# DEVELOPMNENT AND PENENETRATION OF GAS-BARRIER FILMS FOR JAPANESE HORTICULTURE

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1,3-dichloropropne (1,3-D), chloropicrin (CP) and methyl isothiocyanate (MITC) are major fumigants used in Japan to control soil-borne diseases in crops such as cucumbers, gingers, tomatoes, melons, green peppers, etc. For now, these fumigants are seen as the best alternatives for to $CH_3Br$. Therefore, it is expected that the consumption of these chemical alternatives will increase steadily in the future. Emissions during and after application represent a pathway for loses of fumigants to the atmosphere and subsequent movement to non-target areas. Because of this, there is concern over possible risks from exposure to these fumigants that might have acute or chronic human health or ecological impacts.

Soil fumigation in greenhouses and in agricultural fields involves covering the soil surface with a plastic film immediately following application, thereby providing a barrier to reduce the loss of the chemical via volatilization. To reduce emissions and to develop fumigation management practices that protect the environment while providing adequate pest control, they must also maintain their impermeability to fumigant vapors under field conditions. However, commercially available gas-barrier films in Japan are limited to a few kinds of brands, and these films are not fully satisfying requirements of applicators. The purpose of this study was to support the development and promotion of gas-barrier films for soil fumigation, and to evaluate gas-barrier performance of these films.

The provided films for this study were 11 brands of gas-barrier films including 2 prototypes, and the summary of specifications is showed in Table 1. These films are for narrow-strip, bed fumigation in open-fields or overall, broad-acre fumigation, and cover approximately all the requirements for various soil fumigations. The evaluation of the gas-barrier performance against fumigants was carried out by the cup method[1]. This method, which necessitates a minimum of equipment, uses a sealed static chamber to monitor gas diffusion across a plastic film. Fumigant liquids were put into a cup and the gravimetric change of the cup was monitored over time. The effects of temperature and film thickness on the permeability of fumigant vapors to films were determined by measuring the fumigants 1,3-D, CP and MITC. In addition, this study proposes a method for estimating the mass transfer coefficient *(h*, a measure of permeability) of fumigant vapors across agricultural films in the combination of fumigants and film materials by the strength of solubility parameters (SP) as chemical affinity (Table 2 and 3). This method is especially useful as a screening tool for the development of new management practices for soil fumigation. These results, which indicate that the combinations of these fumigants and gas-barrier EVOH are the most effective, and these fumigant compounds traverse the plastic film essentially independently, will aid efforts to model and predict fumigant volatilization using a mass transfer approach, and aid in the development of approaches to reduce emissions resulting from soil fumigation.

**Table 1.** The provided gas-barrier films for this study and the summary of their specifications

| | trade name | color | thickness (mm) | | width | baarier layer | reuse | narrow-strip, bed fumigation | overall, broad-acre fumigation |
|---|---|---|---|---|---|---|---|---|---|
| | | | avg. | CV (%) | (cm) | | | | |
| 1 | High-barrier (old) | black | 0.020 | 10.0 | | EVOH | — | ○ | — |
| 2 | High-barrier (new) | black | 0.020 | 5.9 | 95, 135, 150, 180、210, 270, 300, 420, 600 | EVOH | — | ○ | — |
| 3 | High-barrier | transparent | 0.020 | 5.4 | | EVOH | — | ○ | — |
| 4 | Soarnol | black | 0.031 | 3.9 | | EVOH | — | ○ | — |
| 5 | Soarnol | transparent | 0.029 | 5.9 | | EVOH | — | ○ | — |
| 6 | Soarnol | transparent | 0.052 | 3.6 | | EVOH | ○ | — | ○ |
| 7 | T prototype | black | 0.022 | 6.0 | | EVOH | — | ○ | — |
| 8 | Barrier-star | transparent | 0.046 | 5.3 | 300, 420, 460, 600, 700 | EVOH alloy | ○ | — | ○ |
| 9 | Grand King-5 | transparent | 0.072 | 7.0 | raw film 600 | EVOH | ○ | — | ○ |
| 10 | O prototype | black | 0.022 | 6.4 | | PVA application | — | ○ | — |
| 11 | Orgalloy | transparent | 0.050 | 10.6 | | polyamide alloy | — | — | ○ |
| 12 | FC50 poyethylene | black | 0.020 | 5.5 | | — | — | ○ | — |
| 13 | FC50 polyethylene | transparent | 0.018 | 7.8 | | — | — | ○ | — |

**Table 2.** Mass transfer coefficient, h estimated using combination of chloropicrin and gas-barrier films

| | trade name | mass transfer coefficient (m/hr) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 20°C | | 30°C | | 40°C | |
| | | avg. | CV (%) | avg. | CV (%) | avg. | CV (%) |
| 1 | High-barrier (old) | 1.32E-04 | 3.37E+01 | 8.28E-04 | 7.88E+01 | 9.76E-02 | 3.48E+01 |
| 2 | High-barrier (new) | 5.36E-04 | 4.90E+01 | 1.59E-02 | 6.01E+01 | 8.25E-02 | 1.90E+01 |
| 3 | High-barrier | 7.56E-04 | 5.56E+01 | 7.37E-04 | 7.66E+00 | 9.34E-03 | 6.45E+01 |
| 4 | Soarnol | 7.53E-04 | 6.50E+01 | 1.04E-03 | 5.11E+01 | 7.67E-03 | 2.00E+01 |
| 5 | Soarnol | 5.66E-04 | 6.87E+01 | 4.78E-04 | 4.10E+01 | 4.44E-02 | 3.26E+01 |
| 6 | Soarnol | 9.75E-04 | 4.46E+01 | 1.25E-03 | 3.22E+01 | 3.54E-02 | 4.08E+01 |
| 7 | T prototype | 3.15E-04 | 6.51E+01 | 9.00E-04 | 4.87E+01 | 8.27E-03 | 7.75E+01 |
| 8 | Barrier-star | 9.03E-03 | 1.94E+01 | 3.32E-02 | 1.20E+01 | 7.02E-02 | 1.09E+01 |
| 9 | Grand King-5 | 1.67E-04 | 9.88E+01 | 9.13E-04 | 8.39E+01 | 9.04E-02 | 3.76E+01 |
| 10 | O prototype | 8.30E-04 | 7.71E+01 | 1.30E-03 | 1.21E+02 | 1.98E-03 | 5.03E+01 |
| 11 | Orgalloy | | | | | | |
| 12 | FC50 poyethylene | 1.13E-01 | 2.83E+00 | 1.81E-01 | 5.51E+00 | 3.18E-01 | 6.22E+00 |
| 13 | FC50 polyethylene | 1.13E-01 | 3.89E+00 | 1.63E-01 | 3.08E+00 | 2.61E-01 | 4.54E+00 |

**Table 3.** Estimation of the affinity of fumigants to polymeric materials by solubility parameter differences $|\delta f-\delta p|$ $(MPa)^{1/2}$

| fumigant | polyethylene | polyvinyl chloride | polyamide 66 | EVOH |
|---|---|---|---|---|
| 1,3-dichloropropene | 2.9 | 0.4 | 8.6 | 19.7 |
| methyl bromide | 2.9 | 0.3 | 8.5 | 19.6 |
| methyl iodide | 3.5 | 0.2 | 8.0 | 19.0 |
| chloropicrin | 3.8 | 0.5 | 7.7 | 18.8 |
| methyl isothiocyanate | 3.8 | 0.5 | 7.7 | 18.7 |

This study was supported by a grant “The Environmental Research and Technology Development Fund” from the Japanese Ministry of the Environment.

1) Y. Kobara, Y. Yogo, A. Terada and M. Hosomi: *Journal of Pesticide Science* **37**, 28-36 (2012).