PROCESS DRIVEN MODELS FOR SPRAY RETENTION OF PLANTS

Plant Protection Chemistry NZ

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The aim of this project was to investigate and develop physical models of the process of spray retention on plants. This depends upon many factors including the droplet distributions (size and velocity), the spray formulation's surface tension, the plants' leaf characteristics (such as being waxy or hairy), and finally the properties of the plant canopy (such as overall shape, height and the distribution of leaves and leaf angles).

The MISG group divided the problem into a number of sub-problems: a spray model; a collision model; a run-off model; and a plant canopy model. From the canopy models the probability of hitting a leaf is determined. From the spray and trajectory model the droplet size and velocity is determined at the point of hitting the leaf (in fact a whole spectrum of values is required). The behaviour of the droplet and whether it bounces, adheres or shatters is determined from the collision model. Finally run-off must be monitored and allowed for. As well as their own experience and experimental results, the PPCNZ representatives brought an extensive collection of papers from the scientific literature. The information therein provided a large part of the foundation for the different component models.

The spray droplet characteristics are highly dependent upon the type of sprayer used. Sprays can have many forms with different initial distributions of droplets, droplet velocities and release heights above the crop. As an initial scenario, the group assumed a typical situation with a boom sprayer 0.5 metres above the crop with numerous nozzles. This scenario is a relatively common one for the spraying of low crops such as onions, potatoes and the like. The distribution of droplet sizes was taken to be 100 to 1000 microns and these droplets leave the nozzles at about 15 metres per second for a typical nozzle. Droplets of less than 100 microns were considered to be in the driftable fraction of the spray and so were not included. The droplets are taken to fall vertically and there is assumed to be no wind present. These factors can be incorporated in the model at a later stage if more complexity is desired. If allowed to fall for a sufficiently long time the droplets will slow down and approach their terminal velocity, at which time the forces on the droplet due to gravity and the drag of the atmosphere balance one another. For the sprays considered here the droplets are released from the nozzles at speeds much higher than their terminal velocities and it was determined that most droplets do not have sufficient time to reach terminal velocity by the time they reach the level of the plant canopy. If they do not impact on the plant surfaces immediately then they will continue to slow down as they fall further through the canopy. For the typical case here, only the very smallest droplets of less than about 160 microns reach terminal speed before arriving at the top of the canopy. For this reason the velocity of each droplet must be determined before the following impaction and retention models can be used.

There are a number of effects to be considered in the collision model. Very small droplets at lower speeds directed towards a leaf can be swept in a flow around the leaf. However, it was shown that this is not a significant effect for even the smallest sizes of droplet considered here (100 microns). It is therefore reasonable to assume that droplets moving in the direction of a leaf will impact upon it. For droplets colliding with a leaf there are three main categories of collision: the droplet may adhere to the leaf; it may bounce off the leaf retaining its integrity as a single droplet; or it may shatter into a number of smaller droplets. Initially upon contacting the leaf the droplet spreads under the kinetic energy due to its momentum. As the droplet spreads the forces due to surface tension act to reverse this spread and return the droplet to a more spherical shape. During this stage energy is lost due to viscous dissipation. An expression for the critical changeover from a droplet sticking to the leaf to it bouncing off the leaf was investigated by estimating when the kinetic energy of the droplet is entirely lost by viscous dissipation. The formulae developed for this have the correct qualitative behaviour but further work is necessary to quantify some of the leaf characteristics such as leaf roughness before it can be used in a predictive capacity. Whether a droplet bounces as a single entity or shatters is a more complicated matter. The group found some approaches for estimating the changeover point for this scenario.

Even if droplets initially adhere to the leaves, they may later run off the leaves either on their own or as larger agglomerated drops. With continuous application, the quantity of spray retained on the plant leaf surface continues to grow until the drops reach a critical point beyond which they begin to slide down the surface and drip off (this is referred to as run-off). Further spraying usually increases run-off and so the maximum retention occurs just before the initial point of run-off. The model relating to run-off and maximum retention depends upon droplet size, leaf angle, the surface tension of the spray and advancing and receding contact angles for the spray droplets upon the surface.

To be able to apply the above models to actual plants a model of the plant canopy was needed. This plant canopy model needs to be able to represent plants with different characteristics: there will be varying leaf angles and distributions and leaf surface area projections. Overall these models need to be matched to specific crop types. An L-system method was investigated and it was found that it can be used to construct plants with the appropriate characteristics. A self-similar fractal model may be used for the branches although this will be unsuitable for some crops, e.g. onions. A simplified two-dimensional plant was constructed in this way and a ray-tracing model was used to estimate the percentage retention assuming that all droplets striking a plant adhere without run-off. This should be extended to the three-dimensional case and the effects of non-adhesion and run-off incorporated.

To construct a model of the whole retention process all of these sub-models need to be brought together. Members of the MISG group constructed a flow-chart to illustrate the process and calculated retention for a simplified model by assuming some of the probabilities involved in the process.

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