

Focused spraying

Fighting plant disease without making a mess



The operating principle of electrospraying

by Arno Schrauwers

Each year in the Netherlands alone, some 8,000 tons of pesticides are sprayed onto crops. Some of this is used inside greenhouses, on plants, flowers, and fruit. The problem with spraying is that a large part of the pesticide, something like 80%, ends up anywhere but on the plant. This is not only a waste of material, it also puts the environment at risk, with airborne or water-borne pesticides possibly contaminating our drinking water resources. However, there is hope of improvement in the form of an electrospraying method devised by Dr Kees Geerse, who recently gained his doctorate. His plan may well result in a better method of fighting plant disease.

Geerse has reservations about the (initial) results of his research which involved investigating whether (and if so, how) the electrospraying method could be used to improve the effectiveness of crop spraying. He has not yet reached the point where the method can be tested on a larger scale, but even so, the results of the laboratory tests so far look very promising.

Electrospraying is a technique in which a liquid is atomised and charged by means of an electrostatic force. Dr. Ir. Jan Marijnissen's group is currently exploring the method for possible use in a number of applications at the TU Delft faculty of Chemical Technology. The possible applications include the administering of medicines to asthma sufferers, a field of research in which Geerse has already made his mark.

Attraction

Back to the greenhouse and the technology in hand. Applying an electrical charge to droplets of liquid has a double effect. First, since particles with a similar charge repel each other, widely dispersed clouds of fine particles are produced. These are then attracted by the target object, in this case a plant, which has a lower (earth) potential, or may even carry an opposite charge. The attraction between the droplet and the plant is one factor supporting the idea that electrospraying pesticides would yield much better, more focused results than simply squirting the liquid all over the place. It ensures that the liquid carrying the pesticide arrives at its destination. Another benefit of electrospraying over conventional (uncharged) spraying techniques is that the droplets get distributed onto the plant much more evenly. Once a charged droplet attaches itself to the plant, any subsequent particles will not be as eager to land on the same place, since similar charges repel each other.

Geerse: 'The problem was that to obtain useful results,



When a liquid is slowly pushed through a syringe, it will form into a spherical head at the tip of the syringe before flowing along the shaft. If a high voltage is applied between the syringe and a counter electrode, a remarkable phenomenon will occur. Positive or negative ions in the liquid, depending on the direction of the electromagnetic field between the syringe and the counter electrode, will move to the surface and accelerate the liquid. The result is an electrostatic pressure acting on the surface of the liquid and aimed outwards. If the field is raised to a sufficient level, the drop of liquid will obtain the shape of a cone (a so-called Taylor Cone). This is the point at which the electrospraying phenomenon occurs. At the tip of the cone a jet is formed from which a great number of minute droplets are generated. As a result of the electrostatic charge carried by these droplets, they will fan out into a spray. The British physician, William Gilbert, who dabbled in physics in his spare time, described the electrospraying phenomenon as early as 1600 in his book, 'De Magnete'. During the nineteen-sixties, Sir Geoffrey Taylor finally managed to provide a mathematical description of the cone observed by Gilbert, which since that date has been known as the Taylor Cone.

you must start by setting up a suitable test environment, and in this case, that took a bit of time. Consequently, we have not been able to test the system on a larger scale. On a small scale, with up to eight nozzles, the tests proved that the method was successful. The nozzles used for electrospraying have to be small to be able to create the Taylor cone. This limits a single nozzle's flow rate, so you need quite a few of them, as many as 100. Eight nozzles, so the tests showed, could not supply the amount of liquid needed.'

Fluorescence

Geerse: 'We did not use pesticides for the tests, so we could not analyse the relationship between the spraying technique and any reduction in disease incidence. What I have done, and this is a core part of the research, is to look at the distribution of the droplets across the plants by means of image analyse techniques.'

Using fluorescence, Geerse chose capsicum plants to find out how much pesticide actually lands on the plants. — Fluorescence is a phenomenon in which matter emits light of a visible wavelength after illumination with a wavelength of higher energy. A fluorescent was added to the spray liquid instead of a pesticide. The right type of fluorescent, when illuminated by ultraviolet light, will light up to show to the naked eye where the droplets have landed on the plant. Geerse took photographs of the leaves covered in fluorescent dots. He then used a pattern recognition algorithm that he had developed to calculate how well the liquid had been distributed across the leaf surface. By rinsing the spray liquid from the leaves and using a fluorimeter, he was able to determine the amount of fluorescent material that had actually landed on the leaf. 'The tests showed,' Geerse says, 'that electrospraying produces a very even distribution of the droplets containing the pesticide, even on the underside of the leaves, where most of the pests occur. The method still needs optimising and to improve the technique you would have to look at it in greater detail to find out more about how the system works. It would enable us to find out the best method for optimising the result, e.g. by applying a voltage to the plant.'

Automation

The great thing about greenhouses is that they contain a highly regulated environment, in which the plants are set out in equidistant rows, and where you do not have to cope with the annoying effects of wind and rain that mar outside experiments.

Geerse: 'The spraying itself is easy enough to automate, of course. That is already being done. The point of this technique is that it reduces waste and soil pollution.'

On the downside, the new spraying technique requires a rather refined pump for each nozzle capable of pumping out a highly regular flow. Most liquid pumps tend to have a pulse flow. The type of pump used by Geerse is also used in hospitals for intravenous feeds.

'These are pumps that cost a thousand euros each, and a full-scale spraying system uses dozens of nozzles, each with its own pump. It won't be easy to find a buyer for the spraying system if it is going to cost hundreds of



The electrospraying technique given shape in the form of a nozzle as used by Kees Geerse in his greenhouse tests. The nozzle was designed by Charles Marijnissen, the 80-year old uncle of Dr. Ir. Jan Marijnissen, and was made at the faculty workshop.



The body of the nozzle is made of Delrin (a Teflon-like plastic), and contains a feed duct, a stainless steel needle, and a high-voltage ring acting as a counter electrode.



thousands of euros in pumps alone.

‘Anna Hubasz, another doctorate student, from Poland, will be looking into this side of the matter’, Geerse says. ‘My part was to see if the technique can be used to produce an evenly distributed fine mist. Verifying where the droplets land, as I have done, is not something I’ve seen done elsewhere. And another thing I did not look into was how well the pesticides work in combination with the electro spraying technique.’

Pests

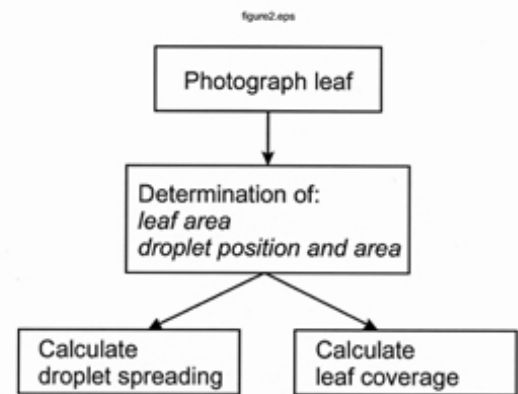
Geerse expects the electro spraying technique to help reduce wastage of pesticides, and so reduce the negative impact on the environment, both inside and outside the greenhouses. Even so, wastage will not be reduced to nil. ‘You simply cannot avoid hitting other objects beside the plant. What you can try though is to make the system as efficient as possible, for example by experimenting with applying a voltage to the plant. However, from this point of view the electro spraying method is much more efficient than the current method using a high pressure.’

Which brings us to the obvious question, is it really necessary to spray pesticides? Is there no other way, say by making the plant absorb some sort of chemical that will see off any pests or diseases?

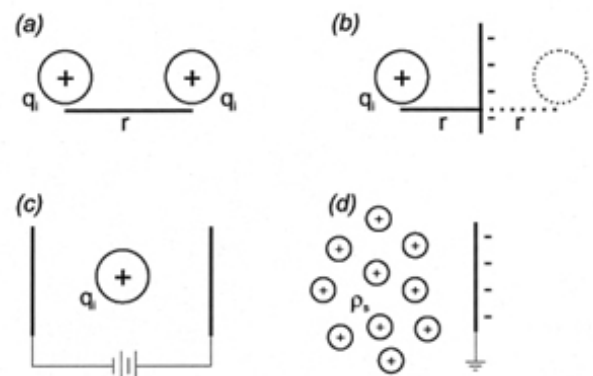
Geerse does not know of any such means.

‘Modern techniques to control pests include using ichneumon wasps and birds, but pests are not the only things threatening plants. As it is, the best way to fight diseases is from the outside, which means spraying.’ And if you have to resort to spraying, it had better be done in the most efficient way possible, in which case electro spraying would seem to be a good candidate for the job. Geerse has not been able to deliver the full proof, but the results of his first steps appear to be very promising. According to Dr Marijnissen, industry contacts have been made in an effort to develop a fully-fledged version of the sprayer.

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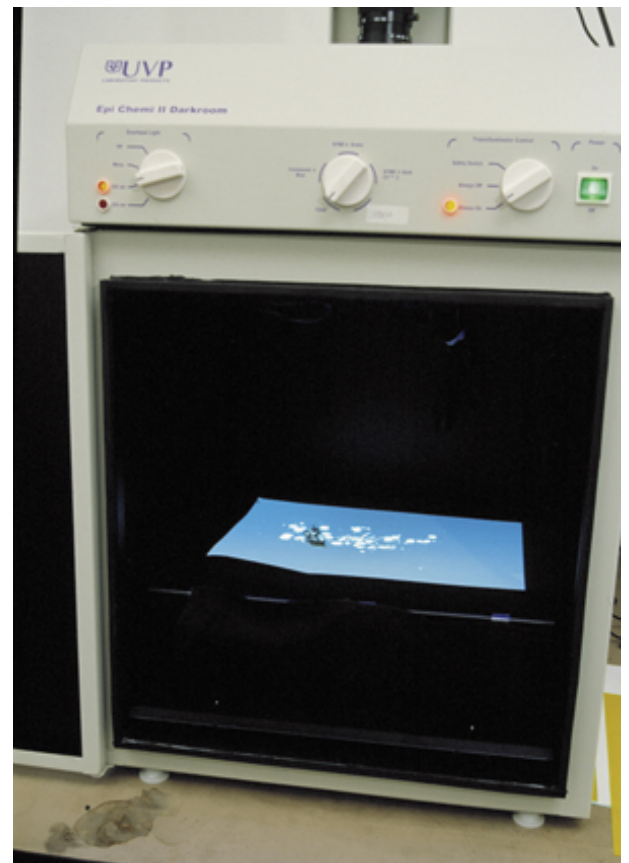
Pesticides can be applied in a number of different ways, depending on the type of crop. Chrysanthemums are sprayed from above, but capsicums need to be sprayed from the side. Whatever the direction of application, only a small part of the pesticide actually lands on the plant. Most of it ends up polluting the environment. Apart from the environmental impact, this greatly reduces the efficiency of the pesticide. One way of increasing the efficiency is focused spraying. This picture shows an electro spraying test set-up in a capsicum glasshouse at the Applied Plant Research Institute at Naaldwijk, which forms part of Wageningen University.



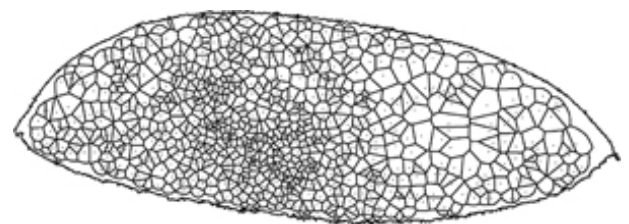
The interaction between a charged droplet and its surroundings: a) droplet/droplet interaction; b) image-force, increased attraction between a droplet and a neutral object. As a result of the electrical field caused by the (positive) charge of the droplet, free charge carriers migrate to the (neutral) surface of the liquid, leaving increasing numbers of negative charge carriers behind. The result is enhanced attraction; c) electrically charged particle in an electrical field; d) same as b, but with a group effect.



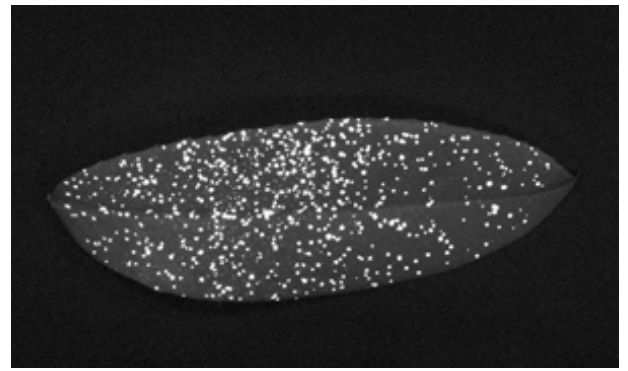
Test set-up for the analysis of the sprayed leaves. It consists of a microcomputer (on the right) and a dark chamber (on the left) carrying a very sensitive camera.



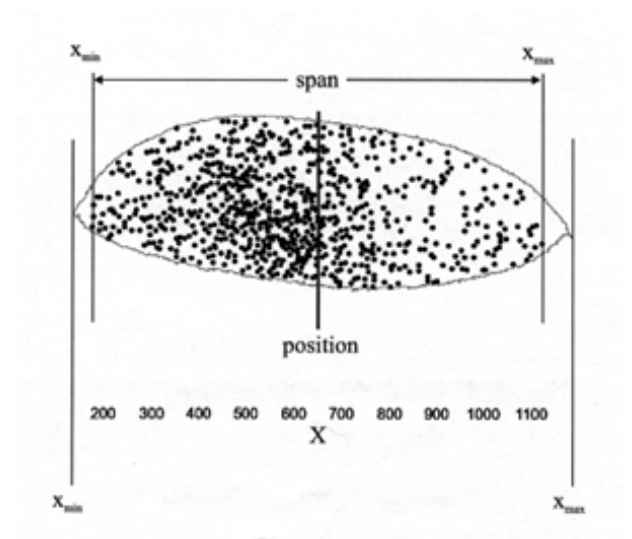
The plants used for the test were sprayed with a fluorescent (Tinopal) using the electrospraying method. The plants were then illuminated by ultraviolet light source, causing the droplets to glow up in the dark.



Using the imported data, MatLab generates information about the distribution and coverage, as shown in this graphical representation. The dots represent the centres of the droplets, the lines around the dots show the free space around the droplets.

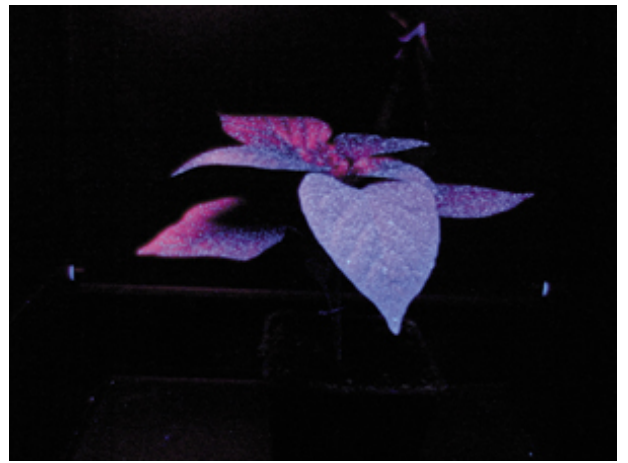


Black-and-white image of a sprayed leaf, taken in the dark chamber. Black-and-white was used because of the higher sensitivity of the camera for greyscale values. The camera can distinguish between up to 4,000 greyscale values, allowing very high resolutions to be used. Using image processing techniques, the picture is analysed for a) the leaf surface area; b) the droplet surface areas and positions. The data are then exported and subjected to mathematic algorithms by MatLab.



Using MatLab, Geerse was able to automatically generate a graphical representation of the average distribution of the droplets.





Sprayed plant under normal light and under a UV source. The droplets on the leaves are so small (50 - 100 μm) that they can hardly be seen in normal light. When subjected to UV light, they light up, allowing them to be detected with the naked eye.



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