Bull. Environ. Contam. Toxicol. (1992) 48:394–400

Environmental Contamination and Toxicology

Effect of Weather Variables on Methyl Parathion Disappearance from Cotton Foliage

Guye H. Willis,[1] Leslie L. McDowell,[2] Sammie Smith,[2] and Lloyd M. Southwick[1]

[1]USDA-ARS, Soil and Water Research Unit, P.O. Box 25071, University Station, Baton Rouge, Louisiana 70894-5071, USA (in cooperation with Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center) and [2]USDA-ARS Sedimentation Laboratory, P.O. Box 1157, Oxford, Mississippi 38655, USA (in cooperation with Mississippi Agricultural and Forestry Experiment Station)

Foliar persistence times of insecticide residues affect the insecticides' efficacy, its' potential for pollution of nontarget areas, and worker reentry times. Information concerning pesticide foliar persistence is needed to develop and improve models that predict the environmental fate of applied pesticides.

Weather factors reported to affect the rate of pesticide disappearance from foliage include rain, wind, temperature, sunlight, and relative humidity (Willis and McDowell, 1987). Rain has the most dramatic effect on residues, especially if it occurs within 24 h after pesticide application. Rainfall amount appears to have a greater effect than rainfall intensity on washoff of emulsifiable concentrate (e.c.) formulations of insecticides from cotton (Gossypium hirsutum L) plants (McDowell et al., 1987). The primary effect of wind on pesticide disappearance from foliage is through turbulent transfer of volatilized pesticide from plant surfaces to the atmosphere (Spencer et al., 1973). Temperature affects pesticide disappearance from foliage through its influence on pesticide vapor pressure and volatility (Harper et al., 1983). Sunlight affects pesticide disappearance through photochemical alteration of the pesticide (Crosby, 1972). High relative humidity has been reported to both increase pesticide persistence on plants by facilitating foliar absorption and decrease persistence by favoring volatilization (Willis and McDowell, 1987).

The effects of weather variables on pesticide persistence on plants has been studied extensively by Nigg and coworkers in Florida citrus (Nigg et al., 1977a, 1977b, 1978, 1979; Nigg and Allen, 1979; Nigg and Stamper, 1980). They state that pesticide disappearance from foliage is a dynamic process and that cumulative expressions of weather variables, rather than mean values, better represent the dynamic environmental processes that regulate pesticide disappearance from plants. The importance of one variable over the others in being a better predictor of pesticide disappearance from foliage usually depends on the prevailing environmental conditions during individual studies.

Send reprint requests to Guye H. Willis at the above address.

For this reason, "as many variables as is practical should be measured until there is ample evidence that a particular variable is unimportant to a pesticide's disappearance" (Nigg et al., 1978).

The objective of this study was to determine the effect of several weather/microclimate variables on the foliar disappearance of methyl parathion applied in oil, oil + water, or water formulations to cotton plants.

MATERIALS AND METHODS

The study was conducted in a 10-ha cotton field near Oxford, MS in August and early September, 1983. An emulsifiable concentrate formulation of methyl parathion was applied at a rate of 0.280 kg active ingredient (a.i.) ha^{-1} in either soybean oil, soybean oil + water, or water to cotton plants (1.22-m mean height, 1.0-m wide rows, 5.0 ± 0.7 stalks m^{-1} of row, 100% canopy cover) by an 8-row sprayer equipped with conventional hydraulic nozzles (two per row) and rotary atomizer controlled droplet applicators (CDA) (one per row). The various treatment/application conditions are given in Table 1, and are discussed in more detail elsewhere (Willis et al., 1991). The spray nozzles/CDA were set at 0.38 m above the mean canopy height. Each treatment was applied to three separate areas (replicates) 8 rows wide and 50 m long. Treatment sites were separated by a minimum of 50 m both down-row and across-row. For each replication a single spray application was made on each of six successive days, i.e., the six treatments in a single replication

Table 1. Application methods and sprayer operating conditions for methyl parathion application to cotton plants.

Treatment	Carrier[a]	Spray[b] Formation Device	Volume, L ha^{-1}	Pressure, kPa
HiOil-CDA	oil	CDA-20	9.4	97
LoOil-CDA	oil	CDA-14	4.7	69
LoOilW-CDA	oil+water	CDA-30	21.4	83
LoOilW-TX2	oil+water	TX2	21.4	276
LoOilW-TX8	oil+water	TX8	79.5	276
Water-TX8	water	TX8	79.5	276

[a]Oil - refined soybean oil with emulsifier and formulated insecticide; Oil + water - 4.7 L ha^{-1} soybean oil/emulsifier/insecticide plus either 16.7 or 74.8 L ha^{-1} water; Water - 79.5 L ha^{-1} water with formulated insecticide.

[b]CDA - controlled droplet applicator with orifice # 14, 20, or 30; TX - hydraulic hollow cone 80° nozzles that deliver either 18.7 or 74.8 L ha^{-1} (2 or 8 gal $acre^{-1}$). Applicator ground speed 5.6 km h^{-1} for LoOil-CDA, 8.1 km h^{-1} for all other treatments.

were randomly applied over a 6-day period. Each pesticide application was made at 1000 h (central daylight savings time), after the dew had dried. Portable shelters (light-weight tarps stretched over aluminum frames) were placed over plots (1.5-m sections of row) prior to all rain events and at night.

Cotton plants were collected immediately after spraying and 0.25, 0.5, 1, 1.5, 2, 6, 25, and 49 h after pesticide application. Plants were cut at the soil surface along a 1.5-m length of a single row and extracted in methanol. Four rows were sampled each time, i.e., quadruplicate samples for each sampling time for each replicate. The plants were extracted by allowing them to soak in methanol at ambient temperature for a minimum of 4 h. The methanol was mixed thoroughly and a 125-ml aliquot was removed and stored in an amber bottle at 4 C until analysis. Methyl parathion extraction efficiency was 95 ± 2 % as determined from a laboratory study with fortified samples. The methanol extracts were diluted with benzene to volumes appropriate for gas chromatographic analysis by electron capture detectors (Willis et al., 1991).

Several microclimate variables were measured throughout the study by means of analog-signal-producing sensors, a signal conditioning (analog to digital) unit, and a cassette-tape-equipped data logger. Windspeed was measured 1 m above the canopy surface by a low-threshold (0.27 m sec^{-1}) anemometer. Air temperatures were measured at the canopy surface and 1 m above the canopy surface by shielded, 3-thermistor-composite sensor probes. Large temperature gradients contribute to rapid volatile losses of pesticides in concert with other weather variables (Harper et al., 1983). Solar and net radiation were measured with a star pyranometer and a Fritschen-type net radiometer, respectively, each positioned 1 m above the canopy surface. Relative humidity was measured at the canopy surface with a shielded, polymer-thin-film-capacitor-type sensor equipped with a sintered brass filter.

Due to battery failure, weather variables were not measured during rep 1 of treatment Water-TX8, and were measured only during the first 24 h of rep 1 of treatment LoOilW-CDA. Further, because of drought-induced poor canopy quality, plants in rep 3 of the LoOilW-TX8 treatment were not sampled for insecticide residues.

Cumulative weather variables were developed by summing mean hourly values for each of the measurement periods.

RESULTS AND DISCUSSION

Mean values for weather variables during the 49-h study period are given in Table 2 for each treatment. Since most pesticide loss from foliage occurs during daylight hours (Harper et al., 1983), mean values for weather variables during daylight hours (0600 to 1800, central daylight savings time) only are given. Clouds associated with nearby convective thunderstorms during the HiOil-CDA and LoOilW-TX8 treatments resulted in slightly lower temperature and radiation values and slightly increased relative humidity.

Table 2. Mean wind, temperature, relative humidity and radiation values during daylight hours only for combined replicates throughout the 49-h study for each treatment.

Treatment	Wind, m sec^{-1}	Air Temperature, °C	
		Canopy Surface	1 m Above Canopy Surface
HiOil-CDA	1.33 ± 0.72	29.0 ± 4.3	28.0 ± 3.6
LoOil-CDA	1.21 ± 0.54	32.1 ± 3.7	31.4 ± 3.3
LoOilW-CDA	1.29 ± 0.75	32.1 ± 4.4	31.3 ± 3.8
LoOilW-TX2	1.43 ± 0.71	32.1 ± 4.0	31.5 ± 3.6
LoOilW-TX8	1.39 ± 0.69	29.4 ± 4.1	28.5 ± 3.6
Water-TX8	1.07 ± 0.51	33.0 ± 4.6	32.5 ± 4.1
	Relative Humidity, %	Radiation, W m^{-2}	
		Solar	Net
HiOil-CDA	70 ± 16	391 ± 230	286 ± 181
LoOil-CDA	62 ± 15	503 ± 237	363 ± 181
LoOilW-CDA	65 ± 17	475 ± 244	342 ± 188
LoOilW-TX2	64 ± 16	475 ± 237	335 ± 181
LoOilW-TX8	70 ± 16	391 ± 223	293 ± 175
Water-TX8	63 ± 18	503 ± 251	363 ± 195

Table 3. Equations describing methyl parathion disappearance from cotton foliage as a function of cumulative weather variables and elapsed time for each application treatment.

Treatment	Equation[a]	d.f.[b]	r^2
HiOil-CDA	MP = 0.753 - 0.110 ln(HDH16)	13	0.99
	MP = 0.493 - 0.108 ln(ΣTime)	13	0.98
LoOil-CDA	MP = exp[0.085 - 0.199(ΣWind)**0.5]	14	0.95
	MP = exp[-0.081 - 0.317 (ΣTime)**0.5]	14	0.88
LoOilW-CDA	MP = 1.247 - 0.132 ln(ΣSR)	12	0.98
	MP = 0.427 - 0.116 ln(ΣTime)	13	0.96
LoOilW-TX2	MP = 0.560 - 0.096 ln(ΣWind)	13	0.95
	MP = 0.473 - 0.111 ln(ΣTime)	13	0.94
LoOilW-TX8	MP = exp[0.052 - 0.187(ΣWind)**0.5]	8	0.96
	MP = exp[-0.128 - 0.313 (ΣTime)**0.5]	8	0.89
Water-TX8	MP = exp[-0.013 - 0.247(ΣWind)**0.5]	9	0.99
	MP = exp[-0.172 - 0.324 (ΣTime)**0.5]	12	0.87

[a]MP = fraction of initial methyl parathion load remaining on foliage; HDH16 = heating degree hours above 16°C; ΣWind = cumulative wind (km); ΣSR = cumulative solar radiation (W m^{-2}); ΣTime = elapsed time (h).

[b]d.f. = degrees of freedom.

Equations describing methyl parathion disappearance from cotton plants as a function of cumulative weather variables for each treatment are shown in Table 3. The empirical, best-fit equation listed for each treatment was selected based on the best combination of r^2 and predictive reliability, i.e., some equations with slightly higher r^2 values were poor predictors at either the beginning or end of the curve. Overall, cumulative wind was the best predictor of methyl parathion disappearance from cotton foliage. Increased wind is an indicator of greater turbulence and greater volatile loss of pesticides from plant surfaces (Willis et al., 1983). HDH16, which expresses cumulative temperature above 16°C, and cumulative solar radiation (ΣSR) were the two other best predictors. Increased air temperature results in increased pesticide vapor pressure and subsequent volatile loss from soil (Spencer et al., 1973) and plant (Harper et al., 1983) surfaces. Solar radiation is a measure of the energy available to drive the various heating and energy-consuming processes, including disappearance processes (primarily volatilization). Elapsed time was as good a predictor as weather variables for the HiOil-CDA, LoOilW-CDA, and LoOilW-TX2 treatments.

Table 4. Equations describing methyl parathion disappearance from cotton foliage as a function of selected cumulative weather variables for all application treatments combined except LoOil-CDA.

Equation[a]	d.f.[b]	r^2
$MP = \exp[-0.194 - 0.206(\Sigma Wind)^{**}0.5]$	59	0.87
$MP = 0.978 - 0.114 \ln(\Sigma RH)$	59	0.92
$MP = \exp[-0.024 - 0.025(\Sigma SR)^{**}0.5$	59	0.94
$MP = \exp[-0.077 - 0.207(HDH25)^{**}0.5]$	59	0.91
$MP = 0.491 - 0.110 \ln(Time)$	63	0.93

[a]MP = fraction of initial methyl parathion load remaining on foliage; ΣRH = cumulative relative humidity; ΣSR = cumulative solar radiation; HDH25 = heating degree hours above 25°C.

[b]d.f. = degrees of freedom.

Statistical analysis revealed that, except for the LoOil-CDA treatment, few differences in initial methyl parathion deposits or residual loads occurred throughout the study (Willis et al., 1991). Initial methyl parathion deposition on cotton foliage in the LoOil-CDA treatment was significantly less, presumably due to drift, than for the other treatments. The treatments, except for LoOil-CDA, were combined and the effect of cumulative weather variables on methyl parathion disappearance determined (Table 4). The regression equation for ΣSR had the highest r^2, but ΣSR was not a significantly better predictor than any of the other weather variables, nor was it

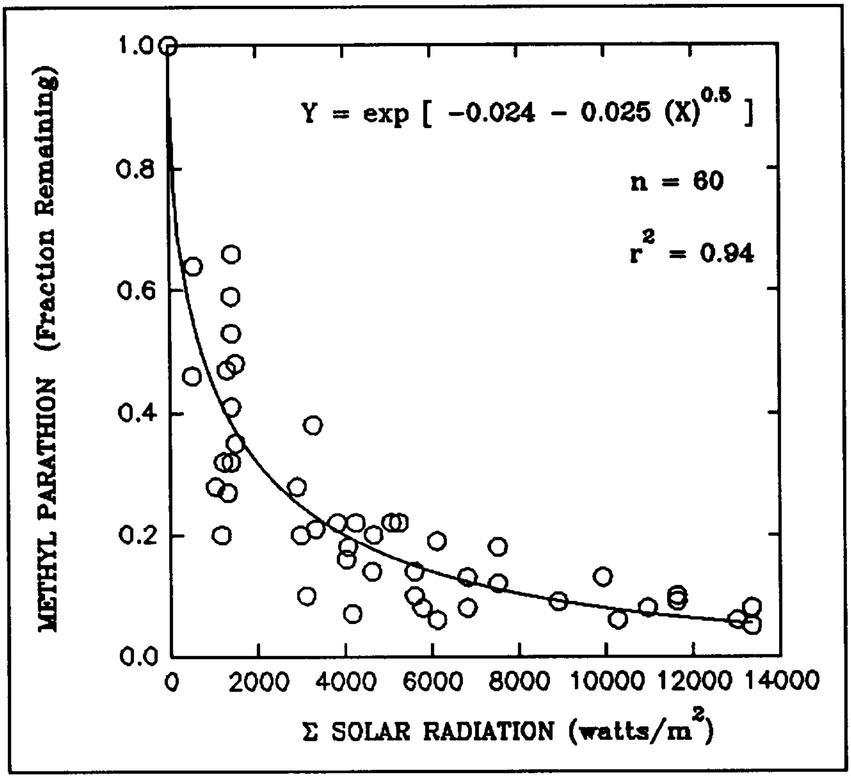

Figure 1. Fraction of residual methyl parathion remaining on cotton plants as a function of cumulative solar radiation.

better than elapsed time. Figure 1 shows the data scatter for the residual methyl parathion as a function of cumulative solar radiation. ΣNR and HDH16 were not different from ΣSR and HDH25, respectively, and were not included in Table 4.

Under the conditions of this study, cumulative weather variables were good predictors for methyl parathion disappearance from cotton foliage, but were better predictors than elapsed time in only a few cases.

REFERENCES

Crosby DG (1972) Environmental photooxidation of pesticides. In: Degradation of synthetic organic molecules in the biosphere. Conf Proc San Francisco, CA, June 12-13, 1971. Natl Acad of Sciences, Washington, DC, pp 260-278.

Harper LA, McDowell LL, Willis GH, Smith S, Southwick LM (1983) 1983. Microclimate effects on toxaphene and DDT volatilization from cotton plants. Agron J 75:295-302.

McDowell LL, Willis GH, Southwick LM, Smith S (1987) Fenvalerate wash-off from cotton plants by rainfall. Pestic Sci 21:83-92.
Nigg HN, Allen JC (1979) A comparison of time and time-weather models for predicting parathion disappearance under California conditions. Environ Sci Technol 13:231-233.
Nigg HN, Allen JC, Brooks RF (1977a) Weather and pesticide residues. Proc Int Soc Citric 2:437-441.
Nigg HN, Allen JC, Brooks RF, Edwards GJ, Thompson NP, King RW, Blagg AH (1977b) Dislodgeable residues of ethion in Florida citrus and relationships to weather variables. Arch Environ Chem Toxicol 6:257-267.
Nigg HN, Allen JC, King RW (1979) Behavior of parathion residues in the Florida "Valencia" orange agroecosystem. J Agric Food Chem 27:578-582.
Nigg HN, Allen JC, King RW, Thompson NP, Edwards GJ, Brooks RF (1978) Dislodgeable residues of parathion and carbophenothion in Florida citrus: a weather model. Bull Environ Contam Toxicol 19:578-588.
Nigg HN, Stamper JH (1980) Persistence of phenthoate (cidial) and phenthoate oxon on fruit, leaf, and soil surfaces and in air in Florida citrus. Chemosphere 9:343-350.
Spencer WF, Farmer WJ, Cliath MM (1973) Pesticide volatilization. Residue Rev 49:1-47.
Willis GH, McDowell LL (1987) Pesticide persistence on foliage. Rev Environ Contam Toxicol 100:23-73.
Willis GH, McDowell LL, Harper LA, Southwick LM, Smith S (1983) Seasonal disappearance and volatilization of toxaphene and DDT from a cotton field. J Environ Qual 12:80-85.
Willis GH, McDowell LL, Smith S, Southwick LM (1991) Application method effects on methyl parathion and permethrin deposition and persistence on cotton plants. J Agric Food Chem 39:408-411.

Received June 10, 1991; accepted October 2, 1991.