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Welcome and Opening Address
Jim O'Mahony Teagasc

This event is very timely given that the EU is in the final stages of drafting radical new legislation concerning the placing on the market and use of Plant Protection Products (PPPs). This legislation has implications for farmers and growers, pesticide manufacturers and distributors, training and educational bodies, advisers, garden centres and nurseries, landscape contractors and local authorities, amongst others.

The theme of the event **'Making every drop count'** is particularly appropriate this year given the poor crop margins anticipated and our concern for the environment.

The tillage crops and horticultural industries contribute significantly to the national economy – worth close on € 1 billion and over 30,000 jobs.

Welcome

I welcome especially today our speakers from abroad:

- *Tom Robinson, Syngenta UK*
- *Erno Bouma, NL*
- *Mikkel Nilars, Hardi DK*

'Céad Míle Fáilte'

I extend a warm welcome to our Irish speakers including our chairman Bernard Rice from Teagasc, Gordon Rennick from the Pesticide Control Service, Department of Agriculture, Fisheries and Food and John Kelly from Kildalton College.

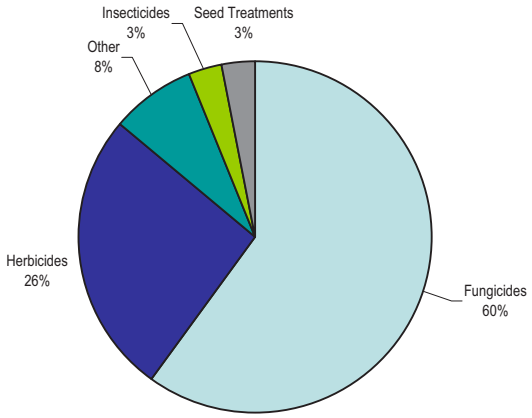
You the practitioners and industry observers are the focus of this event and are most welcome.

Agrochemical market 2008

The total agrochemical market is valued at €48.5m. The graph shows the % of value by sector. Note fungicides account for 60% of the total and herbicides a further 26%.

Our damp mild Irish climate has enabled our cereal growers to produce the top yields in Europe with the aid of PPPs but unfortunately without these products disease and pests would devastate our crops.

Teagasc trials over many years indicate that appropriate **fungicide** disease control programmes will give yield responses of up to 4.75t/ha in winter wheat, 3.0t/ha in winter barley and 2.75t/ha in spring barley. Quality of grain and straw will also be assured.



Aphids are the most significant pests of cereals in Ireland. These pests cause yield losses by transmitting virus diseases and by direct feeding on foliage and heads of wheat, oats and barley. Yield reductions, due to aphid transmitted viruses, in winter barley can be as great as 40%. Yield reductions of 20% and 11% due to aphid transmitted virus and aphid feeding, respectively, on spring barley have been recorded. Feeding by aphids on the heads of winter and spring wheat was found to reduce grain yield by 15%.

In some seasons and on particular soil types, **slugs** may cause serious damage to both winter and spring wheat crops. Reductions in plant populations and grain yield of 34% and 23%, respectively, due to slugs have been recorded at Oak Park. Yield responses to **herbicides** in cereals depend on crop as well as weed species and intensity. Teagasc trials indicate the following responses to effective broadleaved weed control – up to 6.0t/ha for winter wheat, 2.0t/ha for winter barley and 3.0t/ha for spring barley.

The **green image of Ireland's food** is paramount to maintaining our status as a food exporting country. An important part of that green image is to have fully traceable, quality food which exceeds the most stringent standards demanded by our export markets.
I thank all our speakers today for their invaluable contributions and wish all involved a successful and informative day.

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Farm Sprayer Operator of the Year Competition

Teagasc, Syngenta and the Irish Farmers' Journal are pleased to announce that they are coming together to hold the 'Farm Sprayer Operator of the Year Competition' in 2009. The competition will promote best practice in the skills required to perform a top-class practical spraying task and in its organisation. Entry forms for the competition are available at:

- The National Pesticide & Sprayer Event
- www.teagasc.ie
- Irish Farmers' Journal
- Syngenta Waterford

EU Pesticide Law - "Now and in the Future"

Gordon Rennick
Pesticide Control Service
Department of Agriculture, Fisheries & Food

Now

Plant Protection Products (PPPs) are among the most essential inputs for the sustainable production of high quality and safe food at affordable prices. Plant Protection Products are biologically active and are intended to control certain harmful organisms in crop production, in as targeted a manner as possible. These harmful organisms include weeds, insects, plant pathogens and essentially anything injurious to the health and integrity of the plant or plant product (obviously excluding weather etc.).

The current regulatory system for PPPs in EU Directive 91/414/EEC established a very high level of protection for man, animals and the environment. In many ways this Directive is ultra conservative, to provide reassurance to consumers and the population in general, that PPPs are applied safely and only where absolutely necessary and in the least amounts possible.

In the EU, active substances are evaluated by a Rapporteur Member State (RMS), on behalf of the European Commission. This evaluation is then peer reviewed by the member states and the European Food Safety Authority (EFSA), and if found to be suitable for use in the EU it is entered into Annex I of the Directive (positive outcome). In turn, each PPP (product you see on the shelf in agri-retailers) containing that active substance (now in Annex I) is then evaluated individually, by authorities in each member state.

The evaluation of the active substance and indeed the evaluation of individual products, is divided into two categories, hazard and risk.

First, the hazards of the chemical are assessed. This is accomplished by a detailed evaluation of studies carried out using either the active substance or the individual product, e.g., different indicator species of animal, insect, plant or fish etc are exposed to varying quantities of pesticide. It is then possible to assess what doses of a particular pesticide will generate a reaction in the animal, insect, plant or fish being tested. From these types of studies we can derive the No Observed Effect Level (NOEL), the No Observed Adverse Effect Level (NOAEL) or if appropriate the

No Observed Effect Concentration (NOEC) for different indicator species (accepted worldwide) such as rat, rabbit, dog, rainbow trout, quail spp., earthworms, Daphnia magna and Typhlodromus pyri, among others.

There are three human health endpoints of particular interest to us, the Acceptable Daily Intake (ADI), the Acceptable Operator Exposure Level (AOEL), and if appropriate, the Acute Reference Dose (ARfD). These endpoints are calculated using the lowest, most conservative relevant NOAEL, employing multiple safety factors to allow for intra and inter species variation. Similarly, environmental endpoints are derived again by using the figures from the most conservative studies deemed appropriate.

Second, the risks that arise from PPP use are assessed using the most up-to-date scientific information, models and techniques. PPPs are not authorized for marketing and use, unless it is shown that there will be no harmful effects on human health and no unacceptable impact on the environment. Using the endpoints and figures from the hazard assessment of the studies, mathematical models and calculations are used to calculate the extent of the risk of certain events occurring. The possibility of ground water and surface water being contaminated with pesticides is calculated using FOCUS modelling tools. The possibility of non-target species being affected by pesticides is arrived at by calculating the Theoretical Exposure Ratio (TER). Operator exposure is estimated using various predictive modelling tools. The theoretical exposure of non-target organisms in the environment may be refined using field studies, as opposed to using laboratory based data. When risks are identified and quantified, risk mitigation measures may be required to permit the use of the PPP in the field. Such measures include the use of buffer zones, personal protective equipment or other specific requirements.

Science, technological advancements, experience and history have taught us to concentrate on risk reduction strategies. The separation of the principles of hazard and risk is fundamental to the way in which the marketing of PPPs is currently regulated.

A hazard is a situation which poses a level of threat to human or environmental health. Most hazards are dormant with a theoretical risk of harm, if a set of circumstances are fulfilled, e.g., a bottle of poison is hazardous, it is quite safe if it remains in the bottle and quite deadly if consumed.

Risk is essentially the probability of the above set of circumstances being fulfilled, e.g., there is a higher risk of the bottle of poison being consumed if the bottle is not labelled as a poison, or if the bottle used is a soft drinks bottle, or if the bottle has no lid.

Our current approach to PPP approvals (risk-based) allows hazardous substances to be handled and used safely, if the risk assessments deem it appropriate, i.e., the risk

assessments prove that where due care and attention is practiced and all instructions for use are adhered to, the product can be used safely. Attention to reducing risks associated with pesticide use has resulted in safe traceable food being made available to European consumers at reasonable costs. At user level, the current regime has ensured that the user has the necessary information at hand to use the product safely. The number of accidents or incidents involving pesticide poisoning in the EU is low, considering the widespread use of these products. To ensure that this statistic remains positive, many EU member states have introduced voluntary and compulsory schemes on sprayer testing and operator training. Ireland has had voluntary initiatives from Teagasc on sprayer testing and operator education, and indeed the trade body BASIS has offered a crop protection module to allow those in the trade to increase their awareness and education on such issues as well as other crop protection topics.

At user level, the current Directive is not very prescriptive but nonetheless it allows for MSs to elaborate the principles of Good Plant Protection Practice (GPPP). Ireland has such a set of guiding principles appended to its implementing legislation (SI 83 of 2003 as amended)

Future

Revision of PPP registration regulations (Directive 91/414/EEC)

The revision of Directive 91/414/EEC was undertaken with a view to updating and streamlining the regulatory system for PPPs, the European Council and the European Parliament examined a range of proposals designed to improve the efficiency of the regulatory system and to reinforce measures designed to ensure their sustainable use. The resulting regulation contains much of the old directive, but it deviates in a number of significant areas. Despite the rather conservative approach to the approval of PPPs explained above, recent discussions and negotiations in Brussels have resulted in an even more conservative set of rules and regulations. These new rules and regulations will have a major negative impact on the range of products currently available to growers. These new rules will also have a major damaging impact on the research and development type companies, in attempting to bring new product chemistry to the market in the European Union.

The area of most relevance to end users is where the new regulation uses hazard-based cut-off criteria to approve active substances to be used in PPPs (currently we use a risk-based approach). This will result in the loss of quite a number of active substances currently in use in Irish crop production over time. Using the ‘bottle of poison’ example, this means that this bottle will no longer be available for use, regardless of the measures taken to avoid misuse. Among the active substances likely to be affected are compounds such as most of the triazoles (epoxiconazole,

metconazole, cyproconazole, tebuconazole, flusilazole), mancozeb, maneb, quinoxyfen, pendimethalin, linuron, glufosinate-ammonium, metribuzin, deltamethrin and esfenvalerate. There is a temporary derogation allowing a phase-out of such active substances but nonetheless the negative affects will be difficult to avoid. Unless the R&D companies can produce a genie from a bottle or better again about three dozen replacement active substances, the production of certain crops will be extremely challenging, and the maintenance of current yields nigh impossible.

Resistance management strategies in crops such as potatoes (late blight *Phytophthora infestans*) and cereals (*Septoria spp*. etc) will be severely affected, as certain actives substances with multi-site activity will no longer be available to support active substances with single-site activity. The net effect of this in Irish conditions will be that certain pesticide groups, particularly fungicides, will be more vulnerable to development of resistance than heretofore.

On top of this, end users and advisors alike will be faced with the challenge of "comparative assessment" and "substitution" at product level, i.e., where a number of products are available for the same use in the same crop, the least hazardous product must be chosen regardless of cost, and a rationale will be required to support choice of such products.

This regulation will have the following impacts at farm level:

1. Records must be kept for at least three years and 3rd parties may request access to them through the DAFF, PCS.

2. A rationale for product choice must be available if products are chosen that are candidates for substitution.

3. The range of products available will be reduced.

Sustainable Use Directive

The second important piece of legislation all but agreed at this stage is what we term the 'Sustainable Use Directive'. There is currently no legislation covering this area in Ireland. However, there is a statutory guideline termed 'Good Plant Protection Practice' which outlines some basic principles of appropriate PPP use. This 'Sustainable Use Directive' is aimed at regulating the 'use' phase of PPPs i.e., PPPs from retailer to professional user level. This Directive will have the following impacts at farm level:

1. Professional end users (farmers, landscapers etc) will require training for PPP use and sprayer operation.

2. Professional end users will be required to ensure their PPP application equipment is registered and is tested at the appropriate intervals.

3. End users will be required to fully implement Integrated Pest Management (IPM).

4. National Action Plans incorporating quantitative use reduction targets.

Advisers and others engaged in retailing and storage of PPPs will also be required to have basic training and continuous training as the need arises. End users and advisers will be responsible for adherence to the principles of IPM and as such record keeping will be critical in so far as providing a rationale for methods used or why PPPs were used in preference to non PPP methods. End users have until 2014 to become fully compliant in this area.

Regulation on Statistics and Farm Machinery Directive

A new regulation on the collection of statistics in relation to the use of PPPs is only months away from agreement. This will not have a significant impact on end users. However, end users, when requested, will be obliged to make available records for PPP use. The information that is made available by end users for the purpose of collation of statistics will be treated as confidential.

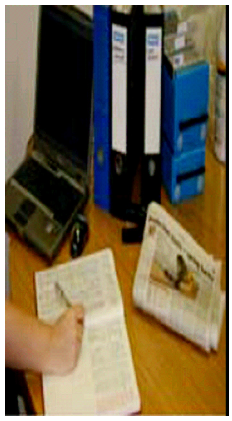
Further legislation on farm machinery including pesticide application equipment is currently being discussed in Brussels but is not expected to have dramatic effects at farm level. This legislation's primary aim is to harmonise basic standards that new sprayers must adhere to before being placed on the market.

Before and after in a nutshell

Before

Product approval	Use phase	Residues food	Statistics	Machinery
	**No EU harmonised regulation**		**No EU harmonised regulation**	**No EU harmonised regulation**
Directive 91/414/EEC		Regulation 396/2005/EC		

After

Product approval	Use phase	Residues food	Statistics	Machinery
 	 	 		
New Regulation Directive 91/414/EEC revised	**New Directive** "Sustainable Use Directive"	**Existing** Regulation 396/2005/EC	**New Regulation** Regulation on Statistics	**New Directive** Directive on machinery revised

As much of this legislation is not like to be passed into law until 2010/2011 the Pesticide Control Service of the Department of Agriculture, Fisheries and Food will engage with all stakeholders in an attempt to ensure that all regulations are enforced in a fair, equitable and practical manner.

Further information can be had directly from:

The Pesticide Control Service,
Department of Agriculture, Fisheries and Food,
Backweston Campus,
Young's Cross,
Celbridge,
Co. Kildare.
Tel: +353 1 6157618
Fax: +353 1 6157575
www.pcs.agriculture.gov.ie
email: pcs@agriculture.gov.ie

Pesticide Application Technology

Tom Robinson
Syngenta Crop Protection

The aim of all crop protection is to maximise output per hectare and minimise the cost per tonne of yield. At the same time, one must minimise the risk to the environment, bystanders, and the operator.

The optimum result would be 100% control of the target pest. This control is made up by:

1) Correct choice of product.
2) Optimum timing of the application.
3) Correct maintenance and setting of the machinery.
4) Correct choice of spray nozzle.

Correct choice of product

There are many good products on the market from a range of manufacturers. From the point of view of efficacy and ease of application, premium branded products from a company like Syngenta are consistent in their manufacture, formulation, and field performance and are a good starting point, where they are appropriate for the job in hand.

Optimum timing of application

This is the single most important aspect of spray application. As a rule of thumb, spraying cereal acreage should be completed in three days. A T2 application applied one week too late will lose 0.5 tonnes/ha of yield. To keep on top of a blight spraying programme one should be able to spray the potato crop in two days.

Techniques for improving spray timing include:

- Using lower water volumes where appropriate to gain more sprayed ha/day
- Using drift reducing techniques i.e. keeping the boom low
- Using drift reducing nozzles such as the Amistar nozzle.

Maintenance and Setting the Machinery

The goal is a uniform application of the spray across the field. The boom should be straight, the suspension system in good condition and well lubricated. New nozzles should be fitted annually. Tyre pressure has a big effect on boom stability and should be the minimum recommended for the maximum load being carried.

Minimising spray drift

The single most important factor for reducing spray drift is to keep the boom at the optimum height of 40-50 cm above the crop. Small increases in boom height result in big increases in spray drift. Drift is some six times greater when the boom is operated at 80 cm above the crop than at 50 cm above the crop. Further reductions in drift can

be obtained by fitting air induction nozzles. Typically these reduce drift by 75% compared to a 110^0 Fan Jet

Boom Height 0.8m

Boom Height 0.5m

Air Induction Nozzles 0.5m

Keeping the boom at the correct height

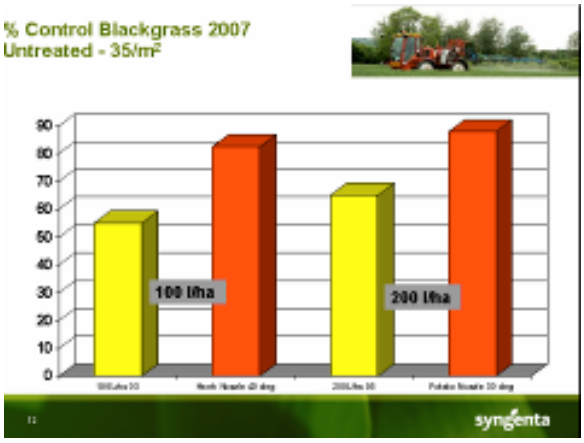
The latest sprayers can be supplied with electronic, automatic boom height sensors and controllers. For most sprayers however, the simplest solution for monitoring boom height is to fit a cable tie to both ends of the boom. Snip the cable tie off at 0.5m below the nozzles, and use it to monitor the boom height.

Choosing the right nozzles

For a long time there was little choice in nozzles and most spraying was done with 110^0 Fan Jets. Research and field trials in the past 10 years show that there are significant gains to be made in product performance and drift control by using nozzles designed for specific tasks.

Pre-emergence sprays

For numerous years it was thought that pre-emergence herbicides would redistribute themselves evenly. How they were applied was of limited importance. Application research at Syngenta Crop Protection showed that residual herbicide performance can be significantly improved by evenly coating the soil. To do this one needs to get spray on the back and underside of the soil clods. This can be achieved by using angled fan jets such as the Syngenta Hawk Nozzle, and the Syngenta Potato Nozzle. Point them alternately forward and backward on the boom.



Cereal fungicide sprays

Syngenta cereal fungicides such as Amistar, are very systemic, and move through the plant easily. The spray needs to be well retained and to evenly cover the plants. Coverage however, is not that important so a coarser easily controlled spray from an Amistar air induction nozzle is the best spray for cereal fungicides. The Amistar nozzle has a small backwards angle to help counteract the forward speed of the tractor which gives a very uniform distribution as well as producing very little drift.

In trials, the Amistar nozzle has typically increased yield by 0.3 tonnes /ha.

Wild oat control with Axial

The recently introduced graminicide Axial, is extremely effective at controlling a range of grass weeds including wild oats in wheat and barley.

To get the best control, attention to application is required. Graminicides are systemic upward in the weed, so penetration is important. Keeping the boom low can halve the number of wild oats remaining in the crop after treatment. It is important to use a minimum of 1 l/ha of the adjuvant Adigor. The best nozzles include conventional fan jets up to a 110-05, and the Amistar nozzle. The maximum forward speed should be no more than 12 km/h

Pesticide and Weather Interactions

Erno Bouma
Agro-Meteorological Advisory Service
Netherlands

Weather report doesn't tell the whole story

The temperature in official weather reports is measured at 125cm above mown grass in a Stevenson's screen. However, a crop grows on or in soil. If you look at the temperature progression at different heights (10cm and 125cm) on a sunny day, the temperature at ground level is lower in the morning and higher during the course of the day, compared to the temperature at 125cm. Why is this? Well, the sun warms the plants/leaves and then the plants/leaves warm the air, not the other way round. As a result, the surface of the soil and the crop are warmer than the surrounding air during the day. The leaves of the plants act as a heating element. The difference between the leaf temperature and the temperature at 125cm may be as much as 10°C. At night, the leaves and surface of the soil cool the air down with the lowest temperatures being found at ground level and close to the leaves.

Rate of uptake

Oil-based formulations adhere to the wax layer very quickly. Examples include the emulsifiable concentrates (EC). All crop protection products with these abbreviations in their trade name or on the label such as the synthetic pyrethroids (e.g., deltamethrin and lambda-cyhalothrin) are absorbed very quickly. For the water-based formulations the relative humidity (RH), soil moisture content and solar are more important than temperature. Water-based formulations can be identified by the addition of the letters SL, EW, SC or WG to the product name or on the label (e.g., Plenum 50 WG or Sencor WG).

Relative humidity, very important for uptake of Plant Protection Products

Moisture in the air plays an important role in many processes in agriculture such as the release and germination of fungal spores and the wetting of leaves by dew. The extent to which plant protection agents are absorbed by the leaf, or simply run off it, is also largely determined by moisture in the air.

Important for adhesion, a dry leaf

The adhesion and uptake of crop protection agents also depends to a great extent on whether the leaf cuticle is dry. Crop protection agents don't adhere well to a wet cuticle. If it is windy after spraying, or if it rains shortly after spraying, the spray droplets merge with the dew droplets. Then the dew combined with spray droplets run off the plant. In such situations there is absolutely no point in reducing the spray

mixture from 300 to 250 litres per hectare. The crop can hold after a dew-night, 10.000 litres of water per hectare!

Dynamics of the wax layer

In dry weather, with a low rh, high insolation and a moisture deficit at the roots (which is very important), a plant produces a lot of wax. As the plant risks transpiring more water than it can afford to lose, it increases its protection against drying out: this is known as hardening off. It is not only the thickness of the wax layer that changes under these conditions so also its structure. This has a substantial effect on the uptake of crop protection agents.

How are agents absorbed?

Many people believe that crop protection agents are absorbed mainly via the stomata, but this is not possible in the case of agents that are sprayed with water. The spray droplets are too large to enter through the stomata. Even if the droplets sprayed on to the leaf merge together to form a film, the surface tension of the spray mixture is still too high to allow penetration via the stomata.

Oil-based formulations are intended to enter the plant's moisture circulation system by diffusion from the wax layer. A key indicator that says something about how systemic crop protection agents are, is how well they mix with water. If they have low miscibility they remain in the wax layer after absorption. If they have high miscibility they are absorbed into the sap circulation. Temperature is the most important parameter: it determines the speed of absorption by the wax layer.
Synthetic pyrethroids (such as Decis, Karate and Sumicidin) are not easily transported by the moisture within the plant, so are not systemic.

Water-based formulations

In the case of water-based formulations, many more meteorological conditions are important. Polar substances are intended to be absorbed via the cutin layer by diffusion. That layer must first be very swollen with moisture that was already on the leaf. The relatively small quantity of spray mixture is not enough to swell the cutin layer. On average, transport through the cutin layer takes around six hours with formulations of this type. If the spray mixture dries up soon after spraying, due to very drying conditions and bright sunshine for example, this does not necessarily always spell doom for the spraying outcome. High light intensities, high temperature, strong wind and low rh accelerate the evaporation of the water (acting as solvent and carrier) and shorten the potential absorption time. As a result, less of the active substance is able to penetrate.

The right time to apply

In dull, good growing weather with some precipitation an arable farmer should get his spraying equipment ready. After a few days of this conditions are best for virtually all crop protection agents intended for absorption: weed control agents that work via the leaf: contact herbicides and growth substances, systemic insecticides, systemic

fungicides and leaf applied fertilizers. Absorption and effect are so much better that it nearly always pays off to wait for these ideal conditions.
For example, identifying the right time to apply water-based contact herbicides such as MCPA and glyphosate is a matter of precision. The plants' cutin layer must be as swollen as possible which is usually the case after a few days of dull, rainy, good growing weather. During application and for 48 hours afterwards the rh must be high, and there shouldn't be too much insolation.

Good growing weather

Warm, dry and sunny weather is a lot more enjoyable but don't expect a sprayed agent to have its maximum effect in such conditions because the plants won't be able to absorb it sufficiently. Examples of agents to which this applies include, all hormone herbicides (such as MCPA), but also glyphosate (e.g., Roundup), metribuzin (Sencor at low application rates), and bentazon (Basagran). Apply these only in good growing weather. If the application conditions are ideal you can often cut back a bit on the application rate.

When to apply contact fungicides?

Contact fungicides or preventive fungicides, such as mancozeb, fluazinam (Shirlan) or captan, are intended to work on the outside of the plant to prevent fungal spores from germinating or penetrating. Apply these at a time when the plants are dry to maximise their adhesion. The weather conditions after application should also be drying. The ideal time is in the afternoon, in clear, sunny weather with a slight breeze. The drying time under such conditions is approximately one hour. Never apply a contact fungicide early in the morning when a crop is wet with dew. The crop will contain a large amount of water from the dew.

Systemic fungicides

Systemic fungicides, such as the cereal fungicides tebuconazole and epoxyconazole, are intended to be absorbed by the cutin layer. To ensure that this layer is sufficiently swollen, wait for good growing weather. Apply the agent preferably in the early evening, during a dull period and in a dry crop, or in the morning on a crop that is almost dry, in a spell of dull weather. Systemic fungicides should also not be sprayed on a crop that is wet with rain or dew! Spraying with a cereal fungicide does not protect the whole plant. Fungicides with a systemic effect work on the outgrowth only. They are transported to the extremities of the leavesand not to the growing points. The strobilurins, such as trifloxystrobin and kresoxim-methyl, are a bit of a mixture. They have a local systemic effect, a contact effect and a vapour effect. Within the strobilurins group, moreover, there are substantial differences between these three modes of activity.

Book: Weather & Crop Protection

Far more information and answers to a lot of questions concerning the most optimal moment to apply and the possibilities of reducing the dose, can be found in the book: Weather & Crop Protection. It can be ordered by the Irish Farmers' Journal, Irish Farm Centre, Bluebell, Dublin 12.

New and Future Developments in Sprayers

Mikkel Nilars, Cand. Agro. MSc
Head of HARDI ACADEMY
HARDI INTERNATIONAL A/S
Denmark

Sprayers are getting bigger – and there is an increased focus on environment and operator safety. This has been the mantra for the last number of decades – and it will probably continue so for the next number of decades. At the same time farms are growing in size and the focus on capacity is becoming a more vital part of farm management.

New developments

Intelligent functions

Modern technology is increasingly used in farming as well as in all other businesses. One of the big advantages in spraying is to let the controller take over where the driver either hasn't got the chance of doing athe perfect job or where there is a high risk of failure. HARDI has looked into the different operations in practical spraying to find the areas which are most stressful for the operator. The first step was to divide the operations into two i.e., spraying and service. Spraying operations are the jobs the operator does in the field while spraying and service operations are the jobs done when not spraying.

In this list all the operations are listed with the most stressful at the top:

Spraying operations	**Service operations**
Steering the tractor	Cleaning
Boom height adjustments	Chemical filling
Controlling tractor speed	Water filling
Open and closing sections	Calibration
Variable rate control	Folding/unfolding booms
	Nozzle/filter cleaning

Considering this list the engineers have developed a range of intelligent features to assist the spray operator. Some of the jobs are related to the tractor and some to the sprayer. Auto steering is today a common feature on larger tractors – a good example of development done by tractor manufacturers to assist many of the implements used in the field.

Some of the features are however specifically used on the sprayer and therefore developed especially for this. I will now concentrate on these features and discuss them in order of priority from the table above. Please note that some of the features mentioned in this paper have just been introduced and are not yet available on the market.

Spraying operations

Boom management

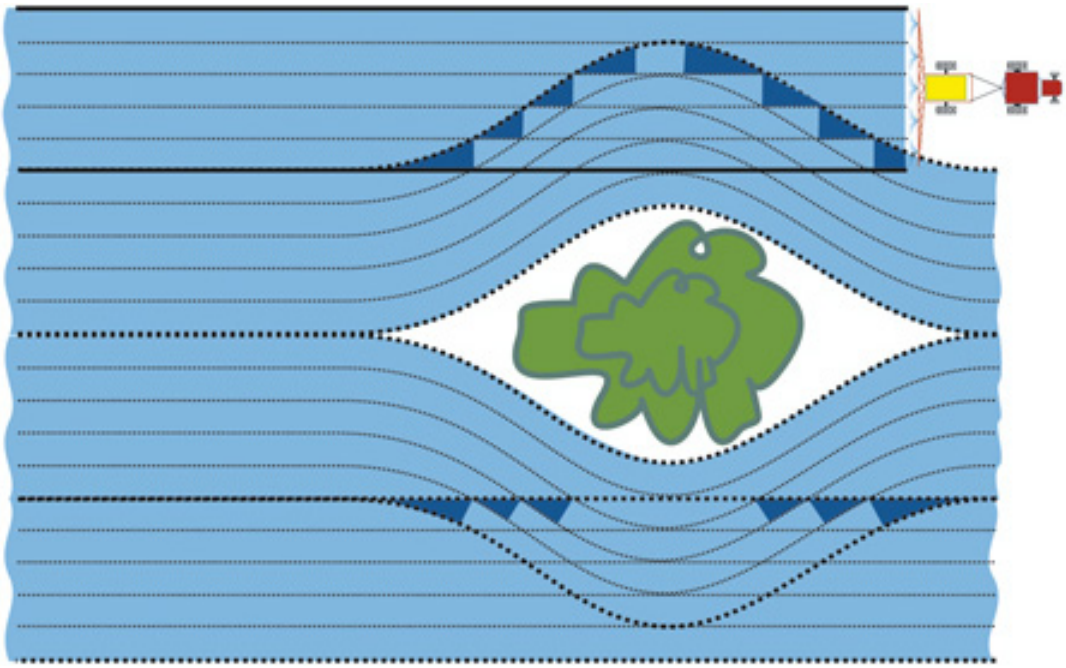
Wide booms are difficult to control – and we now see more sophisticated systems to assist the driver in controlling the boom. Most important is a good boom suspension which takes care of all sudden movements e.g., when the sprayer hits a rock or a furrow in the field. However, these boom suspensions cannot deal with low frequency movements caused by undulating terrain or movements caused by turning at the headland.

Low frequency movements are best controlled by an automated boom management system. Most of these systems are based on ultrasonic height sensors and can, via the hydraulic system on the boom, keep the boom levelled at a fixed height. There are huge differences in the performance of the various systems on the market. Most of the sensors are simple distance sensors from the car industry. These sensors measure the distance to the first object they 'see', making them unusable in row crops or crops with varying density. There are only a few systems on the market (as HARDI Autoheight and other systems developed by NORAC) which are using sensors especially designed for agricultural use. These systems can often differ between measuring to the crop or to the ground – enabling the driver to choose the setting that suits the actual spray job best.

Automatic section control

To minimise the overlap when crossing already sprayed areas the automated section control can be of great help. Boom sections controlled by GPS – AutoSectionControl (ASC) receive control signals from the NMEA protocol, which most GPS systems (e.g., auto guidance on the tractor) can supply. After the sprayer operator has sprayed the headlands and by that set the field boundaries, he now simply drives the sprayer up and down the field. The ASC controls the individual boom sections and thereby avoids overlap and saves chemicals (see Figure 1). Practical use shows a reduction of up to 4% in chemical use by reducing the overlaps with the use of ASC and GPS.

Figure 1: AutoSectionControl – automatic on/off of individual boom sections.



Variable rate control

The possibility to change the application rate 'on the go' has been on the market for at least 10 years. However, it has not really been implemented on farms. The most likely reason for this is that changing the rate is only half of the system, the application map of what to apply where is the other half, and these maps are not yet practically useable. A lot of research today is focusing on 'real-time' sensor systems that establish what to spray and thus reduce the amount of chemicals dramatically. These systems are being developed in research centres and will become commercially available in the next decade.

Service operations

Automatic cleaning

I think all farmers feel a little uncomfortable when cleaning sprayers – the operation can be complex and there can be a high risk of crop damage to the next crop. It is possible to clean a sprayer very well with the water available in the rinsetank. If the instructions in the manual are followed carefully the sprayer will be cleaned at a level so that the risk of crop damage is close to zero. The possibility of error is great as good cleaning demands a good knowledge of the liquid system on the sprayers and the cleaning procedure involves several steps. Furthermore, the cleaning procedure also demands that the spray-operator jumps out of the tractor cabin several times during the process to operate valves on the sprayer – this puts the operator at risk of contamination. An automated cleaning procedure improves the working environment for the driver as well as limiting the risk of expensive damage to the next crop.

A good example of an automated cleaning system is the HARDI AutoWash feature on COMMANDER and ALPHA sprayers. By changing all valves on the sprayer to electric valves and then controlling these by sophisticated software, the sprayer can clean itself totally on the inside. The process is optimised and consists of up to 39 steps which clean the machine better than a trained operator can do. Another benefit is that the operator doesn't have to leave the cabin and doesn't need to come in contact with the contaminated machine.

Filling chemicals

Most of the larger sprayers today have induction hoppers as standard equipment. These hoppers make chemical filling much safer and easier in comparison to filling through the tank lid. In some countries induction hoppers are now mandatory on sprayers. There are huge differences between the performances of the different hoppers, especially in their capability to mix powders.

Filling water

The biggest risk when filling water is normally overfilling the sprayer. Automated filling systems are now on the market, some of them are simple flow meter combined with an electric valve that shuts off when a preset volume is filled in the sprayer, other systems are more sophisticated as they measure the actual tank volume and avoid overfilling the spray tank.

Many other intelligent features will come on the market in the coming years. Most of these functions will mainly assist the driver and make his daily work more comfortable and ensure he avoids making fatal mistakes.

Focus on economy

Today's farmers have greater need than ever to constantly focus on the economics of their business. Therefore, when talking about sprayer development now and in the future economics must not be forgotten. Since the sprayer is the most used piece of machinery on the farm (apart from the tractor) and applies high value chemicals to the field, it is essential that it is used in the most efficient way.

The factors when considering economy in plant protection are related to spraying technique and are sprayer capacity and chemical dosage. When these are both managed correctly there is a high potential to increase economies in the spraying budget.

Increased capacity

Capacity can normally be increased in two ways i.e., more ha/hour or more hours/month for spraying.

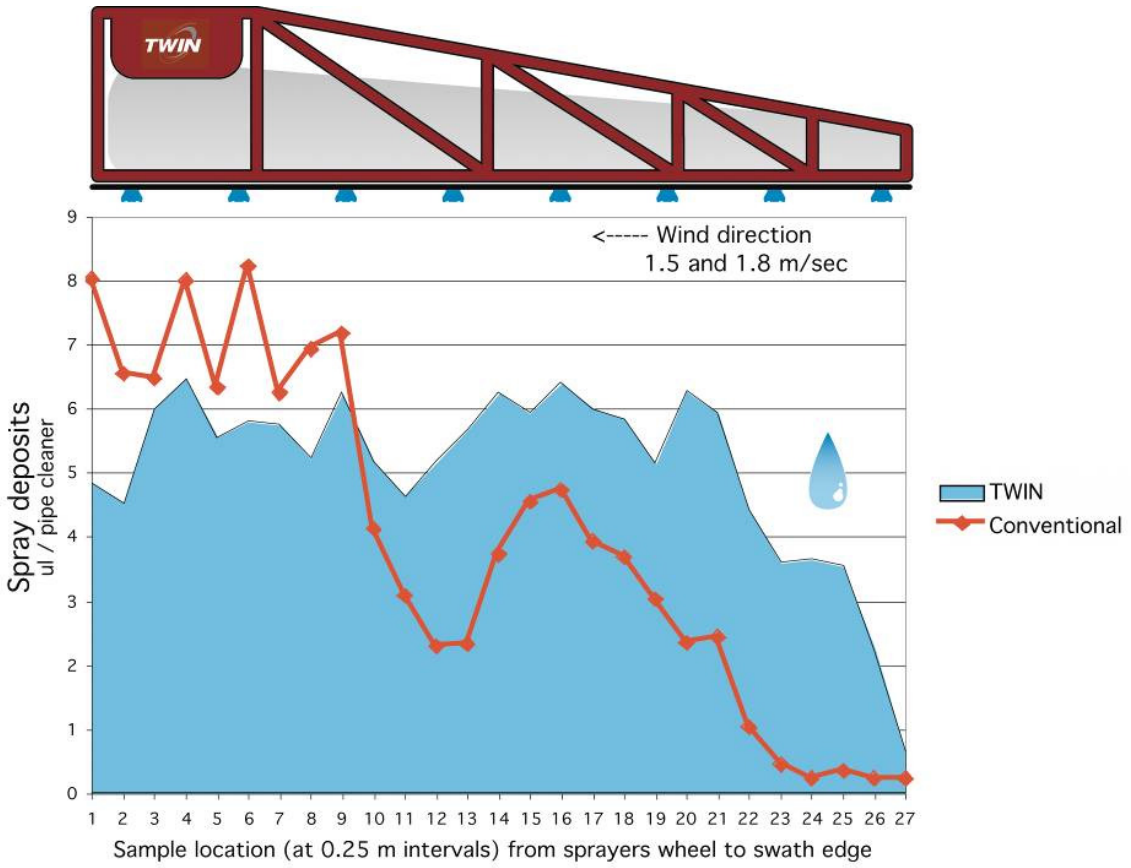
More ha/hour

To get more ha/hour we need to drive faster or to minimise the service time (time where the sprayer is not spraying). Driving faster increases the risk of drift and normally also decreases the deposit of chemicals on the target plants. Minimising service time often means lower water volume (= less time for filling the sprayer). Lower water volume gives the same result as above i.e., higher drift risk and poorer deposit.

Drift problems, for obvious reasons, cause a lot of concern for the environment. Drift to the surrounding areas pollutes nature. This is of major concern to the general public.

Drift also has another important effect which can sometimes be forgotten. Large, high-speed sprayers, often applying low water volumes, may inadvertently be applying a non-uniform swath. Even at low wind speeds drift can easily give a 20-30% difference in the spray deposit at different locations under the boom (see Figure 2).

Figure 2: Spray swath displacement by drift.



More hours/month

To increase the 'spraying window' (hours where spraying is possible) we need to be able to spray in more windy conditions, which normally also increases the risk of drift. A normal guideline is that we should avoid spraying at wind speeds above 4 m/s. With some drift reducing techniques (coarse nozzles or HARDI TWIN air assisted sprayers) it is possible to spray at higher wind speeds. If the limit is increased from 4 m/s to 8 m/s the number of hours/month are almost doubled (see Figure 3 (Danish weather conditions)).

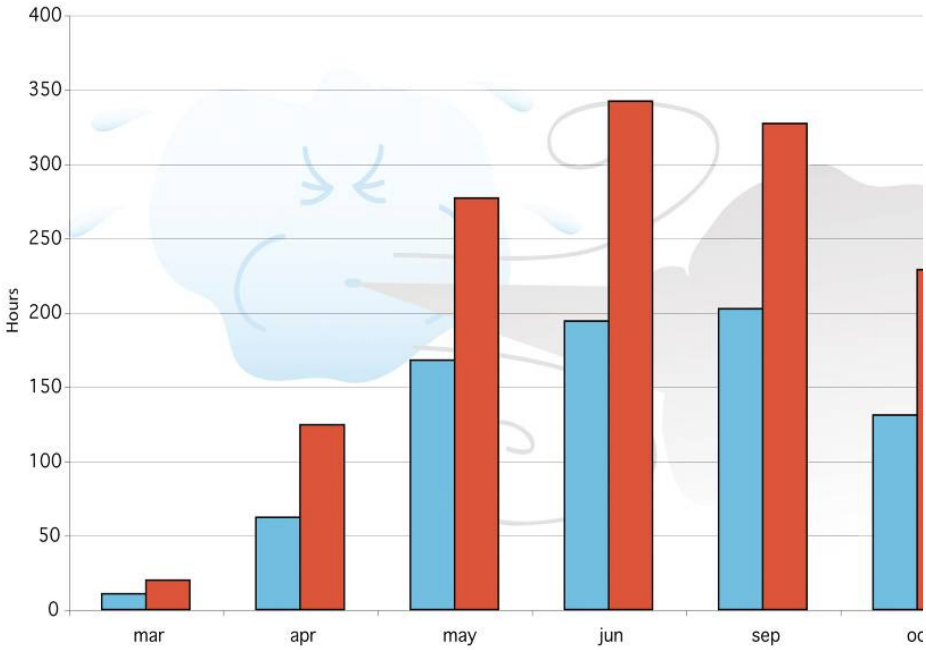


Figure 3: Hours/month were spraying is possible – in the months were spraying is normally done.

Conditions for minimum 3 consecutive hours /day:
- Temperatures day min. 1°C and min. up on 10°C, night > 1°C
- Rain < 0,1 mm/h, and < 2 mm from 3h before till 6 h after spraying.
- Relative humidity 50-95%
- Wind speed must not exceed 4 m/s for conventional
- Wind speed must not exceed 8 m/s for TWIN

Increasing the drop size unfortunately negatively influences the efficacy of most of the chemicals. Therefore, coarse droplets should only be used as an 'emergency' treatment if spraying can not be postponed.

Reduced chemical dose

The budget for chemicals on modern farms today is very high. Therefore an even small reduction in dosage has affects profit. Reducing the chemical dose is possible,

but puts high demands to the way the chemicals are applied. Timing and distribution are critical to ensure a good result. Drop sizes must be optimised, in most cases only fine droplets are efficient enough and uneven distribution caused by drift must be avoided. This means either spraying in optimal weather conditions at low driving speed or using a HARDI TWIN sprayer.

Because of the increased focus on the environmental impact of farming, Danish farmers have over the last 20 years worked intensively with reduced chemical dosages. A very detailed advisory system has been build up and farmers get detailed information on the best chemical to use and the recommended dosage. The system is today used by most agricultural advisers in Denmark when assisting the farmers in planning their plant protection. The system runs via the internet and is called Crop Protection Online. As it is a very complex system it is not possible to outline it here. Details are available at the links below.

The Danish system shows that if the correct spraying techniques are used it is possible to have and good efficient plant protection with reduced doses. By doing so farmers are reducing costs while also helping the environment. Danish farmers will sometimes spray with as low as 20-30 % of the recommended dose on the label if all conditions are optimal. It is important to mention here that we do not have increased problems with resistant weeds compared to other European countries.

Further information

Crop Protection Online - the Danish system to choose chemicals and dose:

- **http://pvo.planteinfo.dk/cp/menu/menu.asp?id=demo&subjectid=1&language=en**
  (click: “solve problem”)
- **http://www.lr.dk/planteavl/informationsserier/info-planter/plk07_crop_congress.htm**

Guidance to calibration, nozzle choice and reduced drift and increased capacity:

- **http://www.hardi-international.com**

Sprayer Operator Training at Kildalton College

John Kelly,
Teagasc, Kildalton College

Introduction

Learning is like rowing against the current: not to advance is to drop back.
(An old Chinese proverb)

Kildalton College was set-up as an agriculture and horticulture college in 1971 by the Department of Agriculture. It is now Teagasc's largest agricultural college with over 400 students attending various courses relating to the land-based sector. On completion of these courses students are either awarded certificates from the Further Education and Training Awards Council (FETAC) or, if they have completed a joint course with Waterford Institution of Technology (WIT) their certificate is awarded by the Higher Education and Training Awards Council (HETAC).

A fundamental component of most courses at Kildalton college relates to the area of pesticides. All our agriculture and horticulture students receive some level of training in two distinct areas:

- The safe use of pesticide products.
- The operation of either a hand operated knapsack sprayer or a tractor mounted boom sprayer.

Proficiency tests

As a FETAC provider, Teagasc courses must meet FETAC's quality assurance and be validated before being delivered to students. Following widespread consultation, Teagasc introduced Proficiency Testing in 2001 to assess competence. Being proficient at a task means a person has knowledge and experience of carrying out the task. It implies a competence derived from both training and practice.

Students are trained in Kildalton and practice their skills on placement and on the home farm. The proficiency tests that Teagasc developed are designed to measure and ascertain if students are competent.

There are many proficiency tests mainly relating to livestock, crops and machinery. Examples include; milking and dairy hygiene, breeding and rearing cattle, sheep shearing, tractor driving, fertilizer application and mechanical hedge trimming. More importantly there are two proficiency tests that directly relate to this conference:

- Safe use of pesticide products.
- Pesticide application by boom sprayer.

Each proficiency test is a comprehensive assessment. For this reason it is divided into logical sections called Learning Outcomes (LOs) that students progress through both while being trained and examined.

Safe use of pesticide products (MT01)

This proficiency test is important for anyone involved with pesticide use, and must be completed prior to taking the Pesticide Application by Boom or Handheld Sprayer test. Upon successful completion of the Learning Outcomes (LOs) the candidate will be able to:

LO 1: State responsibilities, under current legislation, relating to the use of pesticides.
LO 2: Outline main types, formulations and modes of action of pesticides.
LO 3: Interpret hazard (warning) symbols and instruction labels/literature.
LO 4: Outline procedures to prevent operator contamination and to deal with a case of contamination.
LO 5: Procedures for handling pesticides.

Within these competencies candidates should be able to:

- Identify, select and understand the wearing, maintenance and storage of the correct personal protective equipment recommended for use when handling pesticides.
- Follow appropriate personal hygiene procedures to prevent personal contamination.
- Follow the appropriate procedures for dealing with accidental personal contamination.
- Calculate required quantities of pesticide and water for a given example in accordance with chemical label.
- Understand the correct procedures for the storage of pesticides.
- Understand the correct procedures for the disposal of empty pesticide containers, surplus pesticide and washings.
- Understand the records that should be kept.
- Understand the situations where pesticide application may pose a risk to people or the environment.

When students have completed training and taken time to learn the required information they undertake a written test consisting of short answer questions. Candidates may not refer to any notes during the assessment. As this is a proficiency test candidates must get an 80% mark in order to be deemed competent.

Pesticide application by boom sprayer (MT04)

On completion of the Safe Use of Pesticides test candidates normally complete Pesticide Application by Boom Sprayer. Upon successful completion of the Learning Outcomes (LOs) the candidate will be able to:

LO 1: Prepare boom sprayer for work.
LO 2: Make up a pesticide spray mix.
LO 3: Apply pesticide with a boom sprayer.
LO 4: Prepare boom sprayer and PPE for storage.
LO 5: Carry out troubleshooting and maintenance.

Within these competencies candidates should be able to:

- Choose appropriate PPE.
- Prepare the applicator for work and to identify and check sprayer components.
- Calibrate and operate the sprayer to ensure correct application rate without risk to themselves, other people and the environment.
- Use the information detailed on a given product label to determine the approved uses for the product and its potential hazards to human safety, non-target areas and the environment in general.
- To make up a spray mix for a given area and apply this mix to that area.
- Carry out the correct procedure for cleaning personal protective equipment and application equipment which may have been contaminated with pesticide.
- Carry out daily and routine maintenance on the applicator.

After students have completed training and taken time to learn and practice the skills required, they must complete a practical test with a tractor mounted sprayer. This test takes 2 to 3 hours to complete the Learning Outcomes 1-5. Candidates have access to manuals and checklists during this test.

Training on the safe use of pesticides

Training for proficiency tests is comprehensive. For the Safe Use of Pesticides test, students are taught in groups of up to 16 in a classroom situation for an equivalent of 8-10 hours. They are given a comprehensive specification of the material that must be known for the test.

Different techniques can be used in the classroom but mostly consists of presentations covering the required information along with workbooks. A range of personal protective equipment (PPE) is made available to students, allowing them to try it on and at the same time showing them the order to decontaminate it in.

Reference to product labels and data sheets is a very important part of the training. Many different labels are given to students. Different exercises, examples and questions are based on these labels e.g., risk and safety information, warning

symbols, active ingredients, recommended PPE, dose rates, water volume rates, pressure recommendations etc.

Students are shown on video and on the demonstration sprayer in the workshop, the relationship between droplet size, pressure and nozzle selection and how drift can be minimised.

Students are given sample log books showing clearly what information should be kept in relation to pesticides. Finally, students are taken to our chemical store and shown the requirements for the safe storage of pesticides.

Training on pesticide application by boom sprayer

While most are competent tractor drivers not all students who carry out this test have operated a boom sprayer to any great extent before coming to Kildalton college. For these reasons the training in the college starts from a basic level and takes about the equivalent of 8-10 hours to complete. For the students with less experience it is extremely important that they spend an equal amount of their own time practicing either in the college or at home.

The training takes place with groups of up to eight. It starts with a classroom session. This is used to explain about the basic principles of how sprayers work, sprayer components and the different nozzles. It then moves to the workshop where a working cutaway sprayer is used to back-up what has been taught in the classroom.
Subsequently, the majority of the training takes place in the yard and field. Students select and put on the required PPE. Sprayer components are identified and checked for leaks and general condition. The operation of the sprayer is then shown. Every student gets an opportunity to carry out these operations during the training as two tractor/sprayer combinations are available.

After this a simulated pesticide is chosen to spray on a specific area on the college farm. The required pressure, water volume rate and forward speed are chosen and the sprayer and tractor forward speed is calibrated accordingly. Once calibrated, a simulated pesticide mix is made-up and the sprayer chemical induction system is shown and used by the students. They are then shown at this point how to properly rinse containers and how to deal with containers that have chemical remaining.

The training then moves to the field. Students are shown correct field procedures and are given an opportunity to practice these procedures within the training course. Once the field is sprayed, water is transferred from the rinse tank in order to carry out the first washing of the sprayer. After spraying this onto the headlands, we return to the yard to carry out the rest of the rinsing procedure for the sprayer.
On completion of spraying and washing, students prepare the sprayer for storage, decontaminate and remove their PPE and finally fill in the required log book.

This training course is only for competent tractor drivers. On completion of the course students must learn the course material and practice what they have been shown before completing the Proficiency test assessment.

Passing the boom sprayer proficiency test assessment

A candidate is only deemed proficient if he/she can carry out the test without any critical faults and a limited number of minor faults. If the candidate carries out something or, is about to carry out something that will endanger themselves or the examiner then the test is terminated and the candidate fails, i.e., a critical fault. Critical faults can also be incurred for other serious errors. If more that two minor faults are incurred at a particular stage of the test then the candidate is deemed 'not yet confident' and must repeat the test at a later date.

For example, if a candidate identifies one component wrong at the first stage of the assessment, then later in the assessment splashes some chemical onto their glove and at the end of the assessment forgets to close the lid after washing the sprayer, then they would still pass as the minor faults were at different stages in the test. However, if the candidate identifies three components incorrectly at the start of the test then they have failed as they have more than two minor marks at a particular stage during the test.

To succeed a candidate must be well prepared for the test. To date, approximately 90% of candidates pass after either their first or second attempt.

Conclusion

Kildalton college has a long history of delivering agricultural education in Ireland. It maintains strong links with industry and the farming sector. The college, along with Teagasc's Curriculum and Quality Assurance Unit, has developed relevant courses which help people learn. Training in relation to pesticides not only helps us improve health and safety but also ensures that we use expensive chemicals confidently and efficiently thus eliminating waste and minimising the risk to the environment, the food chain and the public.

MT04 Pesticide Application by Boom Sprayer Test Report Form

Candidate Name

Assessment Centre

Date of Assessment

Start Time of Assessment

Duration of Assessment **Hrs**

Assessment Activity		Minor Faults	Critical Faults	*Performance Evaluation* 1	2	3	4
LO 1 – Prepare boom sprayer for work							
(a)	Carries out risk assessment for spraying						
(b)	Wears appropriate PPE						
(c - d)	Selects applicator and identifies components and their functions						
(e)	Checks sprayer before and after attaching to tractor (with access to checklists)						
(f)	Assesses prevailing weather conditions						
(g)	Selects nozzles from nozzle chart						
(h)	Calibrates static boom sprayer (with access to worksheet)						
(i)	Calibrates tractor forward speed (with access to worksheet)						
LO2 – Makes up a pesticide spray mix							
(a)	Wears appropriate PPE						
(b-c)	Half fills tanks with clean water & sets agitator running						
(d,e,f)	Measures pesticide accurately, adds correct dose and rinses containers						
(g - h)	Tops up tank and washes off traces of chemical						
(i - j)	Returns pesticide to store and completes Chemical Store Stock Record Chart						
LO3 – Applies pesticide with a boom sprayer							
(a - b)	Follows instructions, including PPE for product and avoids contamination						
(c)	Marks out bouts/or uses tramlines						
(d, g)	Sets nozzles at correct height , uses pressure and forward speed from calibration						
(e, f)	Checks wind speed and direction and starts spraying from downwind end						
(h, i)	Sprays 2 bouts, square turns, around perimeter leaving first headland upsprayed						
(j)	Uses marker to locate place to restart after refilling						
(k, l)	Rinses sprayer and sprays out first rinsings on unsprayed headland						
(m)	Completes Sprayer Operators Log						
LO 4 – Prepares boom sprayer and PPE for storage							
(a)	Prepares boom sprayer for storage						
(b)	Prepares PPE for storage						
(c)	Stores PPE in a clean, dry ventilated locker						
(d)	Washes hands & exposed skin						
LO 5 – Carries out trouble shooting and maintenance							
(a)	Demonstrate knowledge of troubleshooting						
(b)	Demonstrate knowledge of maintenance						

Result of Assessment

Tick 4as appropriate:

LO1, LO2, LO3, LO4 & LO5: **Not yet competent** ☐ **Competent** ☐ **Competent at advanced level** ☐

Assessment Terminated: In the interest of safety ☐ **At request of candidate** ☐

Comments of Assessor			
		Signature of Assessor	
Comments of Candidate			
		Signature of Candidate	

Teagasc Sprayer Survey

Tom Ryan, Teagasc

In January 2009 Teagasc carried out a survey of 14 crop sprayers to check their general condition and their ability to apply pesticides accurately. Almost 3,000 hectares (x 4 times on average) per annum are sprayed with these sprayers. Measurements were made and recorded and a report with recommendations on each sprayer prepared.

The accuracy of the forward speed and the pressure gauge was measured. The nozzle output of one set of nozzles on the boom was measured. Nozzle output is a key indicator of accurate application rate as well as evenness of application. Checking all the nozzles along the boom also focuses on problems such as leaks, streaks, dirt and blockages. Filtration, cleanliness, leaks and general repair and maintenance were also recorded.

Forward speed

Forward speed ranged from 8 to 11.5 km/hr. The speed for 12 of the sprayers was equal or almost equal to what was indicated in the tractor, while one sprayer was 1.4km/hr and another 1km/hr faster than indicated in the tractor.

Pressure gauges

Table 1 shows the results of the pressure gauge tests with regard to gauge error, reading zero when stopped and glycerine level. Generally, gauge error should normally be less than 0.2 bar. Pressure gauges are delicate and can be damaged by excessive pressure. Frost this year caused problems with a lot of pressure gauges leaving them reading well above zero when stopped at rest. Some gauges were not easy to read because they were too small or the scale has had too big a range, or both.

Gauge accuracy can be checked by attaching temporarily a second gauge, known to be accurate and comparing the sprayer gauge to it. Another way is to use a few new nozzles to relate outputs to gauge pressure based on nozzle chart values.

Table 1. Pressure gauge results

	Number of sprayers	
	yes	no
Gauge error < 0.2 bar	10	4
Reading zero when stopped	10	4
Full of glycerine	13	1

Nozzle outputs

A summary of the nozzle output measurements is presented in Table 2. Nozzles outputs on six sprayers are clearly in good condition with little or no wear. These sprayers are numbers 2, 8, 9, 10, 11 and 13. There are a few nozzles a little dirty, which when cleaned will not affect results.

A further five sprayers i.e., numbers 1, 3, 4, 7 and 12 are indicating signs of nozzle wear. However, there is a lot of variation in the outputs from sprayer numbers 1, 3, 7, 12, so these should be cleaned and rechecked although the average output is then likely to increase indicating even more wear. The recommendation in that case is to

replace them with a new set. Sprayer 4 has no variation but shows wear, Recheck during next season.

Sprayer number 14 needs to be rechecked. There is very little variation and it seems there is a gauge error, a nozzle identification problem or some other error made during the test.

There is a big variation between nozzle outputs with sprayer number 5, although the difference above the rated output is small. The sprayer should be cleaned out and all rechecked before deciding whether or not to replace the nozzles.
In hindsight it would have been better to have the sprayers and nozzles perfectly clean and have all leaks sealed before the nozzles tests. Any nozzles with streaks not caused by dirt should be replaced with new ones anyway.

The nozzle output of the other sets of nozzles on the boom should also be checked.

Table 2. Summary of the results of nozzle output measurements

Sprayer	% difference from rated	% of nozzles >10% above average	% of nozzles >10% below average	comments
No 1	+5.0	56	19	Wear, streaks, dirt, big variation
No 2	-2.8	0	2	Streaks and leaks, no wear
No 3	+14.6	9	17	dirty nozzles, overall wear
No 4	+9.1	0	1.6	3 dirty, some wear - recheck
No 5	+2.4	13.5	16	Big variation, clean and recheck
No 6	-33.5	52	33	Big variation, streaks, dirt, blockages
No 7	+7.3	22	17	Dirty nozzles, wear, clean and recheck, big variation
No 8	-0.5%	0	3.6	Clean 3 nozzles otherwise fine
No 9	-0.1	0	0	Clean 3 nozzles otherwise fine
No 10	-11.1	10	17	Clean nozzles, no wear
No 11	+6.3	0	0	Fine
No 12	+28.3	14	7	Nozzle wear
No 13	+6.4	0	4	Fine
No 14	-46.7	0	0	Problem with gauge or nozzle identification

Filtering
There were problems with filtering. Many of the sprayers weren't cleaned out before the check-up. We didn't ask for them to be cleaned for the test. As it happens, many of the sprayers were not serviced since last season. It did indicate that filtering may not be adequate on some sprayers and that some products can cause more problems than others with regard to mixing and filtering. Some operators are not as thorough as they should be when it comes to filtering and cleaning. Others mentioned that frost and the use of some spray chemicals loosened scaled on dirt within the sprayer, which led to blockages in the nozzle filters.

Other findings

Generally, the outside of the sprayers was very clean. The inside of spray tanks were also clean. Some basket filters showed evidence of traces of chemical which indicates that basket filters are being used to fill in the chemicals instead of the low level induction bowels. Four sprayers had holes or faulty gaskets on tank lids. Three sprayers had leaks at suction and pressure filters.

Most booms are in good condition. Isolated problems such as sagging, stiff break-back devices, hoses in the spray pattern were seen. Boom folding and suspension systems were good. Of the two air sleeve sprayers one air sleeve needs replacing.

Safety

Safety issues were not recorded. However there were problems on some of the sprayers and tractors with PTO shaft guards and reflectors and lights. Some other safety features not checked were hitches, 3-point linkages, and wheels, tyres and brakes. Some access ladders were faulty.