Project title	Improving the efficiency of spray application for protected ornamental crops: a study of current spraying methods and novel spraying technologies (phase 1: desk study)
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Key workers:	Bill Basford and David Talbot, ADAS
Location:	ADAS Rosemaund Commercial sites: England and Belgium
Industry representatives:	Mr Colin Frampton Hall Hunter Vinnetrow Road Chichester West Sussex PO20 1QD Mr Russell Woodcock Bordon Hill Nursery Stratford upon Avon Warwickshire CV37 9RY
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DISCLAIMER

The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

John Buxton
Horticultural Consultant
ADAS

Signature .... Date ....

Bill Basford
Mechanisation Consultant

Signature .... Date ....

Report authorised by:

Tim O'Neill
Horticulture Research Manager
ADAS

Signature .... Date ....

CONTENTS

GROWER SUMMARY

Headline

- The most common spraying system currently used by ornamental growers is inherently inaccurate, applies too much water and can lead to pesticide run-off.
- Methods to improve spray accuracy and reduce spraying costs are identified.

Background

Spraying methods have changed relatively little in ornamental horticulture over the last few years, whilst in other crops, including arable and fruit crops, there have been significant developments which have improved crop canopy penetration, reduced water volume applied and reduced drift. Many growers of protected ornamentals use a high volume trailed sprayer such as the Brinkman RIPA, coupled with a RIPA spray pistol which is difficult to calibrate and uses water volumes of 1000-5000 l/ha in contrast to an average of 100-200 l/ha in arable crops, where spray booms and nozzle systems are used. There is clearly potential to reduce the water volumes currently applied in ornamentals, with concomitant savings in chemical and labour costs.

This project reviewed a range of new developments in crop spraying technology in order to highlight those that have potential to be introduced to ornamental horticulture in the near future (phase 1). Follow up work will study aspects of current practice *in situ* on nurseries, to identify and quantify the range of factors, such as water volumes, pressures and settings on the RIPA pistol that are currently used by growers. These factors will then inform work using laser droplet spectrum analysers to evaluate combinations of pressure, nozzle diameter and setting on the twist grip most likely to give best droplet spread and penetration for ornamental crops. The biological effectiveness of treatments will not be addressed within the scope of this project.

The overall project aims are:

1. To improve the efficiency of spray application in ornamental crops;
2. To highlight novel technologies that ornamental growers can readily adopt.

The specific objectives are:

1. To review novel developments in crop spraying technology, including those in Europe, and identify those of greatest potential for use on ornamental crops (phase 1);
2. To gather data on current spraying practice and to assess the range of performance

achieved when using the RIPA spray pistol;

3. To identify aspects of best practice and develop guidelines for adoption by growers.

Summary

Current methods used in the UK

The majority of protected ornamentals growers in the UK use trolley sprayers designed to apply pesticides diluted in water and applied under pressure via a spray pistol. One of the most common models is the Ripa model supplied by Brinkmans: www.brinkmans.com. This is infinitely adjustable using a twist grip to vary the droplet size and "throw" of the spray jet. A few growers use spray booms with conventional nozzles, but these are in the minority. For effective use of a boom system, the architecture of the greenhouse and the crop spacing and bed positioning needs to be considered, and can often be a limiting factor.

The main advantage of the spray pistol is its flexibility, and its ability to treat crops grown on benches or the floor, irrespective of the architecture and crop spacing of the greenhouse or tunnel. However, there are many disadvantages of the spray pistol, including the high pressures needed (20-30 bar); difficulty with calibration; uneven application; high volumes of water required and ineffective crop coverage. If the setting on the twist grip of spray pistol is adjusted for a very fine spray cloud, operators may be exposed to more spray mist, with associated hazards, and so full PPE is required when using it in this manner.

Water volumes applied by growers using this system vary from 750 - 5,000 l/ha, depending on the crop and grower concerned. For instance, low growing bedding plants may only require 750 l/ha, whereas a well grown poinsettia crop, which needs application in two passes, up and down the bench, may require 5,000 l water/ha. Obviously, with a high volume rate for any pesticide, the higher the water volume, the longer application takes, and so labour costs increase. If the pesticide is applied at a set concentration rather than a quantity per unit area, more pesticide is needed at high spray volumes. Thus, the total costs per hectare treated can become very high with spray pistol application systems.

The Ripa spray pistol is the main model used by UK growers, and it is normally supplied with a 2.5 mm nozzle. A similar type of spray pistol, which is also adjustable via a twist grip, is the Alumax, supplied by CMW Horticulture:

(www.cmwhorticulture.co.uk/pestdisease.htm).

When questioned, many growers were unaware of the fact that the Ripa spray pistol can be supplied with nozzles of various sizes from 1.0 mm up to 2.5 mm (Table 1). These nozzles are easy to exchange and can reduce the water volume used cheaply and easily. This fact

alone, if better publicised, could save growers time and money by substituting a smaller nozzle in their existing spray pistol.

Research findings on current practice

Extensive studies in Europe (e.g. Foque *et al*., 2012) have shown that boom systems, either hand held, or automated boom or gantry type systems, apply pesticides more evenly, using lower pressures, can achieve better underleaf coverage and result in less operator exposure than hand held spray pistols or lances such as the Ripa pistol.

Surveys of agricultural sprayers, using conventional spray booms and either cone or flat fan nozzles (Basford, 2012) showed that the range of pressures used varied from 2-4 bar and the water volume applied ranged from 100-200 l/ha. For a few specialised operations such as potato haulm destruction, as much as 600 l/ha was used, but this was exceptional.

Therefore, in protected ornamental horticulture, between 3.5 and 25 times more water per hectare is used to apply pesticides than is currently used in arable systems. There is clearly scope to reduce this major discrepancy in the future. Vegetable growers also use higher water volumes than arable applications, but even here the maximum volume (applied using tractor mounted spray booms and special nozzles) is unlikely to exceed 800 l/ha. (Syngenta crop protection leaflet, 2012).

Novel nozzles and spraying systems

There are many new spray nozzles designed to fit spray booms, including air inclusion, twin air nozzles, and the new Syngenta vegetable nozzle. However, they are not practical for ornamental growers to use unless they change from the spray pistol to a boom based system. For this to be possible, however, bed spacing would have to be adjusted to allow access for spray operators. This has been done by some growers (see illustration figure 4), but inevitably space for cropping is reduced due to the need for pathways at regular intervals.

Completely novel spraying systems include the Electrostatic (ESS) system, the Micothon air assisted semi automated system, automatic spray booms from Visser, the Degramec spray cabin, ULV based systems such as the Micronair and the robotic sprayer from CMW horticulture. Details of these systems are given in the main body of the report.

SCIENCE SECTION

Current spraying practices used in the UK and Europe

Consultancy experience over many years, and recent HDC sponsored events such as spray workshops and the DVD "spray check" production has confirmed that the great majority of UK growers use a trolley sprayer (figure 1) with some type of spray pistol or lance. The most common model is the Ripa spray pistol from Brinkmans (figure1), but there is also an Alumax model (figure 2) and Brinkmans supply a "trident" type mini boom called a Bologna art 6, which has three brass cone nozzles with swirl plates (figure 3). This latter type has the advantage that it can be easily calibrated, provides good "throw" for wide beds, and is more likely to give even coverage than a Ripa spray pistol. It is felt that the Bologna mini boom and lance should be better known by UK growers. Boom sprayers do not necessarily allow better underleaf coverage than spray pistols, however, and the skill of the operator is crucial in this regard.

The spray pistols have advantages, including:

- Ease of use.
- Robust construction.
- Flexible and adjustable with ability to "throw" the spray cloud up to 3 metres, thus allowing coverage of crops grown on the floor in wide beds with narrow paths.
- Experienced operators are able to vary the spray angle so as to improve under leaf coverage, and the high pressure may allow good crop penetration (figure 5).

They also have disadvantages, including:

- Difficulty of calibration
- No markings on the twist grip so that different operators can use the same settings
- Produce a range of droplet sizes from very fine to coarse
- Tend to apply high water volumes and need high pressures to achieve a good throw of the spray cloud.
- No data on droplet sizes produced at different settings.
- Lack of information on the different nozzle sizes available, so growers tend to stick with the one supplied.

Data on flow rates for different size nozzles for the Ripa pistol are shown in Table 1. The data shows that the effect of reducing nozzle size has a dramatic effect on water flow, especially at the high pressures (15 bar and above) that are often used by UK growers.

High volume “Ripa” tank trolley sprayer

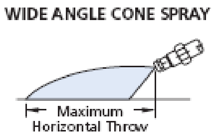
“Ripa” spray pistol

Figure 1. Typical trolley sprayer (left) and spray pistol (right) used in the UK

Table 1. Flow rates from Ripa pistol using different nozzle diameters and varying pressures

Nozzle No.	Ripa pistol outputs (l/min) (fully open) at:		
	5 bar	10 bar	15 bar
1	2.2	2.7	3.1
1.2	2.9	3.7	4.3
1.5	4.6	5.7	6.7
2.0	8.3	10.2	11.8
2.5	12.9	15.9	18.5

Adjustment of the spray pistol nozzle affects both the spray cone shape and the horizontal throw:



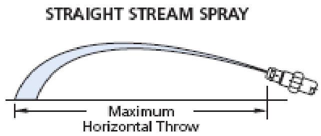


Figure 2. The Alumax spray pistol

Figure 3. The Bologna trident mini spray boom

Figure 4. Beds set up to allow access for a boom sprayer along spaced pathways.

Figure 5. Operator aiming spray pistol "up and under" to improve under leaf coverage.

Research findings on current practice

There is a large amount of published information on spray application in ornamentals, but one of the most active teams is at the ILVO (Institute for Agricultural and Fisheries research, Merelbeke, Belgium. Website: www.ilvo.vlanderen.be).

The author visited the team of Dr David Nuyttens at the ILVO in March 2012, and had useful discussions about their research on spray technology for ornamental crops, as well as visiting some Belgian growers. The ILVO have excellent facilities for research into spray technology, including a diffraction laser to analyse droplet size and velocity and are interested in co-operative research projects.

Given the demise of the spray facilities at Silsoe, and the general reduction in research capability in spray application in the UK, this might be of interest for future research projects. Contact the research team leader David Nuyttens at david.nuyttens@ilvo.vlaanderen.be

A survey of 120 ornamentals growers in Belgium (Goosens *et al*, 2004) showed that over 70% of growers used a spray lance or pistol. Only 10 % of growers used a boom, and it is thought that a similar picture applies in the UK, although no definite statistics are available. The research by Goosens *et al*. also showed that 55% of growers used high spraying pressures, between 20 and 40 bar (300-600 psi).

The authors speculate that these pressures are likely to cause premature wear of nozzles and also apply more water than needed for good spray coverage, with a large % of the spray running off the crop onto the ground. Application technique was also investigated, and the researchers found that over 60% of operators applied the spray while going up the pathway and again coming back, so they had to walk into the spray cloud twice. Where appropriate, good practice would be to walk backwards so you do not walk through the spray cloud at all. Braekman and Sonck (2008) also confirmed that many Belgian growers with spray pistols or lances used them at high pressures, leading to water volumes up to 6,000 l/ha being used. The growers surveyed felt that this water volume was needed to achieve coverage in dense crops, but inevitably run off to ground occurred, thus wasting pesticide.

Testing of sprayers is compulsory in Belgium, whereas it is voluntary in the UK, and although the take up of the STS (sprayer testing scheme as supported by the Voluntary Initiative) is over 75% in UK agriculture, in horticulture it is much lower, although detailed data is not available.

Knewitz *et al*. (2003) conducted trials in greenhouses and compared the spray distribution from a boom fitted with cone nozzles with a spray pistol fitted with a single nozzle. Overall, the boom provided significantly better spray distribution in the canopy of a poinsettia crop than the spray pistol. The 1 metre boom was light enough to be carried by hand, and the effective spray width could be varied by shrouding or turning individual nozzles on and off along the boom.

Langenakens *et al.* (2002) also found that boom spraying provided more uniform distribution of spray deposits than a handgun or spray pistol, when ornamentals were grown on the floor. Nuyttens *et al*. (2004) at the ILVO found that 35 cm spacing of flat fan nozzles on a boom provided better spray distribution than the same nozzles on a 50 cm spacing, and the best nozzle to target distance above the crop for flat fan nozzles was 30 cm. These results confirm the improved effectiveness of boom systems compared to spray pistols, but as stated earlier, the architecture of the greenhouse or polythene tunnel does not always allow boom systems to be used.

A related study by Derksen *et al.* (2008) compared spray pistols adjusted to three different settings, which provided high (>1000 l/ha), medium (500 l/ha) and low (250 l/ha) water volumes respectively. The water volume was varied by adjusting the pressure on the spray pistol and this also had the effect of making the spray quality coarse, medium or very fine, at low, medium and high water volumes respectively. An Alumax type spray pistol made by Dramm Corporation (see figure 2) was used in this work. Coverage of leaves on a well grown poinsettia crop by the different spraying settings was compared, and the results showed that the spray deposits on leaves were similar for all three treatments. However, canopy orientation had a significant effect on coverage and front and upper canopy areas of poinsettias had better coverage than lower areas and the backs of the plants.

Lindquist (1988) found a similar result and concluded that the skill of the operator had more influence on canopy deposition than spray volume or spray quality (droplet size). Derksen *et al.* speculate that treating the target from two directions would help improve the uniformity of spray coverage, but point out that a single nozzle spray pistol will always be subject to variability in deposits across the sprayed area. They state that growers would benefit from spraying methods (such as a boom) that would ensure more uniform applications whilst maintaining the flexibility and manoeuvrability of a spray pistol.

Foque and Nuyttens (2010) at the ILVO tested a spray boom applying pesticides to potted ivy plants with different types of nozzles, including hollow cone, air inclusion flat fan, and standard flat fan with or without an inclined spray angle. They found that the hollow cone and air inclusion nozzles, and the inclined flat fan, gave improved coverage of a dense ivy crop, due to the effect of swirling droplets with a high momentum that were able to penetrate the foliage better. A later paper by the same authors (Foque and Nuyttens, 2012) showed that air assistance did improve spray coverage, and this was optimum when an inclined flat fan at a 30 degree forward angle was used. This gave the best overall coverage of a dense ivy crop. These research results show that, not only can boom systems improve spray coverage compared to spray pistols, but by choosing the correct nozzles, coverage can be improved even more

Nozzle type and new nozzle developments

The conventional flat fan or cone nozzles have been supplemented by a range of newer nozzles, as a result of extensive research and development work carried out by academia, extension workers and private companies over the past five to ten years. Amongst these are:

a) Guardian Twin Air (figure 6 and 7). These have two outlets mounted on each nozzle, facing at 30 degrees forward and back and are 100 degrees flat fan nozzles. As the crop is sprayed, the droplets are angled forwards and backwards in the same pass, resulting in better spray coverage of dense crops.

b) Air inclusion nozzles (figure 8). These allow air into the nozzle during application and make the spray droplets larger by forcing air into the droplets. These are thus less prone to drift and are applicable mainly to arable situations. When the droplet hits the target it shatters into many smaller droplets, improving coverage of the leaves

c) Syngenta vegetable nozzle (figure 9). These were specially developed to improve the coverage of dense hearted crops such as lettuce. By using a 65 degree flat fan and high impact droplet velocity, the spray penetrates into the crown, and can improve the efficacy of fungicides and insecticides on brassicas and carrots.

All these developments can only be beneficial to ornamental growers if they can adopt boom spray technology, but further work is needed to develop compact booms that can work within the limits of complex greenhouse and tunnel architecture.

Figure 6. Guardian Twin Air nozzle

Figure 7. Guardian Twin air spray pattern

Figure 8. Air inclusion nozzle

Figure 9. Syngenta Vegetable nozzle, showing spray pattern

Novel spraying systems

There are many research papers dealing with novel spraying systems and also much information published by manufacturers. The main types of system include:

- Electrostatic sprayers (ESS systems)
- ULV systems (e.g. Micronair, Micron, UK)
- Spray cabins (Degramec, Belgium)
- Micothon and CMW semi robotic sprayers
- Gantry sprayers: these can be fully automatic or semi automatic (Visser Spray-O-matic)
- Automatic self propelled sprayer (Balsari *et al*., 2012, also Visser Spray-O-Mat).

ESS systems are being actively promoted in the UK by the company ESS Ltd., (Website: www.esseurope.com), and have application in many types of protected crops including strawberries. The machine most relevant to ornamental crops is shown in figure 10. It consists of a trailed sprayer with electrically powered compressor and two electrostatic spray guns per machine on a mini boom.

The electrostatic principle is well known and has been developed in several areas, but the main difference with ESS systems is the air assistance, which propels the tiny, negatively charged droplets (Volume Mean Diameter or VMD ca. 40 microns) into the crop canopy (which has a positive charge) and assists crop penetration. Otherwise, the electrically charged droplets tend to deposit mainly onto outer leaves and do not reach the inner canopy. Water volumes applied range from 150-200 l/ha, which is much lower than conventional horticultural sprayers.

Advantages include: good coverage of crop without making it very wet, as in conventional high volume spraying. This may aid control of diseases such as downy mildew, which needs high humidity or free water on the foliage for infection. Reduced water volumes needed, so less water usage. The ESS website claims that reduced pesticide rates may be possible without reduction in efficacy against the target.

Possible disadvantages include: Spray nozzles may not be very robust and could be damaged if dropped. Ease of operation may be tricky as two hoses need to be moved through crops; one for the spray liquid and another from the compressor. Tiny droplets may be subject to evaporation in high summer temperatures. Pesticides would be more concentrated and therefore only products that do not have any of the symbols Toxic/Very Toxic/Corrosive/Risk of serious damage to eyes can be used through ESS systems. Also any product that prohibits reduced or low volume spraying cannot be used in ESS systems, and the maximum concentration must not exceed 10X the maximum concentration recommended on the product label (Anon., 2008).

ULV systems such as the Micronair AU 8000 sprayer (figure 11) are not new, but the AU 8000 is a development of the Ulvafan, which was a very basic model only suitable for treating small areas of glasshouses. The AU8000 is basically a motorised knapsack machine but with a ULV rotary atomizer nozzle. The ULV spinning nozzle produces evenly sized droplets of VMD 100-200 microns, and the air assistance ensures good penetration of the crop. The flow rate can be adjusted to give rates from 50-200 l/ha. Advantages and disadvantages are similar to ESS systems, but the main difference is that the droplets are not electrically charged in ULV systems. For further details, see Micron website: www.micron.co.uk

Spray cabins are a new development which arose from a research project at the ILVO (Nuyttens, pers. comm.). The prototype machine was developed at the ILVO and tested on commercial nurseries, before being taken up and produced by Degramec Ltd (www.degramec.be). The principle is that the plants are taken to the sprayer, rather than the operator taking the sprayer to the plants (figure 12). The cabin uses conventional flat fan nozzles, but arranged in a vertical and 45 degree plane around a framework, so that plants passing through the cabin on a conveyor belt are treated thoroughly, with the nozzles angled at 45 degrees aiming droplets into the centre of the plant and underneath the leaves.

The cabin also has a tank suspended underneath so that any spray run-off is caught, filtered and recycled, thus completely avoiding spray losses on the ground. Obviously, this technology is only suitable for nurseries with adequate mechanisation, including the use of conveyor belts to move potted plants around at various times during production. Degramec only manufacture the cabin system to order and each sprayer is individually made for each customer.

Micothon spraying systems are produced in Holland by Micothon Ltd; website www.micothon.com. Their original machines were designed to run along the rails in tomato glasshouses, but the new Micothon EX is a free standing machine (figure 13) that is guided by the operator, and is suitable for glasshouses and polythene tunnels. It is being used already in flower crops in countries such as Kenya and Ecuador, but not in the UK as far as is known. The Micothon system is self propelled, and uses air assistance and high pressure nozzles, arranged in rows which can be spaced to suit the plant beds. It is claimed that reductions in pesticide rates of up to 50% are possible; however, there is no scientific evidence given on the website to back up this claim.

Further investigation is needed to obtain more data on these machines and the company manufacturing them. These machines are also expensive: prices quoted were around 22,000 Euro for the least expensive machine, the Micothon EX. Video film of this machine in operation is available on the company website, www.micothon.com

The UK based company CMW Horticulture (cmwhorticulture.co.uk) provides a range of trolley sprayers, usually supplied with a spray pistol such as the Ripa or Alumax, but they also offer the robotic self propelled spray robot manufactured by Buitendijk and Slaman in Holland (figure 14).

Figure 10. Electrostatic sprayer system from ESS Ltd

Figure 11. Micronair AU 8000 ULV machine

Figure 12. Spray cabin, made by Degramec Ltd in Belgium

This is battery operated and can be set to deliver up to nine different spray patterns, and has an adjustable spray mast so that crops of varying height can be treated.

Figure 13. Micothon spray robot

Figure 14. CMW Robotic sprayer

Figure 15. Automatic spray gantry system by Visser Holland.

Figure 16. Automatic mobile spraying system by Visser Holland.

<u>Gantry systems</u> are well known, but not that common in the UK, and really only suitable for ornamentals grown in glasshouses rather than polytunnels. Gantry systems are used in larger UK nurseries for accurate watering, but rarely for pesticide application. Microflor Ltd in Lachcristi, Belgium have an automatic gantry sprayer installed (figure 15), and this can be programmed to treat whole runs, individual benches or combinations of benches. The machine was manufactured by Visser, and the grower concerned was very pleased with its performance and versatility. It removes the need for operators to be in close proximity to the sprayer and thus reduces operator pesticide exposure. Conventional flat fan nozzles are used, but there are several nozzles mounted on the gantry, with different flow rates, and they can be switched easily just by rotating the bar.

<u>Automatic self propelled sprayers:</u> As well as the semi automatic or fully automatic gantry sprayer systems, (Spray-o-matic), Visser produce a less complex system which is simply

wheeled from bed to bed, and runs along the heating pipe rails, using its own in built spray reservoir to apply pesticides. This is called the Spray-o-mat (figure 16). This system could be utilised more often in the UK, in modern glasshouses that have pipe and rail systems and concrete pathways. In this system the spray boom is moved around on a carrying system and then lifted onto the overhead rails, and is then self propelled down the rows. Videos of this system and the Spray-O-matic are available on the Visser website (www.visser.com).

An automatic self propelled spray machine has also been produced by Balsari *et al.* in Italy (2012) as a prototype; the machine is not yet in commercial production, but is illustrated in figure 17. The boom is flexible and can be folded to allow entry into polytunnels or glasshouses, and it is intended to be fully remote controlled by an operator with a control panel. The operator can stand outside the tunnel whilst spraying is carried out by the machine.

It utilises conventional flat fan nozzles, and the research results from Balsari and his team showed that spray deposits in tests were very even using this machine. The main advantage claimed is the complete safety to the operator and removal of the risk of pesticide contamination.

Figure 17. Balsari prototype self propelled robotic sprayer.

Conclusions

1. The most common spraying system used currently by protected ornamentals growers is inherently inaccurate, applies too much water and can lead to pesticide run-off.
2. Extensive research has shown that boom-based systems, ideally with air assistance of some type, can improve spray accuracy and spray coverage whilst using less water.
3. The architecture of many greenhouses and polythene tunnels does not allow the use of boom based spraying systems in many cases, which has limited their uptake.
4. If growers adjusted their crop bed spacing to leave room between beds for a boom system to travel, then they could more easily be used, but this would lead to reduced crop per unit area of floor.
5. There are many novel nozzles which could be utilised in boom based systems and some are able to improve spray penetration in dense crops.
6. The Bologna mini boom system (figure 3) from Brinkmans can be used in systems with close cropping and should be better known; it may offer possibilities for improved spray application without incurring high costs.
7. Some manufacturers have produced semi or totally automatic spraying systems, which could be extremely useful for larger greenhouses as they avoid operator exposure to pesticides completely, whilst maintaining accurate and even application. However, these systems can be very expensive (the Micothon simplest system costs 22,000 Euros).
8. One of the simplest and least costly ways for growers to reduce their spraying costs would be to test smaller diameter nozzles in the Ripa spray pistol. Assuming that spray coverage could be maintained, there would be savings in time, labour and costs of pesticides by using this strategy. Many growers are unaware that different nozzles are available for the Ripa pistol.
9. The spray droplet pattern and range of droplet sizes produced by the Ripa pistol are still unknown, and this information would be very useful in understanding how these pistols operate, at different settings and flow rates, so that optimum settings could be found. This information can be gained by funding work in specialist laboratories and by practical work on nurseries.

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