ACS SYMPOSIUM SERIES **853**

Environmental Fate and Effects of Pesticides

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Sponsored by the
ACS Division of Agrochemicals

American Chemical Society, Washington, DC

Chapter 5

Environmental Fate: Development of an Indoor Model Test for Runoff

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A new indoor test system with controlled rain conditions was developed to better understand field runoff. Containers ($0.7m^2$) packed with soil from the plow layer were used as test plots and placed under a rain-making machine. The test system was able to simulate a field runoff event. The runoff obtained by the test system approximates the runoff in the field. Some model tests using the indoor test system with sloped test plot, a mixture of three pesticides (chlorothalonil, diazinon and dimethoate), and a 30mm/hr rainfall were performed to detect the difference in runoff between cropped and non-cropped test plots. Furthermore, the test system was applied to prediction of water runoff in fields.

Background

Water runoff from croplands has been a major concern due to the soil erosion (*1*) that it causes and the potential hazard it poses by the transport of pesticides to public waters (*2*). Soil loss and erodibility have been studied not pF value of 2.9-3.0 in air and 1.4-1.6 in water. Thus, the pF value in each test plot was measured between these ranges.

The relationship between soil moistures of test plots just before rainfall (initial pF values) and ratios of runoff water calculated at 1L collection by 30mm/hr rainfall was investigated by the indoor test system. The results are shown in Figure 2. The test plots dried around pF3.0 need longer rainfall to collect 1L of runoff water. Thus, lower ratios of runoff water such as 2% were observed. On the other hand, the test plots with soil moisture around pF1.5 need less rainfall to collect 1L of runoff. Thus, higher ratios of runoff water such as over 10% were observed. When the initial pF value of each test plot was reduced to pF1.6 by the rainfall, water runoff was usually observed from the test plots. Furthermore, at least 30-60mm of accumulated rain precipitation was needed to obtain the pF1.6 for the test plots.

Verification of The Indoor Runoff Test System

For the verification of the indoor runoff test system, a field runoff occurred on Sep. 22, 1996, by a heavy rainfall of typhoon storm (*7*) was simulated by the indoor test system. As the model pesticides, a 70ml of pesticides mixture containing 400mg/L of chlorothalonil (TPN) and diazinon and 430mg/L of dimethoate was applied to the test plot using a hand sprayer at a rate of 100L/1000m^2. The rainfall by the typhoon (Figure 3A) was simulated by the rain-making machine (Figure 3B) just 2 days after the pesticides application. Water samples were collected as field runoff and analyzed by GC-MS (*9*).

The field size was 840m^2, which was 1,200 times bigger than the indoor test plot. The soil (Andosols) used for the indoor test plots was collected from this field surface. In the field runoff a 290L with 5hr rainfall, a 530L with 0.5hr rainfall and 600L with following 2hr rainfall in all 1,420L of runoff water were collected from the field (Figure 3A)(*7*). The results of simulated runoff by the indoor test are shown in Table I. When volumes of runoff water (L/m^2) from indoor test were compared with those of field test, both results were almost the same. Furthermore, the concentrations of three pesticides obtained by the indoor test were also very close to the results of the field test. These results indicate that the indoor runoff test system has the potential to simulate field runoff.

Runoff Model Tests by Indoor Test System

In the indoor runoff test system, a larger amount of runoff water collected from such a small test plot would bring higher ratio of pesticide runoff than that from a field. Thus, 1L of water sample per runoff event was collected from each test plot in the model tests. This is equivalent to 1.43L/m^2, which was almost corresponding to the result of typhoon storm (1.69L/m^2) (*7*).

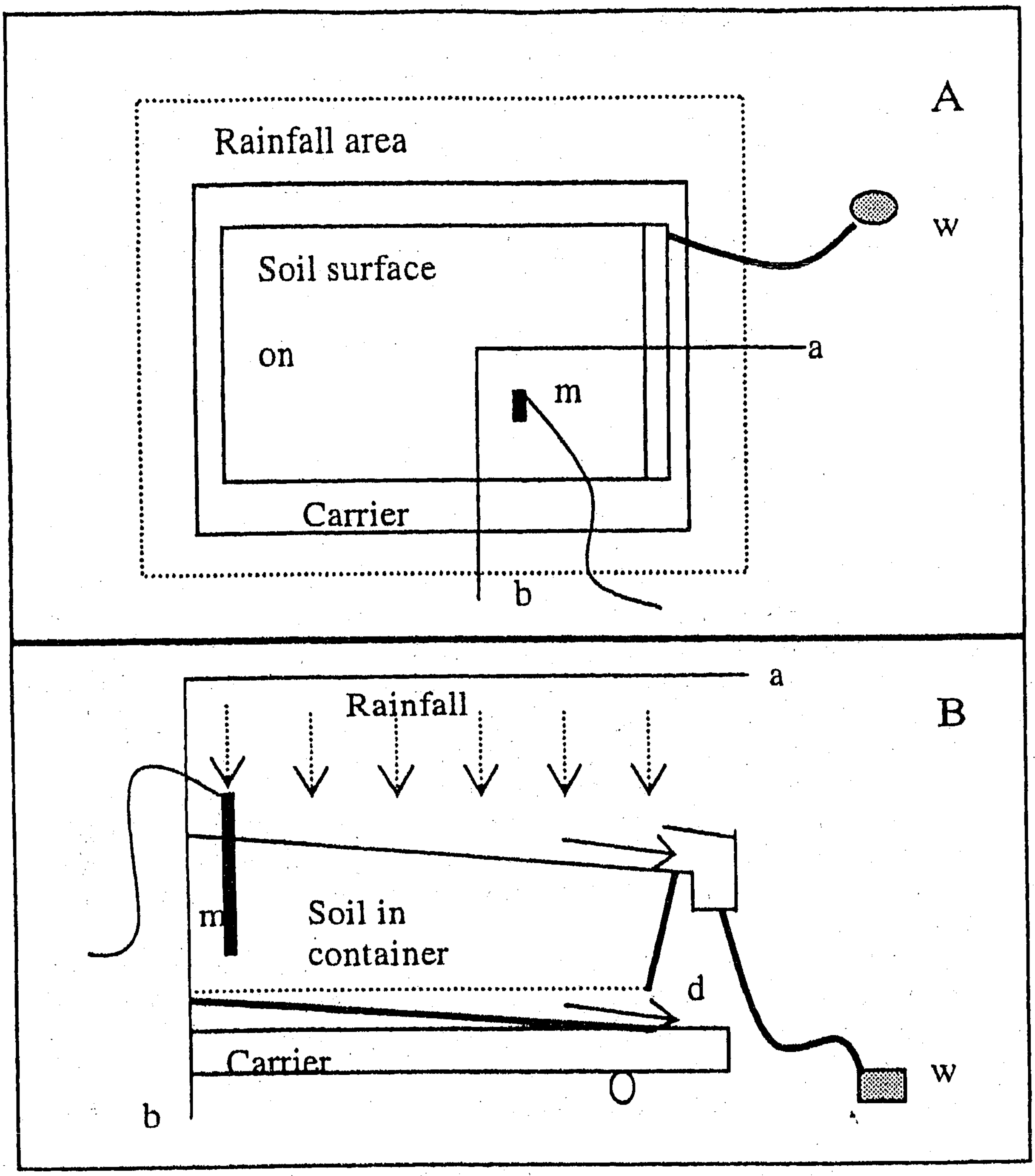

Figure 1. Structure of the test plot for indoor model test system. A: overhead view, B: cross sectional view (a-b), w: water sample collector, d: drainage, m: sensor for soil water meter. Reproduced with permission from reference 8. Copyright 2000 Pesticide Science Society of Japan.)

Table I. Simulation of Field Runoff

Runoff Test	*Runoff Water (L/m^2)*	*Concentration (mg/L)*		
		TPN	*Diazinon*	*Dimethoate*
	0.345	0.005	0.001	0.002
Field test	0.631	0.018	0.002	0.003
($840m^2$)	0.714	0.008	0.001	0.002
	0.421	0.009	0.007	0.008
Indoor test	0.653	0.010	0.005	0.002
($0.7m^2$)	0.834	0.007	0.004	0.001

Runoff from Aged Test Plots

Individual test plots were aged for each period after pesticide application. Each 70ml of pesticide mixture diluted with tap water (TPN and diazinon: 400mg/L, dimethoate: 430mg/L) was applied to 5 test plots by using the hand sprayer at a rate of $100L/1000m^2$. Each test plot placed under sunlight received 30mm/hr rainfall at 1 (No.1 test plot), 3 (No.2), 7 (No.3), 14 (No.4), and 21 days (No.5) after a single application of the pesticide mixture. Approximately 1L of runoff water was collected at each rainfall. Furthermore, a 210ml of the diluted pesticides mixture was applied to a test plot (No.6) for 3 times with 7 days intervals at a rate of $300L/1000m^2$. After one hour from the last application, approx. 1L of runoff water was collected by 30mm/hr rainfall. All water samples were analyzed by GC-MS (*9*).

The concentration of pesticides in water samples from individual test plots (No.1 to No.5) decreases with time after pesticide application (See Figure 4). Furthermore, among the pesticides used, only TPN from test plots No.1 and No.6 showed a high ratio of runoff with suspended solids (SS). It seemed that TPN might be runoff with not only TPN absorbed SS but also flowable particles directly.

In many studies pesticide runoff was greatest when the rainfall occurred immediately and intensely after pesticide application (*10, 11*). Based on the results shown in Figure 4, the pesticide runoff from test plots of No.1 (single application) and No.6 (3 applications) were also greatest. Although the application dosage of the test plot No.6 was totally 9 times greater than other test plots, runoff TPN from the test plot No.6 was almost similar level of the No.1. On the other hand, runoff diazinon and dimethoate were approx. 2 times and 6 times greater than ones of the No.1. Thus, richer times and dosage of the pesticide application were not always increasing the concentration of runoff pesticides in water samples.

Difference in Runoff Between Cropped and Non-cropped Test Plots

When cropped test plots are used, conditions such as deposit, uptake, washoff and degradation on foliages can be expected. Suitable plants for the test plot are of a short stature with many leaves to increase surface area for the spray application and reduce rebounding raindrops from leaves to out of the test plot. The French Marigold (*Tagetes patula* L.) was chosen as the crop. The indoor model tests for runoff were performed to detect the effect of crops on the test plots and for comparison to non-cropped plots.

A 300L/1000m^2 of diluted pesticides mixture (TPN and diazinon: 400mg/L, dimethoate: 430mg/L) was applied to 2 sets of non-cropped test plots (I-1 and I-2) and cropped test plots (II-1 and II-2), respectively. In each cropped test plot, 12 Marigolds (approx. 20cm high) were transplanted just 1 week before the pesticide application. Runoff tests with 30mm/hr rainfall were performed and 1L of water samples were collected from the same test plots after each period (1, 7 and 14 days after pesticide application), respectively. The water samples were analyzed by GC-MS.

The averaged ratios of runoff pesticides between the duplicated test plots are shown in Figure 5. Furthermore, the maximum ratio of pesticide runoff should be estimated from amount of runoff pesticides, which sequentially collected every day and integrated from a day after application to 14th days, as the worst case. The ratios of integrated runoff pesticide are presented in Table II. Based on the comparison of runoff between cropped and non-cropped test plots, both results were very similar in the ratios of integrated runoff pesticides. Furthermore, the ratios of integrated runoff pesticides were unexpectedly very low.

When crops existed in the test system, the soil moistures just before the rainfall and the ratios of runoff water were almost settled around pF2.0 and 5.3% with small changes (pF1.8-2.2 and 3.1-5.3%) between the duplicated test plots and between the runoff tests. However, the concentrations of pesticides in runoff water were maximally over 4 times different between the duplicated test plots of II-1 and II-2 (average 2.3 times). On the other hand, in the non-cropped test plots the soil moistures and ratios of runoff water changed more widely (pF1.4-2.9 and 1.7-5.6%) than ones of cropped test plots. However, the concentrations of pesticides in runoff water collected were maximally 1.8 times different between the duplicated test plots of I-1 and I-2 (average 1.3 times). The ratio of one test plot to the other one was detected between the duplicated test plots and indicated as differentiation. The runoff water ratio and runoff pesticide ratio such as TPN, diazinon and dimethoate were detected. Those results at 3 runoff events were averaged. The differentiations between the duplicated test plots are shown in Figure 6. Non-cropped test plots showed smaller differentiation than cropped test plots. Based on the results shown above, duplicated non-cropped test plots are recommended for the indoor runoff model test.

Table II. Ratios of Integrated Runoff Pesticides

Pesticide	*Non-cropped*	*Cropped*
TPN	0.75%	0.63%
Diazinon	0.25%	0.25%
Dimethoate	0.13%	0.16%

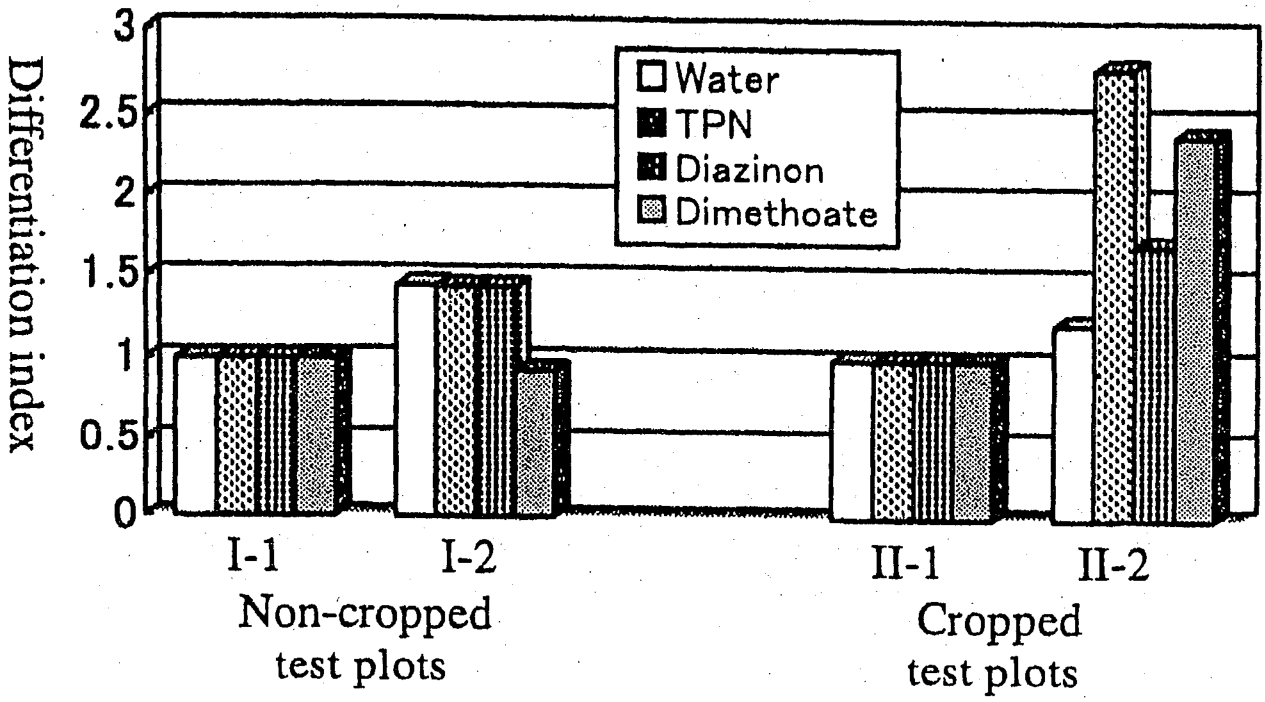

Figure 6. Differentiation between duplicated test plots. Ratios of runoff water and ratios of runoff pesticides were displayed.

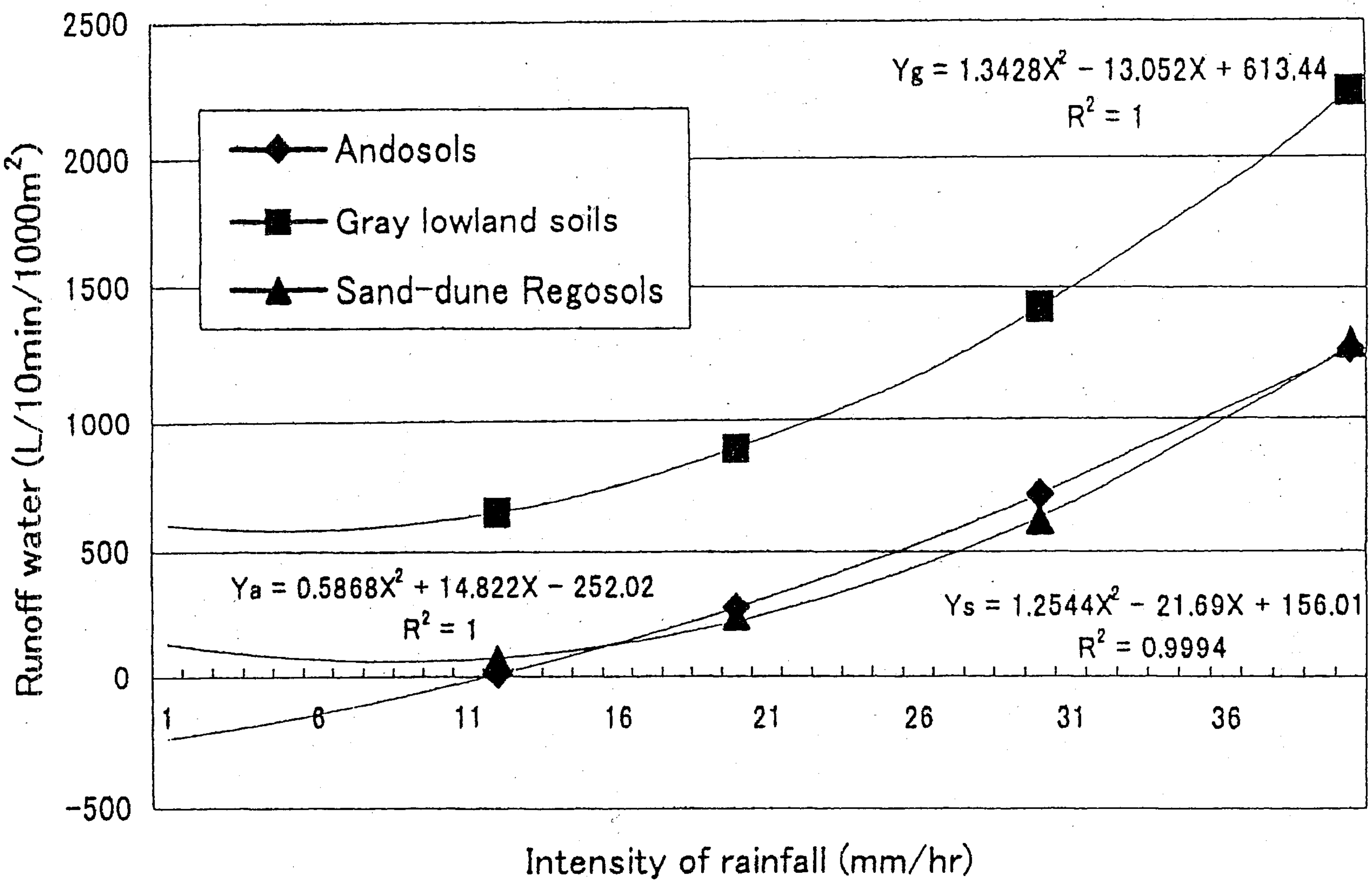

Figure 7. Runoff water from three tested soils at four rainfall intensities.

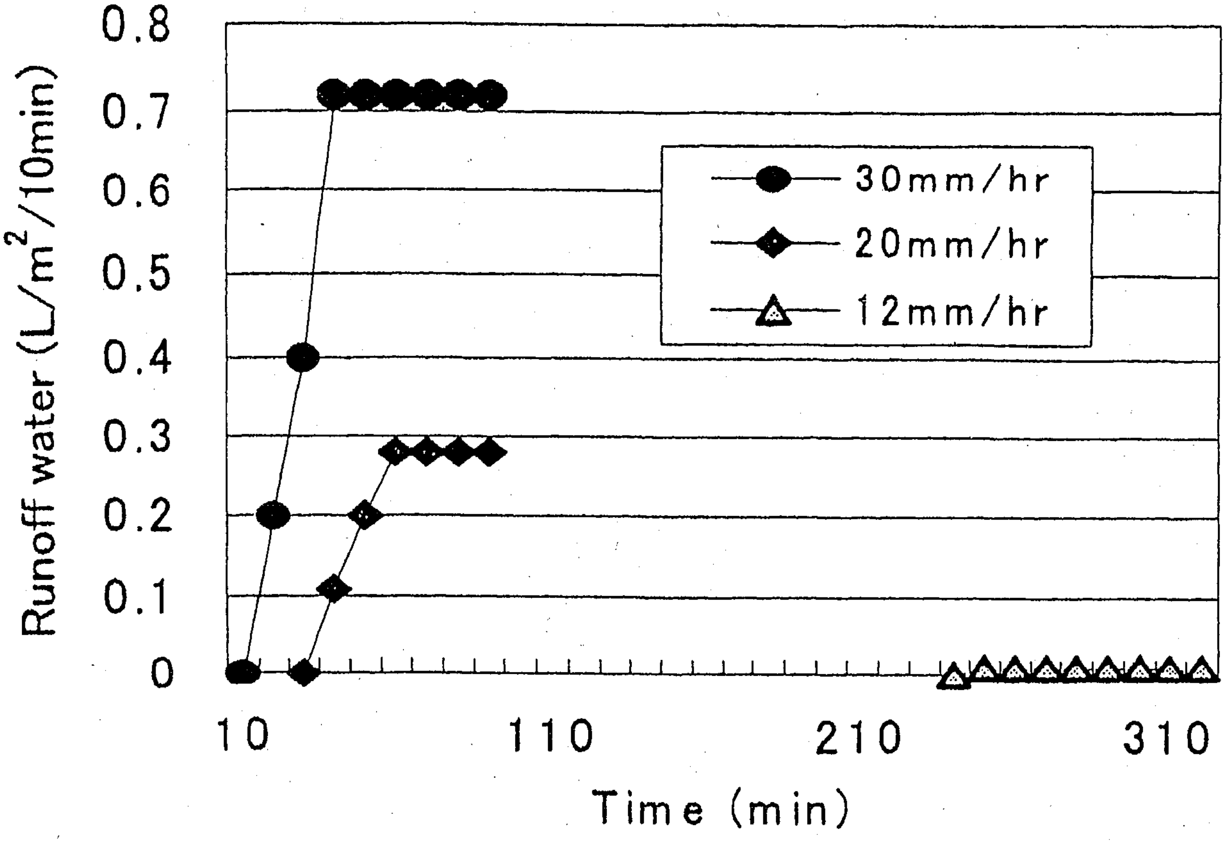

Figure 8. Amounts of runoff water ($L/m^2/10min$) with 3 rainfall intensities (12, 20 and 30mm/hr). (Reproduced with permission from reference 8. Copyright 2000 Pesticide Science Society of Japan.)

Table IV. Prediction of Field Runoff on Andosols

Date of 1996	*Size (m^2)*	*Measured amount (L)*	*Predicted amount (L)*
July 9	700	1.4	7
10	700	0.6	0
Sept. 22	840	1420	2318

NOTE: $7L= 0.01Lm^2 \times 700m^2$, $2318L=(0.2+0.4+0.72 \times 3) \times 840m^2$.

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Published 2003 by the American Chemical Society