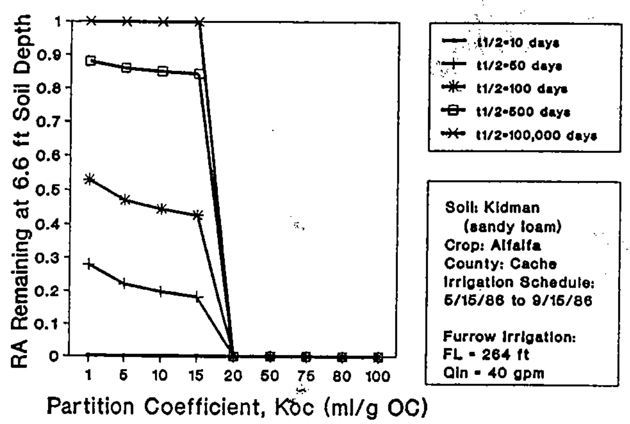


Figure 5: Effects of Pesticide Parameters on Relative Amount (RA) Remaining when a Pesticide Reaches 6.6 ft. (2 m) Soil Depth for Known Site, System and Irrigation Schedule.

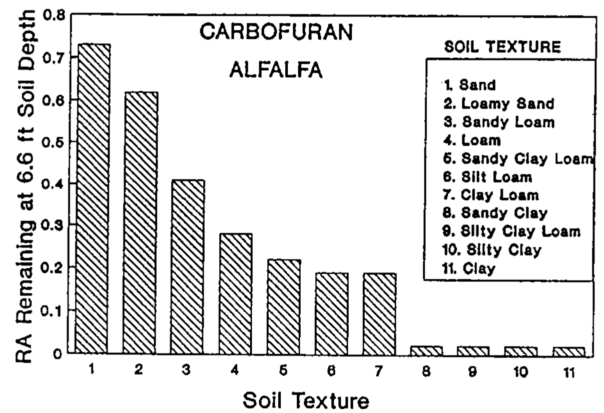


Figure 6: Effects of Various Soil Textures on Relative Amount (RA) of Carbofuran Remaining in the Soil when It Reaches to a Depth of 6.6 ft (2 m).

example, Figure 6 shows that pesticides pose a greater contamination hazard in coarse texture (sandy) soils than in fine texture (clay) soils.

SUMMARY

Furrow irrigation system design and management affect water-storage efficiency and pesticide leaching in turn. Increasing flow rates at the furrow head or decreasing furrow length (within design specifications) improves storage efficiency and reduces pesticide leaching and the risk of potential ground-water contamination.

Proper pesticide selection is also important. For a given furrow length and inflow rate, pesticides with higher partition coefficients and shorter half lives have a lower potential for ground-water contamination (less leaching) than otherwise.

The finer the soil texture, the less potential for pesticide leaching. Pesticides move much less easily in clay soils than in sandy soils.

The combination of proper irrigation system design and management and proper pesticide selection and use comprises a best management system (BMS). Using such a BMS is more economically efficient and environmentally safer than other less integrated approaches.

*Use of trade names for pesticides does not imply endorsement

COOPERATIVE EXTENSION SERVICE • UTAH STATE UNIVERSITY • JUNE 1991 • EL 256

PESTICIDE MOVEMENT IN RESPONSE TO FURROW IRRIGATION AND PESTICIDE PARAMETERS

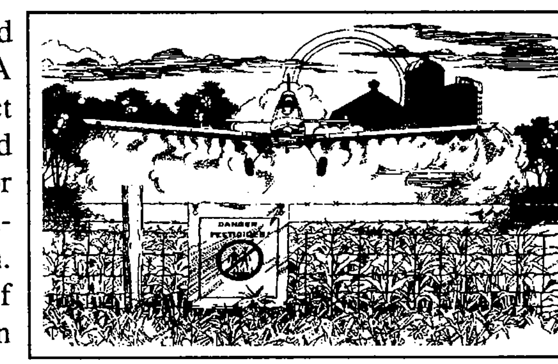
by

Ahmad Yar Ranjha, Richard C. Peralta, Robert W. Hill, and Howard M. Deer.

Authors are respectively Visiting Associate Professor, Professor and Professor, Agricultural and Irrigation Engineering Department, and Extension Pesticide Specialist, Department of Animal, Dairy and Veterinary Sciences Utah State University, Logan, Utah.

Production of adequate supplies of food and fiber currently requires that pesticides be used to limit crop losses from insects, pathogens, weeds and other pests. The term pesticide refers to a large number of chemical compounds. Pesticides include acaricides, fungicides, herbicides, insecticides, nematicides, algicides, arboricides, zoocides, and many more.

Pesticides have been found in the ground water of several counties of Utah. The Utah Dept. of Agriculture (UDA), analyzed ground water samples from 58 of 240 selected wells for 32 pesticides commonly used on Utah crops. Wells were selected in areas identified by the UDA as being most susceptible to pesticide contamination (Your Water, March 1991).



Though the pesticides were found in lower concentrations than EPA lifetime health advisories, the fact that these chemicals have entered the ground water is a cause for concern. Once ground water is contaminated, it is difficult to clean. Since more than 90 percent of Utah's rural population rely on ground water for their domestic needs, it is important to protect this valuable resource (Your Water, March 1991).

The risk of potential contamination of ground water by pesticides depends on many factors, including pesticide properties, soil, agricultural practices, plant uptake, hydrology, geology, climate and topography.

Pesticide Movement Response to Furrow Irrigation and Pesticide Parameters:

Irrigation water is never applied with perfect storage efficiency[1] (Es). Some always percolates below the root zone. The better the storage efficiency, the less water is wasted in this way. As water moves, it carries pesticides along with it. To prevent pesticides from reaching a high water table, irrigation water should not leach to the water table. Alternatively, it should only reach the water table after enough time has passed for the pesticide to degrade and become less toxic.

The term relative amount[2] (RA) is used to describe that fraction of the applied pesticide which is expected to reach a certain soil depth. The higher the water storage efficiency, the less water and the less RA reach a specific soil depth. The following illustrations (based on computer simulation) show the effect of water application practice on the RA reaching a particular soil depth. These illustrations are meant to compare the relative importance of different furrow irrigation designs and to show which design is environ-

[1]The water storage efficiency, or simply storage efficiency, (Es) is given by the relationship:

$$Es = \frac{\text{amount of water (inches) stored in the root zone}}{\text{amount of water (inches) infiltrated into soil profile}} \times 100$$

[2]Relative Amount (RA) is the fraction of the amount of the initially applied chemical that exists within a specified soil depth at a certain time after application.

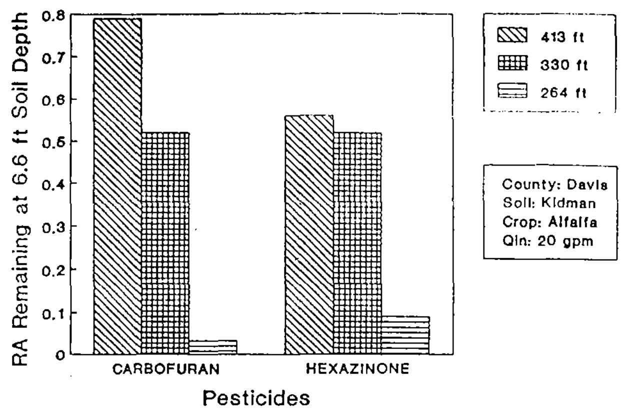


Figure 1: Effects of Furrow Lengths on Relative Amount (RA) of Pesticides Remaining in the Soil when They Reach to a Depth of 6.6 ft (2 m).

safer than another. However, the results are site, crop, irrigation schedule and pesticide specific. Different results may be obtained for other situations.

Figure 1 shows the effect of furrow length (FL) on the RA when the percolating water reaches a depth of 6.6 ft (2 m) below the ground surface. The shorter the furrow length, the greater the Es and the smaller the RA. Figure 2 shows the effect of furrow head inflow rate (Qin) on RA. As Qin increases, Es also increases and pesticide leaching decreases.

Farmers are interested in knowing how to reduce pesticide leaching. Figure 1 shows decreasing RA values of Carbofuran (Furadan) and Hexazinone (Velpar) with decreasing FL. If FL cannot practically be decreased in a particular field, RA values can be reduced by increasing Qin at the furrow heads (Figure 2). Furrows that are too long and/or irrigated with small Qin will have unnecessary leaching of pesticide, particularly in coarse textured soils.

Figures 1 and 2 are somewhat cumbersome to use. However, for a particular site, crop and chemical, they can be combined into a graph like Figure 3. It shows effects of different water inflow rates (Qin) and furrow lengths (FL) on storage efficiency (Es) and on the relative amount (RA) of Hexazinone remaining at 6.6 ft (2 m) soil depth.

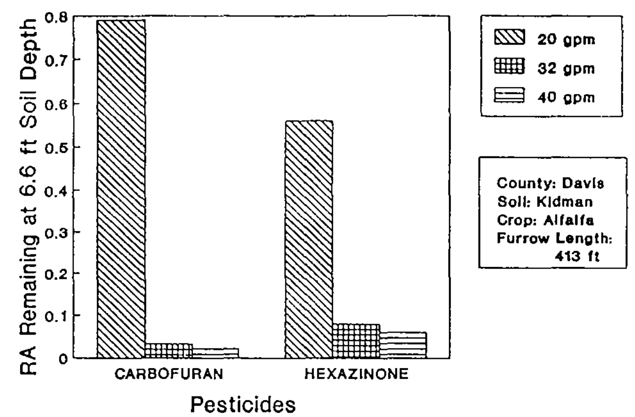


Figure 2: Effects of Furrow Head Inflow Rates (Qin) on Relative Amount (RA) of Pesticides Remaining in the Soil when They Reach to a Depth of 6.6 ft (2 m).

Utilized was a 1986 irrigation schedule for alfalfa, the most commonly grown crop in Cache County, Utah, a 5 ft (1.5 m) rooting depth in Kidman (sandy loam) soil and 0.006 ft/ft (m/m) furrow slope.

Figure 3 illustrates, for example, that three Qin/FL combinations, such as **32 gpm, 264 ft** (2.0 l/s, 80 m), **40 gpm, 330 ft** (2.5 l/s, 100 m) and **48 gpm, 413 ft** (3.0 l/s, 125 m), can yield the same predicted RA of 0.28 for Hexazinone remaining at 6.6 ft (2 m) soil depth. To achieve a target leaching fraction (RA), one can either choose a lower Qin and shorter FL or higher Qin and longer FL. In effect, this figure helps one select the best furrow irrigation system for a specific site, chemical and irrigation schedule.

A different sort of graph is helpful if a farmer wants to select the environmentally best pesticides for a particular site, irrigation system and schedule. Farmers usually have a range of pesticides to choose from. Each pesticide has a different value of its partition coefficient[3] (K_{oc}) and half life[4] ($t_{1/2}$). Respectively, these parameters describe how tightly a pesticide is held to organic material in the soil and how slowly the pesticide biode-

[3]The organic carbon (OC) partition coefficient (K_{oc}), ml/g OC is a measure of the tendency of an organic pesticide to be adsorbed to soil particles.

[4]The half life ($t_{1/2}$) is the length of time (days) required for one-half of the present pesticide concentration to be biodegraded.

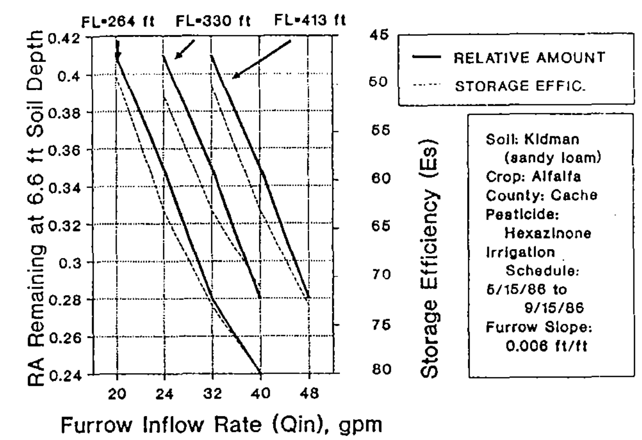


Figure 3: Effects of Different Inflow Rates (Qin) and Furrow Lengths (FL) on Storage Efficiency (Es) and on Relative Amount (RA) of Hexazinone Remaining at 6.6 ft. (2 m) Soil Depth Under Alfalfa Irrigation Schedule.

grades. The greater the partition coefficient the less mobile the pesticide. The greater the half life, the longer the pesticide survives.

The following figures (also based on computer simulation) are intended to compare the relative importance of different pesticide parameters and to show which pesticide is environmentally safer to use than another. The results are site, crop, irrigation system and schedule specific. Different results may be obtained for other situations.

Figure 4 allows one to see what K_{oc} and $t_{1/2}$ combinations cause the lower RA values. Assumed was alfalfa irrigated using a 1986 irrigation schedule in Cache County, Utah, and an observation depth of 1.6 ft (0.5 m). For low K_{oc} values, as the $t_{1/2}$ decreases, the RA remaining at 1.6 ft (0.5 m) soil depth also decreases (Figure 4). For a given $t_{1/2}$, as the K_{oc} increases, the RA remaining at 1.6 ft (0.5 m) soil depth decreases.

For higher K_{oc} values (greater than 75 ml/g OC), the predicted RA is 0.00 regardless of $t_{1/2}$. If the soil were uniform, no pesticide having a high K_{oc} would reach 1.6 ft (0.5 m). All alfalfa pesticides having K_{oc} greater than 75 ml/g OC would be safe to use even with the longest tested $t_{1/2}$ of 100,000 days. In reality, soils are not

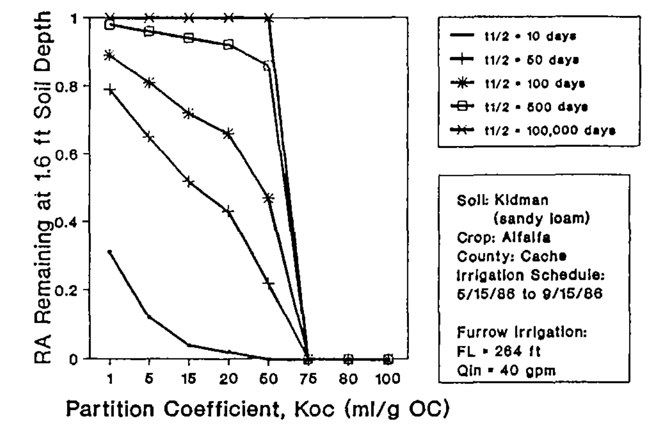


Figure 4: Effects of Pesticide Parameters on Relative Amount (RA) Remaining when a Pesticide Reaches 1.6 ft (0.5 m) Soil Depth for Known Site, System and Irrigation Schedule.

homogeneous (uniform). Water and pesticides can flow more quickly through worm holes and other irregularities than through uniform parts of the soil. Nevertheless, assuming a uniform soil is practical for our purposes.

Figure 5 depicts similar results at 6.6 ft (2 m) soil depth (below the alfalfa root zone). Here, no pesticide with $t_{1/2}$ of 10 days or less reaches 6.6 ft (2 m) soil depth, regardless of K_{oc}. Pesticides with very short half lives biodegrade long before they can percolate deeply at that site. Only pesticides with lower K_{oc} values (20 ml/g OC or less) and longer $t_{1/2}$ (greater than 10 days) will leach below the alfalfa root zone. Such pesticides have a greater potential for ground-water contamination.

Effect of Soil Properties on Pesticide Movement:

The more organic matter in the soil the more a pesticide is adsorbed (sticks to soil particles) and the less it moves. The finer the soil particles (e.g. clay) the slower the water percolates and the more a pesticide biodegrades before reaching a specified soil depth. For