# Tier System for Plant Absorption and Translocation of Pesticides Using Rice Cultivation Model and Mobility Parameters

## (물리화학적 특성과 벼 재배모델에 의한 농약의 흡수이행성 Tier System 개발)

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Tier system for evaluation of the carry-over potential of soil or water residues to plants was proposed by a series of studies on absorption and translocation of various pesticides to rice plants. Total of 14 pesticides, classified as suspected endocrine disruptors, which comprised alachlor, carbaryl, carbendazim, cypermethrin, 2,4-D, dicofol, endosulfan, fenvalerate, malathion, methomyl, metribuzin, parathion, trifluralin and vinclozolin were subjected to parametric and empirical experiments to stepwise evaluate the degree of upward movement to plants. Environmental parameters of pesticides, including log $P_{ow}$ and soil adsorption coefficients, were measured to predict the relative mobility and availability of soil/water residues. Simplified culture systems of rice plants under hydroponic solution and submerged soil were newly designed to clarify the actual absorption and translocation of pesticides to plants.

As a polarity parameter of the compound, *n*-octanol/water partition coefficients(log $P_{ow}$) were measured using a HPLC method in compliance with OECD Test Guidelines. To predict relative upward mobility of pesticides by the environmental parameter, soil adsorption coefficients were also estimated in standard Korean soil(SCL) using a OECD batch equilibrium method. Log $P_{ow}$ values were more closely correlated with logarithms of $K_{oc}$ ($r^2$=0.852$^{**}$) than those of $K_F$($r^2$=0.613$^{**}$), while large deviations in some compounds were found. To estimate soil mobility of a compound, it is considered that $K_{oc}$ values to corresponding soils, in addition to intrinsic log $P_{ow}$, should be also compared. On the one hand, 2,4-D and carbendazim which existed as ionized and nonionic species at pH 5～7, respectively, exhibited $K_{oc}$ and $K_F$ values corresponding to compounds with log $P_{ow}$ of 1.5～1.6.

Rice plants were chosen as model species to estimate the degree of plant absorption of pesticide residues in surface water and paddy soil. Simplified rice growth systems under hydroponic solution and submerged soil were newly designed to actually estimate the systemic property. In hydroponic culture, nonpolar pesticides with the log $P_{ow}$ range of 3.0～5.9, were highly accumulated in the root, presumably indicating that the root acted as adsorption site of the pesticides, while total amount of pesticides translocated to the shoot was less than 5% of the applied dose at maximum. Alachlor and malathion residues in rice plants were quite lower than other pesticides due to rapid dissipation in rice

plants and/or hydroponic solution. Formation of endosulfan sulfate from endosulfan, even though relatively low the oxidative activity might be, was evident both in rice plants and hydroponic solution. In case of polar pesticides of methomyl, carbaryl and metribuzin with log $P_{ow}$ range of 0.23 ~ 2.11 as well as ionizable compounds of 2,4-D and carbendazim, higher residues were remarkably found in the shoot than those in the root. Unlikely to nonpolar pesticides, the root part was merely acted as the temporary site during absorption process of pesticides.

Involving soil component to simulate the field condition, absorption and translocation of nonpolar pesticides by rice plants were also quite limited. Compared with hydroponic culture condition, much less absorption and translocation to rice shoot were observed in all the pesticides tested. Total amount of pesticides in the shoot was less than 1% of the applied dose at maximum during 7 days. No residue of malathion was found in rice shoot and only 1/5 to 1/20 portions in recovery were observed in soil culture comparing that in hydroponic culture. Most of pesticides resided in soil, indicating that the soil was acted as adsorption site of the pesticides in lieu of the root in hydroponic culture. Dissipation rates of pesticides in soil culture were higher than those in hydroponic culture. Vinclozolin could be still evaluated to be quasi-systemic, whereas parathion was estimated to be non-systemic mainly due to fast dissipation rate. In case of polar pesticides in soil culture, absorption and dissipation rates were lower and faster, respectively, than those in hydroponic culture. As rapidly dissipated, methomyl recovery in shoot was only 0.5% of the dose applied and, as a result, carry-over potential was evaluated to be low. Carbaryl, carbendazim and metribuzin appeared still to be systemic in soil culture, even though 1/2 to 1/5 portions in recovery of hydroponic culture were observed.

Among 14 pesticides tested, there was no exception that absorption and translocation rates in soil culture were lower than those in hydroponic culture. Therefore, hydroponic system is not only simple to operate but also provided highest carry-over potential, in other sense, highest possibility of hazardous residues in plants. However, soil culture testing was also needed to precisely evaluate and confirm the systemic property of the pesticides. Coupling parametric and empirical experiments conducted in this study, Tier system for evaluation of carry-over potential of pesticides to plants could be proposed. At first, parametric prediction intrinsic to molecular properties could be applied to the initial step of Tier system for categorization of mobility. Timely distribution and dissipation of pesticides in plant parts and hydroponic media could be employed as empirical stage of Tier system for practical estimation of the highest carry-over potential. Using soil culture system, systemic characteristics of pesticides could be finally evaluated or confirmed. Tier system of 3-step estimation could be used as a component in pesticide registration system to classify and manage currently or newly registered pesticides on the basis of carry-over possibility to plants.

**Key words :** Pesticide, Absorption, Translocation, Rice plant, Hydroponic culture, Tier system
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