crystal gave smaller particle size by coulter counter than visual observation, even if the volume of the particles was the same.

Solubility of S-3552 in 10% aqueous solution of the surfactant was higher than 500 ppm while that in water was 2–3 ppm at room temperature. Therefore the crystal growth seems to be due to Ostwald ripening.[7,8]

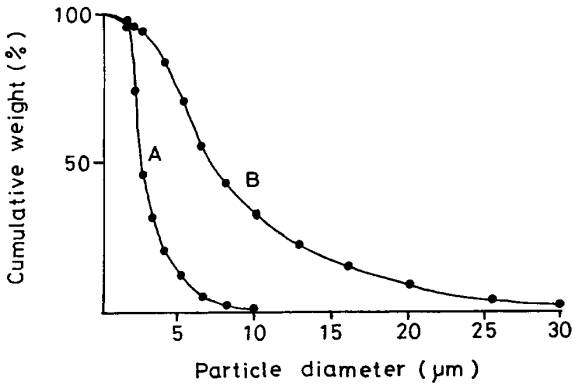

Fig. 2 Particle size change after accelerated storage of S-3552 20% FL formulation containing 10% of polyoxyethylene alkylarylether, measured by a coulter counter (recrystallized material).

A: before storage, B: after storage at 40°C for 14 days.

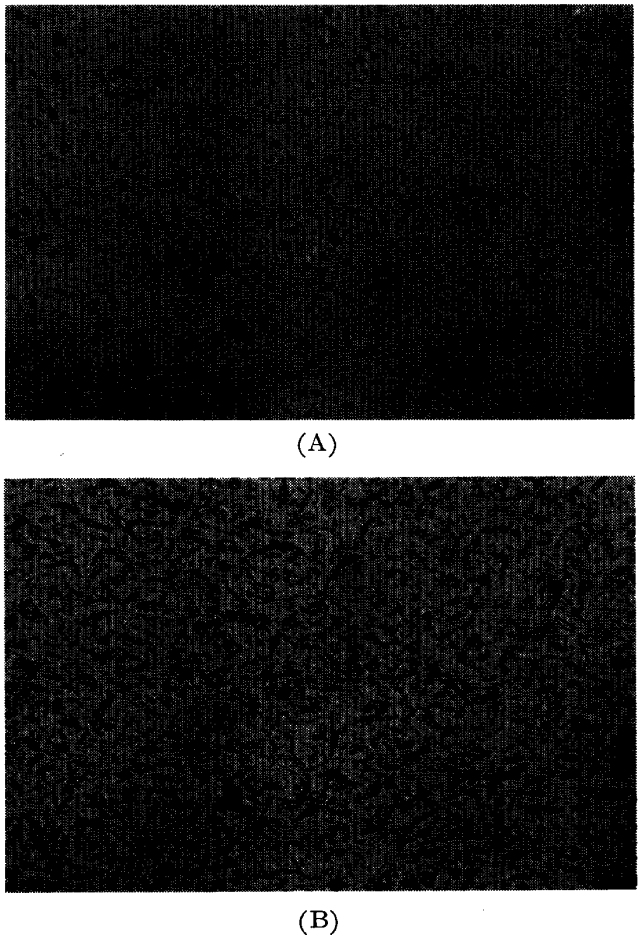

Fig. 3 Particle size and shape change after accelerated storage of S-3552 20% FL formulation (melt crystal).
(A): before storage, (B): after storage at 40°C for 7 days.

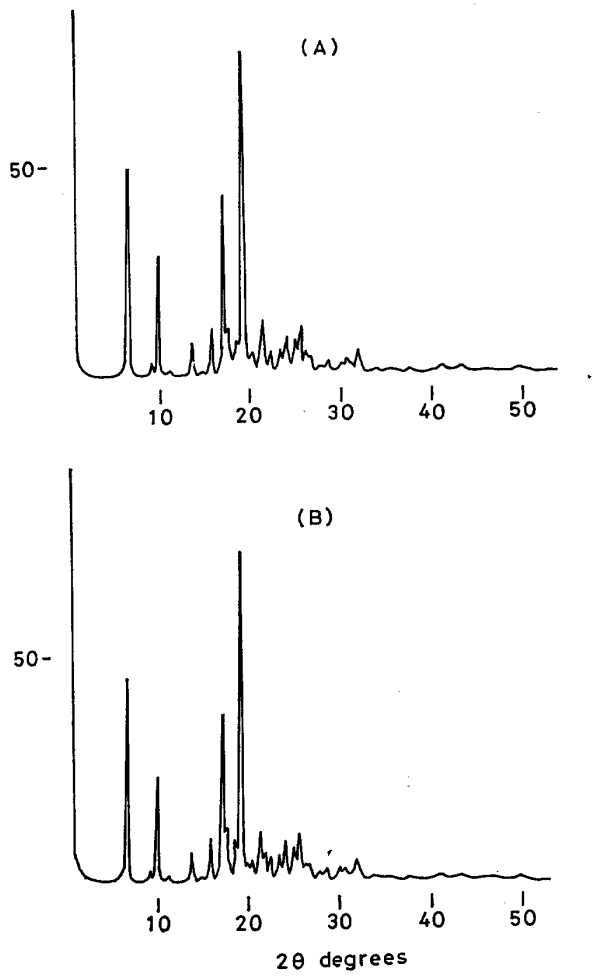

Fig. 4 X-ray diffraction patterns of S-3552 in FL formulation after accelerated storage.
(A): recrystallized material, (B): melt crystal.

X-ray diffraction pattern of recrystallized material in FL formulation after storage at 40°C was slightly different from that before storage and it was almost the same as those of melt crystal in FL formulation before and after storage, as shown in Fig. 4. Therefore melt crystal is thought to be a stable form.

4. Toxicity

Irritation of S-3552 FL formulation on the eyes of a rabbit was found to be clearly weaker than that of S-3552 EC formulation by the test in accordance with EPA guideline [*Federal Register* **43**, 37359–37360 (1978)], as shown in Table 5. Therefore irritation on mucous membrane of S-3552 FL formulation is said to be weaker than that of S-3552 EC formulation. In addition, LD_{50} of acute oral toxicity of S-

Table 5 Irritation on the eyes of a rabbit of S-3552 formulations.

Formulation	Irritation
20 FL	None
20 EC	Moderate

Table 6 Acute oral toxicity in mice of S-3552 formulations.

Formulation	LD_{50} (mg/kg)	
	Male	Female
20 FL	>5000	>5000
20 EC	1340	1680

3552 FL formulation in mouse was higher than 5000 mg/kg while that of S-3552 EC formulation was about 1500 mg/kg, as shown in Table 6. Therefore it is said that S-3552 FL formulation has characteristics of weaker irritation on mucous membrane and lower acute oral toxicity.

ACKNOWLEDGMENTS

The authors are indebted to the Sumitomo Chemical Co., Ltd. for permission to publish these results. Thanks are due to Messrs. S. Hara and T. Suzuki for the toxicity test.

REFERENCES

1) F. Horide, K. Tsuji & R. Yoshida: *J. Pesticide Sci.* **9**, 623 (1984)
2) R. Yoshida, I. Takemoto, K. Kamoshita & S. Sumida: *Chem. Regul. Plants* **16**, 142 (1981)
3) R. Yoshida, I. Takemoto, T. Satomi, K. Kamoshita & S. Sumida: *Weed Res.* **26**, 129 (1981)
4) I. Takemoto, R. Yoshida, S. Sumida & K. Kamoshita: Abstr. 5th Int. Congr. Pestic. Chem. (IUPAC), IId-13, 1982
5) R. Yoshida, I. Takemoto, S. Sumida & A. Mine: Abstr. 5th Int. Congr. Pestic. Chem. (IUPAC), IVd-9, 1982
6) H. Fuyama & K. Tsuji (Sumitomo Chemical Co., Ltd.): Jpn. Pat. (unexamined) 56–73010 (1981)
7) Th. F. Tadros: *Adv. Colloid Interface Sci.* **12**, 141 (1980)
8) Th. F. Tadros: "Particle Growth in Suspension," ed. by A. L. Smith, SCI Monograph, Academic Press, London, p. 221, 1973

要　　約

選択性除草剤 S-3552 のフロアブルの製剤

堀出文男，麩山　浩，吉田　亮，辻　孝三

再結晶で得られた針状結晶の S-3552 原体を用いてフロアブル製剤を製剤する際，構造粘性に起因する高粘度の問題があったが溶融原体を用いると粘度も高くならず良好なフロアブル製剤が得られた．フロアブル製剤の除草活性は乳剤と比べて劣ったが特定の界面活性剤をフロアブル製剤またはその希釈液に添加することによって増大することができた．しかし界面活性剤をフロアブル製剤中に添加すると経時変化によって顕著な結晶成長が認められ，この成長は Ostwald ripening によるものと考えられた．S-3552 フロアブル製剤は乳剤に比べて粘膜に対する刺激性も弱くさらにマウスに対する急性経口毒性もかなり低い特徴を有していた．