Spray Technique

Fieldsprayer

674953-GB-2003/08

Dear HARDI user

All the essential benefits of responsible Plant Protection use are, today, very much judged on whether they are applied in their optimal form, that side effects on the environment are minimised and safety to the operator, bystander and consumer is comprised.

The purpose of this book is to help understand many of those application related issues that will help deliver that increasingly demanded requirement and we hope that you find it helps meet that goal.

At HARDI INTERNATIONAL A/S we invest much resource in ensuring that the quality of our advice is the best and is appropriate to today's needs. However, this is a huge challenge and our success is much dependent on the skills of many experts in this field.

We thank in particular:
Mr Jan van de Zande of IMAG, Netherlands, Prof. Ricardo Martínez Peck, Argentina and Prof. Paul Miller, Silsoe Research Institute in UK for reading the text of this book and making many suggestions for its improvement.

Special thanks to Mr. Per Kudsk for supervising on "Weather conditions", - to Prof. Arne Helweg for supervising on cleaning and decontamination issues and to Mr.Erik Kirknel for supervising on Personal Safety - all from Danish Institute of Agricultural Sciences (DIAS).

We do hope you find it useful and appreciate your comments: Hardi@Hardi-International.com

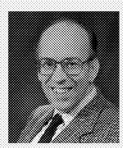
Application Technology Group
January 2003

Professor Paul Miller of Silsoe Research Institute writes:
The use of pesticides, whilst vital in ensuring the quantity and quality of food production, continues to be the subject of close public scrutiny. It is therefore important that all concerned take care to ensure that the correct materials are applied in the correct way to deliver:

- maximum effectiveness and levels of control;
- minimum residue levels in food products;
- the minimum risk of environmental contamination from drift and run-off particularly at the field edge and close to surface water.

The best way to achieve the optimum performance from any machine is to understand how it works and the factors that influence this performance. With regard to the crop sprayer this handbook gives this information in a clear and easily understood way. I commend it to the practical user and all concerned with the design, development and planning related to pesticide use.

Professor Paul C H Miller
Project Director and Head of Process Engineering Division
Silsoe Research Institute



For further information look at our home page:
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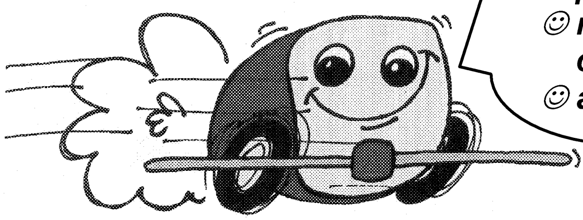
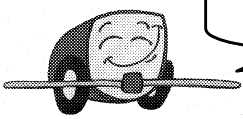
Calibration
is one of the most critical tasks
that you will make with your sprayer
if you are to:

☺ ***ensure optimal use of plant protection products,***
☺ ***minimise risk to the crop, consumer and environment and***
☺ ***avoid wasteful product!***



"Calibration" means:
checking and tuning in your sprayer for precise application



Calibration - WHY?

1. To ensure a high precision spray job where the volume of spray liquid in your tank mix fits exactly with the area you are going to treat. Calibration will prove if:
   - your nozzles are worn a little and the pressure needs to be readjusted.
   - your nozzles are worn out and need to be changed.
   - speed is correct. The tractor speedometer may be incorrect (dependent on e.g. tyre size).
   - you have a pressure drop from gauge to nozzles that needs to be accounted for.
2. To check the nozzles are performing well (no damaged nor blocked nozzles).
3. To check that the sprayer is in good shape and with no leakages.
4. To be able to apply precise dose rates of plant protection products.

Calibration - WHEN?

❍ ***Before spraying with a new set of nozzles, new volume rate, new speed, new tyres, new pressure or any new field or equipment conditions:***
- ***Check driving speed***
- ***Check nozzle flow and pressure***

❍ ***Once a year*** (and before inspections) Hardi recommends a thorough check:

- ***Check driving speed***
- ***Check all nozzles***
  - ➤ if average output has increased more than 10% compared to new nozzles: change all nozzles
  - ➤ if there is more than +/- 5% deviation in nozzle output, change all nozzles

❍ ***During the season*** Hardi recommends frequent quick-checks:

- ***Check 2 nozzles per boom section***
  - ➤ if one nozzle has more than 15% increase in flow, change all nozzles

When do I check ?	Driving speed	Nozzle flow for all nozzles	Nozzle flow (l/min) for 2 nozzles per boom section	Screen for damaged or blocked nozzles	Check liquid system for leakages
Before the season and sprayer inspection ➤	✔	✔		✔	✔
Frequently during the season ➤➤			✔	✔	✔
Before spraying with a • **new set of nozzles,** • **new volume rate,** • **new speed or** • **new pressure:**	✔		✔	✔	✔

➤ See page 39 for a complete check list

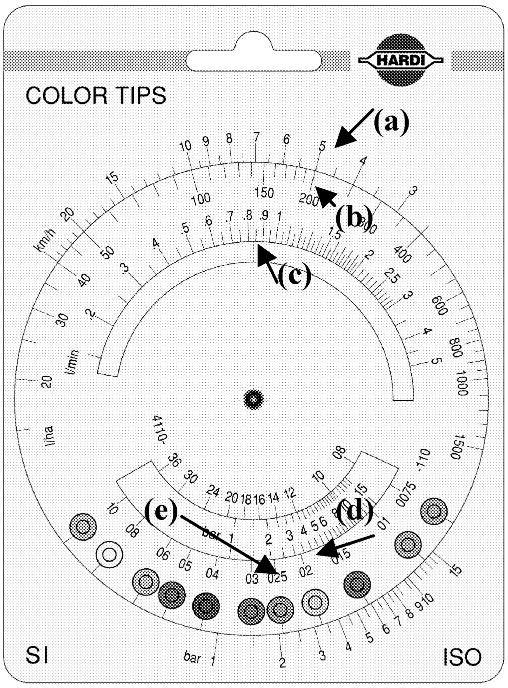
➤➤ The older, or the smaller, the nozzles the more frequent should be your checks.
Also, if spraying with powder or any of the more abrasive formulations - more frequent checks are necessary.

Calibration disc

Calculations for calibration are easy with the Hardi calibration disc with its clear references to both ISO and 4110 nozzles (order no. 285802).

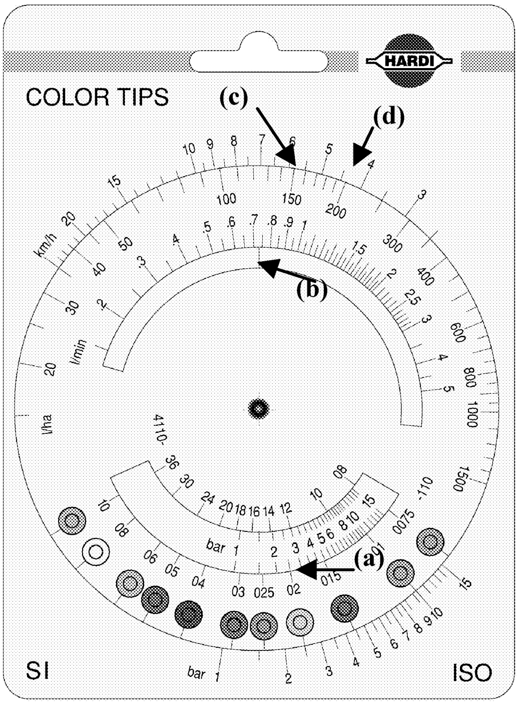
The calibration disc is based on the standard HARDI nozzle spacing of 50 cm.

If you have decided on which water volume rate [l/ha] and spraying speed [km/h] then work your way through from top to bottom of the calibration disc to find the corresponding nozzle flow [l/min], nozzle size and pressure (Example 1).



Example 1
If the speed has been checked to be 5.0 km/h **(a)** and the aim is to apply 200 l/ha **(b)** then turn the disc to align 5 km/h and 200 l/ha. In the window on the top half of the wheel you can read that each nozzle must have a flow of 0.83 l/min **(c).**
On the lower half of the disc you can read that this can be achieved with an 02 nozzle at 3.3 bar (d) or an 025 nozzle at 2.1 bar **(e).**

The calibration disc can also be used to find a nozzle flow and a combination of speed and l/ha with a known nozzle size and pressure. Then you work your way from bottom to top of the disc (Example 2).



Example 2
If wishing to use the 02 nozzle at 2.5 bar, then the two relevant marks are aligned **(a)** and the corresponding flow can be read to be 0.74 l/min **(b).** With this combination of nozzle and pressure you can for instance apply 150 l/ha at 5.9 km/h **(c)** or 200 l/ha at 4.4 km/h **(d).**

Note! If the nozzle spacing is not the normal 50 cm the calibration disc can still be useful to find nozzle/pressure combinations – but it requires an extra calculation:

$$\frac{\text{Required l/ha} \times \text{actual nozzle spacing (cm)}}{50 \text{ cm}}$$

= l/ha on calibration disc

When working the calibration disc you use "l/ha on calibration disc" - and when spraying you get the "required l/ha" at your "actual nozzle spacing".

Calibrate with safety

Always start with a clean sprayer with clean water in the tank. For safety reasons nozzle checking should take place over an area covered with grass or other vegetation in the field.
Always use gloves when touching the sprayer even though it has been cleaned. Personal Protective Equipment [such as gloves, coverall, boots] is intended for precautionary use only.
Remember to take off gloves and any other Personal Protective Equipment – especially if contaminated - every time you enter the tractor.

Calibration for field crop spraying

❶ Choice of spraying parameters:

Good sources of information on how agrochemicals should be applied are often found on the agrochemical label. You may still need to adjust your sprayer to the specific spraying conditions you choose for volume rate, driving speed, nozzles and spray pressure.
Often volume rate and driving speed are decided first – then the nozzle choice is limited to the possibilities within the accepted pressure range (normally 2 to 2.5 bar for conventional nozzles). This is easily found on the HARDI calibration disc or you can calculate the required nozzle flow and find the nozzles in a nozzle table.
Example: We want to apply 150 l/ha at 8 km/h

❷ Check driving speed

- Measure 100 meters. It may be useful to have some 'permanent' markers that are located in a convenient place (in a field or field like conditions).
- From the table in the tractor you find the gear to achieve the speed you want at a given rpm.
- Drive the measured distance (with a ½ filled tank) and measure the time.

- Calculate the speed:

$$\frac{\text{Distance driven (m) x 3.6}}{\text{Time (sec)}} = \text{ km/h}$$

Example: It takes 45 seconds to drive 100 m:

$$\frac{100 \text{ m x } 3.6}{45 \text{ sec}} = 8 \text{ km/h}$$

Other examples of speed calculations

Sec/100 m	**40**	42	44	46	48	50	52	54	56	58	**60**	62	64	66	68	70	72	74	76	78	**80**
Km/h	**9,0**	8.6	8.2	7.8	7.5	7.2	6.9	6.7	6.4	6.2	**6.0**	5.8	5.6	5.5	5.3	5.1	5.0	4.9	4.7	4.6	**4.5**

- If you do not have the speed you want either choose another gear and check speed again or change the rpm to reach the required speed:

$$\frac{\text{RPM from speed check x required speed (km/h)}}{\text{(km/h) from speed check}} = \text{New RPM to get the required speed*}$$

*The pto-RPM should not exceed 540. If agitation is still acceptable the pto, RPM can be reduced down to about 400 as a minimum (that is – 25%).

- Keep a note of gear, speed and RPM .

❸ Calculate the required nozzle flow and choose nozzle size

Either use the calibration disc or formula (nozzle spacing 50 cm):

$$\frac{\text{Checked speed (km/h) x Water rate (l/ha)}}{1200} = \text{Flow for each nozzle (l/min)}$$

Example: By aligning 150 l/ha and 8 km/h on the calibration disc the line in the "window" (l/ha) shows that we need a flow of 1.0 l/min. Then a suitable combination of nozzle size and pressure can be found on the lower half of the calibration disc: ISO 03 at 2 bar (or ISO 025 at 3 bar).

If using the formula:

$$\frac{8 \text{ km/h x } 150 \text{ l/ha}}{1200} = 1.0 \text{ l/min}$$

Nozzle and pressure to obtain 1.0 l/min can also be found in the nozzle catalogue

❹ Check liquid system

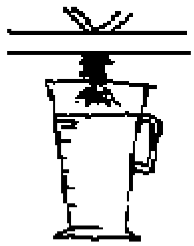
- Always use clean water for calibration.
- Mount the chosen nozzles on the boom.
- Turn on the sprayer and spray at minimum 7 bar whilst you check the liquid system for any leakages.
- Check the agitation

❺ Check nozzle output

- Set the pressure.
- Adjust the pressure equalising valves (see Instruction Book for Hardi-matic system)
- Measure the nozzle output for one minute.
- Repeat this process - measuring at least 2 nozzles for every boom section.
- Calculate average nozzle output

> **HARDI MATIC** *(Pressure equalisation or proportional return)*
> When changing nozzle size, the pressure equalising valves need readjustment to ensure the right volume rate when operating the section valves:
> 1. make sure there is only clean water in the tank
> 3. turn on all boom sections and set the pressure
> 4. turn off one section at a time and readjust on the pressure equalising valve on the operating unit (return to tank) for that section until the spray pressure gauge shows the original pressure again
> 5. repeat for all sections

If the nozzle output is not that required (and the nozzles are not worn more than 10%)



- you can readjust pressure:

$$\left(\frac{\text{New output (l/min)}}{\text{Measured output (l/min)}}\right)^2 \text{ X Measured pressure } = \text{ New pressure}$$

Example: at 2 bar (measured pressure) an average output of 1.06 l/min (measured output) was measured –however the aim was to apply 1.0 l/min (new output) so the pressure needs to be readjusted:

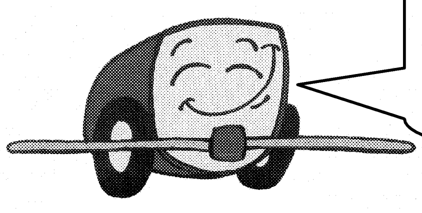
$$\left(\frac{1.0 \text{ l/min}}{1.06 \text{ l/min}}\right)^2 \times 2 \text{ bar} = 1.77 \text{ bar} \cong 1.8 \text{ bar}$$

By readjusting the pressure to 1.8 bar the required flow of 1.0 l/min will be achieved. Measure flow again to check.

- or you can accept a little higher or lower water rate (l/ha). You can either use the calibration disc or this formula to find the final water rate:

$$\frac{600 \times \text{measured nozzle output (l/min)}}{0.5 \text{ m* } \times \text{ speed (km/h)}} = \text{l/ha}$$

* distance between nozzles



If you calibrate your sprayer in advance you are ready to go when timing and weather conditions are optimal.

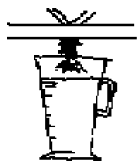
Do not leave calibration to just before spraying –for you are most likely to lose valuable time and you may miss optimum conditions.

❻ Ready to go

If it is not time to extend the calibration with a wear and uniformity check your are now ready to make a precise tank mix of water and agrochemical – see the chapter: Loading the sprayer with plant protection product (p 11) and Useful formulae (p 41).

Checking nozzles for wear and uniformity

A. Wear test – before the season and before inspection:



1.Fix a new nozzle on the boom (same type and size
as the ones you want to check)
This is your reference nozzle

2.Check the flow of this nozzle at your spray pressure. *Example: 1 l/min at 3 bar is reference flow*

3.Calculate the maximum tolerated <u>average flow</u>
= flow for new nozzle + 10%
= l/min for new nozzle x 1.10

Example: 1 l/min x 1.10 = 1.10 l/min

4.Check all nozzles at 3 bar *Example: size 025 nozzles checked at 3 bar*

Nozzle	*L/min*
1	*1.05*
2	*1.09*
3	*1.06*
4	*1.05*
5	*1.10*
6	*1.13*
7	*1.13*
8	*1.07*
9	*1.07*
10	*1.07*
11	*1.11*
12	*1.06*
13	*1.12*
14	*1.10*
15	*1.10*
16	*1.05*
17	*1.07*
18	*1.06*
19	*1.05*
20	*1.08*
21	*1.13*
22	*1.09*
23	*1.08*
24	*1.06*
sum	*25.98*
Average	*1.0825 ≈ 1.08*

Check wear

- Fix a new nozzle of same size as on the boom
- Check flow at working pressure and use as reference
- Check that average flow is maximum 10% higher than reference nozzle flow.

Example

Reference Nozzle	*Pressure*	*Measured reference flow per nozzle*
025	*3 bar*	*1 l/min = 100%*

5. Calculate average
Sum of nozzle flows / number of nozzles

Ex: 25.98 l/min / 24 = 1.0825 l/min ≈ 1.08 l/min

6. Divide measured average flow with reference

Ex: 1.08 l/min / 1 l/min = 1.08

7. Multiply by 100 to get the flow rate in %

Ex: 1.08 x 100% = 108 % that is an increase of 8 % compared to the reference nozzle flow of 100%

8. Accept or replace nozzles

Ex: In this example the flow has increased by 8 % which is less than the 10% maximum that can be tolerated. And the nozzles are fit for some more use.

Uniformity

1. Calculate the maximum and minimum accepted limits for nozzle flows to be within +/- 5%:

   average (l/min) + 5% = average (l/min) x 1.05

   average (l/min) - 5% = average (l/min) x 0.95

   Ex: using the values from wear check we find
   average (l/min) + 5% = 1.08 l/min x 1.05 = 1.13 l/min
   average (l/min) - 5% = 1.08 l/min x 0.95 = 1.03 l/min

2. Check that all measured flows are within the limits.

   Ex: all measured nozzles are just with in the limits – the uniformity is acceptable and it is not necessary to change nozzles yet.

NB! Sprayers equipped with flow meters also need nozzle checks to be sure that the nozzles are not too worn and liquid distribution is acceptable.

Nozzle performance. Do not forget to take a good look at the whole boom performing – try to have the sun behind the nozzles – and see if any nozzles are damaged or maybe partly blocked. “Stripes” in the spraying pattern is a sign of wear, and the nozzles should be changed.

B. Wear test – quick-test during the season:

A quick check-up during the season can be useful (but it still remains very important to carry out the full nozzle test for both wear and uniformity as specified). Measure the flow rate for a sample of nozzles and check that this does not exceed the worst case situation of more than 10% average wear. Remember a further 5% deviation for individual nozzles is allowed [maximum wear (10%) + maximum deviation (5%) = 15% meaning that 15% increase in single nozzle output can be tolerated in the quick-test].

1.Fix a new nozzle on the boom (same size as the ones you want to check) This is your reference nozzle.

2.Measure the flow of this nozzle at your spray pressure. *Example: 1 l/min at 3 bar is reference flow*

3.Measure the maximum tolerated flow
= flow for new nozzle + 15%
= l/min for new nozzle x 1.15

Example: 1 l/min x 1.15 = 1.15 l/min

4. Check a sample of two nozzles from each boom section at 3 bar

Ex: 1.05, 1.09, 1.05, 1.10, 1.06 and 1.13 l/min

5. Accept or replace nozzles

Ex: In this example none of the flows exceed the 15% that can be tolerated - the nozzles need not be changed.

Calibration for liquid fertiliser

Liquid fertilisers may be of a higher liquid density than water and almost all, normal spray solutions. In order to ensure the intended nozzle output is actually used, the pressure must be increased according to the density (g/cm^3) of the fertiliser. The density correction table below states the increased pressure that will be needed to reach the required output with liquid fertilisers.
<u>Before correction of the spray pressure,</u> the fertiliser nozzles are mounted on the sprayer and calibrated with water.
Then, when the required volume rate has been found by calibration with water, this calibration pressure is adjusted according to the density of the liquid fertiliser:

Example:
You need an output of 2,3 l/min. According to your calibration with clean water you get this at 3 bar. If the density of liquid fertiliser is 1.2 g/cm^3 you have to multiply the calibrated pressure of 3 bar with 1.2.
This gives an adjusted pressure of 3.6 bar to be used in the field.
The value can be found in the Table at 3 bar (calibrated pressure) and a density of 1.2 g/cm^3.

Calibration pressure (bar)	***Density (g/cm^3)***				
	1.10	***1.15***	***1.20***	***1.30***	***1.40***
	Pressure for liquid fertiliser (bar)				
1.0	1.1	1.2	1.2	1.3	1.4
1.5	1.7	1.7	1.8	2.0	2.1
2.0	2.2	2.3	2.4	2.6	2.8
2.5	2.8	2.9	3.0	3.3	3.5
3.0	3.3	3.5	3.6	3.9	4.2

Spray pressure for application of liquid fertiliser = calibrated pressure (with water) x density of fertiliser

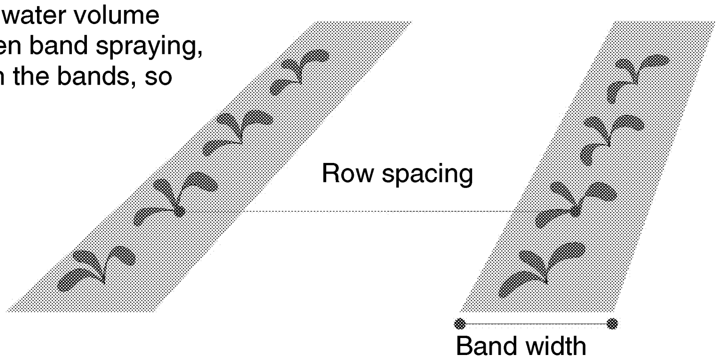
Using the calibration disc:
For 3- and 5-hole nozzles with normal nozzle spacing (50 cm) the calibration disc can be used for calibration with water – just remember to multiply the final calibration pressure with the density of the fertiliser to find the spray pressure to be used in the field. For solid stream nozzles with or without dribble hoses note that the distance between nozzles is 25 cm (see formula page 25).

NB! When spraying with liquid fertiliser it is advisable to protect all unpainted metal parts with a film of anticorrosion oil (for example Hydro Texaco Rust-proof).

Calibration for band spraying

① Check forward speed (see "Calibration for field crop spraying" p.4)

② Water volume rates [l/ha] in the treated band.
Label recommendations usually state total water volume rates l/ha, also called broadcast rates. When band spraying, we only want to apply this broadcast rate in the bands, so instead we will call it here: **l/ha in band.**



③ Required nozzle capacity

$$\frac{\text{L/ha in band x band width (m) x km/h}}{600} = \text{volume of water [l/min] for this band}$$

If 200 l/min is to be applied at 6 km/h in a 0.2 m wide band, the necessary output will be: 0.4 l/min per band. If for instance, 1 nozzle per band is used, every nozzle should apply 0.4 l/min. (If 2 nozzles per band: each nozzle should apply 0.2 l/min).
Nozzle size and pressure can then be found in the relevant nozzle table. Or, if using ISO nozzles or 4110-nozzles use the calibration disc: set the wheel at the required l/min/nozzle (in the see-through "window" on the top half of the disc) and read a combination of nozzle and pressure.

④ Total required water volume

$$\frac{\text{area of field (ha)} \times \text{l/ha in band} \times \text{band width (m)}}{\text{row spacing (m)}} = \text{total required volume (l/field)}$$

For example, if the row spacing is 0.5 m; band width 0.2 m; field 5 ha; and the water volume rate in band is 200 l/ha, then the total required volume will be:

$$\frac{5\ \text{ha} \times 200\ \text{l/ha} \times 0.2\ \text{m}}{0.5\ \text{m}} = 400\ \text{l}$$

⑤ Amount of agrochemical for a tank

$$\frac{\text{Litres of water in tank} \times \text{chemical dose (l / ha)*}}{\text{l/ha in band}} = \text{Amount of chemical for each tank (l/ha)*}$$

*or [kg/ha] or [gram/ha]

If the tank holds 400 l and 2 l/ha of chemical is needed at a volume rate of 200 l/ha the calculation is like this:

$$\frac{400\ \text{l} \times 2\ \text{l/ha}}{200\ \text{l/ha}} = 4\ \text{litre of chemical per tank}$$

Checking spraying technique with water sensitive paper

Water sensitive paper (yellow paper that stains blue where hit by liquid) is a very useful tool to help in optimising spraying technique.
If, for instance, you have a very dense crop and need good penetration with an agrochemical, you can – before the actual spraying itself- check your chosen spraying technique with clean water:

- Place the spray paper on the spray targets (use paperclips or tape – but avoid changing position of leaves).
- Mark the plants i.e. with red tape at the top so you can find the paper again.
- Spray and then check the paper.
- Did the droplets go where you want them to go? If not, you can try to improve by changing the spraying technique.

Water sensitive paper is available at your HARDI dealer (50 pcs. Order no 893211).

Be prepared to optimise spraying technique "on the go"

Rather compromise on drop size than timing.
In many applications - from fungicide spraying in potatoes to dicotyledonous stage, broad leaf weed herbicide treatments -timing is very critical. Here a delay may often prompt the need for a higher dose or an increased number of applications.
The potential efficacy loss due to an increased droplet size - that offers less drift risk - will be less dramatic, as long as a good liquid distribution is maintained. Hence it is a good idea to have a set of low drift nozzles or INJET nozzles ready on the nozzle holders in case wind speed increases – and is a lot more convenient and safer than returning with a half full spray tank. Because the different sets of nozzles may not be worn to the

same extend, (there can be up to 10% difference in flow for new and worn nozzles) both sets of nozzles should be calibrated, in order to be able to make the necessary pressure adjustment when changing from one nozzle type to an other.

Avoid cleaning blocked nozzles or changing damaged ones during spraying
A second matching set of nozzles can also be used to switch into action wherever nozzle blockage/damage has occurred.

Loading the sprayer with Plant Protection Products

When the sprayer is calibrated, and you know the exact volume rate you will be using, the right amount of chemical can be added:

$$\frac{\text{Tank volume *(l) x dose rate(l/ha) or (kg/ha)}}{\text{Water volume rate (l/ha)}} = \text{(l/ha) or (kg/ha) plant protection product per tank}$$

*If you do not need a full tank then you enter the actual volume you will be using.

NOTE If the dose rate is given as an active ingredient/ha you need first to calculate how many kilograms or litres of the formulated product you need per hectare:

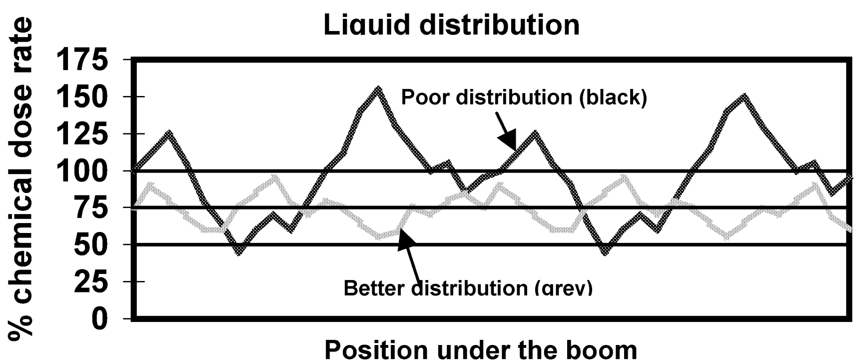
$$\frac{\text{Dose rate active ingredient (kg/ha) x 1000}}{\text{Concentration of active ingredient in formulated product (g/kg)}} = \text{Dose rate formulated product (kg/ha)}$$

Adding the plant protection product. Normally the plant protection product can be added to the spray tank when this is ½ to ¾ filled with clean water and the agitation is on. But if the label recommends otherwise, the label must be followed.
The Hardi Filler makes sprayer loading a safer and quicker process; the operator is not climbing with product onto the machine but is working at ground level. Do consult the instructions for use of the Filler and any advice supplied with the products label. A container rinsing facility will ensure all the product is removed and the container is left clean for disposal or return.

How to ensure a uniform liquid distribution

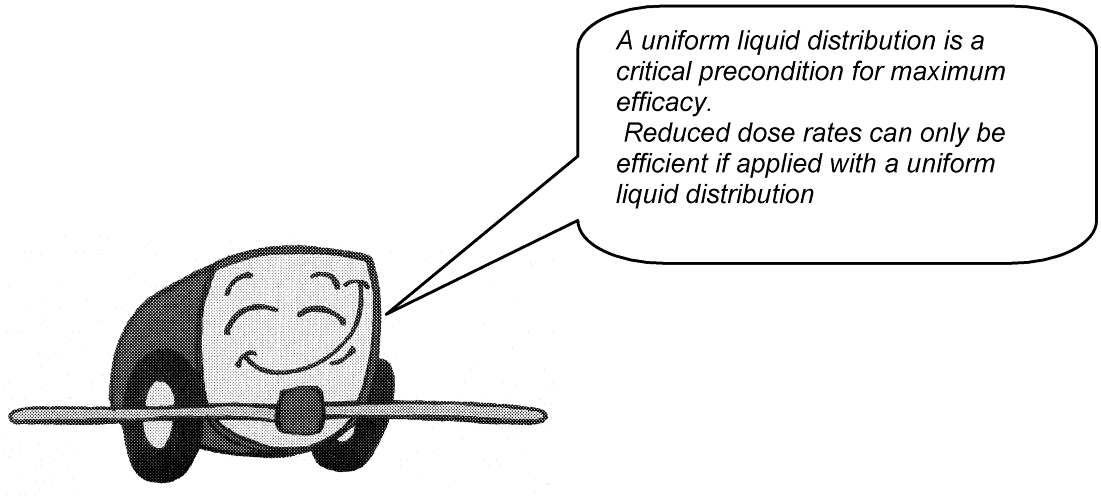
A <u>uniform liquid distribution</u> over the sprayed area - with a suitable volume rate and drop size - are the most important goals in your choice of spraying technique.

The less variation along the driving direction and across the boom, the better the efficiency of the agrochemicals applied; especially important where reduced doses of pesticides are used. This correlation is illustrated in the graph below:



The graph can either illustrate a field variation of deposit under the boom in the driving direction or across the boom. If the variation is along the driving direction it is due to boom movements. If the variation is across the boom it is due to poor nozzles, too low pressure or wrong boom height. Of course wind will distort the liquid distribution both along driving direction and across the boom.
If in this example the biological timing and weather conditions for spraying were perfect and 50% of the dose rate was enough, then both farmers (with grey or black distribution) would experience high efficacy of the

application. However the farmer with the better distribution has the scope to reduce the use of plant protection product by 25% because of less variation in the deposit on the plants.



Spray pattern

A good starting point of coarse is to be sure that the nozzles provide and even distribution – this can be measured with a patternator (e.g. HARDI Spray Scanner). All Hardi sprayers are checked over a Hardi Spray Scanner before delivery to the farmer and in some countries such a check is also a part of a mandatory sprayer inspection.

If the nozzles
- are kept clean (agro-chemicals are not left to dry in the nozzles)
- are with-in the accepted limits for wear,
- have never been cleaned with any hard material that could damage the nozzle opening and -
- make a spray pattern that visually looks good with out any streaks gaps (easier to see with the sun light behind the spray)

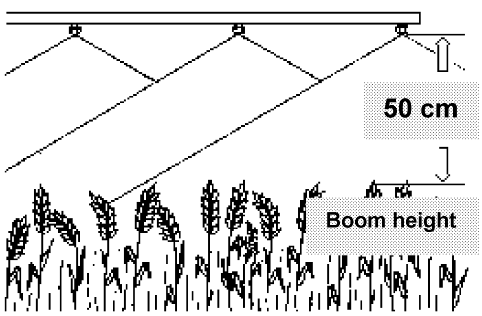
then there is good reason to believe that the spray pattern is acceptable when working at the right boom height.

To be able to maintain a uniform spray pattern delivered from the nozzles a number of factors need to be considered – some related to the sprayer others to cultivation. Wind conditions and nozzle selection is dealt with in the chapter "Choosing nozzles for arable crops". Boom height, boom stability and track width and tyre pressure are described below.

Factors helping to maintain a uniform liquid distribution and deposit in the field:
-Low wind speeds
-Larger drop size / high energy droplets
-Lower forward speed
-No or low nozzle wear
-Steady boom
-Large track width
-Low tyre pressure
-Even terrain
-Equal plant density and height
-Air assistance

Boom height

Correct boom height is important to ensure even distribution: 110° flatfan nozzles spaced at 50 cm have 100% overlapping and can provide a uniform distribution from a height of about 33 cm. But to allow for minor boom movement 50 cm is the recommended boom height.
However there are exceptions: if the field is very level and the boom is very stable, the height can be lowered to 40 cm; an important advantage in controlling wind drift.



If the boom is wide it might be more appropriate to work at 60 to 70 cm, but this will also increase wind drift. For these boom heights, consider using the 80° nozzles to minimise wind drift.

Boom height is always measured between nozzle and the first intervening surface met by the droplets. If the weeds happen to be taller than the crop, the boom height must be measured between nozzles and weeds!

Boom height and tolerances

Nozzle type	Recommended boom height	Tolerances
Flatfan nozzles 110°	50 cm	35 cm – 70 cm
Flatfan nozzles 80°	70	50 cm – 100 cm
Cone nozzles	Depends on spray pressure; the higher the pressure the wider the spray angle –the lower the boom height	None
3-hole nozzle for liquid fertiliser	Depends on spray pressure	None
5-hole nozzle for liquid fertiliser	50 cm	35 cm – 100 cm

Boom stability

There are two kinds of boom movements: up/down (vertical) and parallel to the field (horizontal) also called yaw. Both types of boom movements must be minimised. A poor boom can lead to more than 100% variation in liquid distribution.

Vertical boom movements:
As can be seen from the Table in the boom height chapter, cone nozzles and 3 hole nozzles have no tolerance to vertical boom movements. In practice, zero boom movement is impossible and this is the main reason why cone nozzles are rarely used today, and the 3-hole is expected to be used less in the future; the introduction of a 5-hole nozzle – the Quintastream - allows for vertical boom movement.
Flat fans (and 5-hole nozzles for liquid fertiliser) tolerate some boom bouncing up and down without damaging the spray distribution.

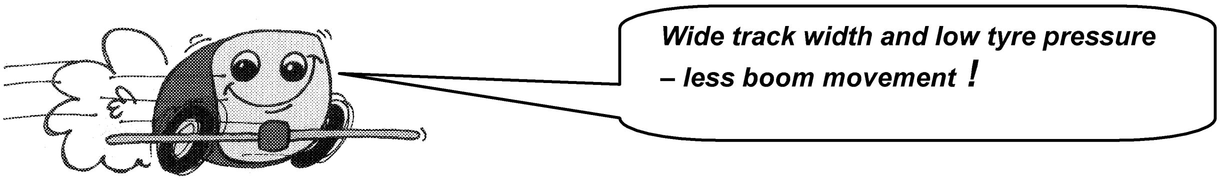
Horizontal boom movements:
Horizontal boom movements, where the relative forward speed of the boom varies between being faster and slower than the tractor speed, is extremely critical and can spoil all the benefits of choosing the right nozzle, chemical timing and so on. Horizontal boom movements may result in several hundred percent variation in the liquid distribution under the boom.

Adjusting for boom stability. Sometimes little adjustments (mostly tightening) on the boom lift or between the boom sections as well as lubrication can make a big difference.
In more severe cases the section joints may need to be renewed. Typically the boom should be adjusted so it is aligned horizontally and is rigid (both vertically and horizontally) along its full length.
If raised above horizontal at one end - it should go back to horizontal without further bouncing when let go.
Look in the instruction manual to see where you need to check on the boom.
And make it a habit to look at the boom whilst spraying to see if boom movements have increased.

Track width and tyre pressure

Wide track width and low tyre pressure are both very efficient ways of making the spray boom move more smoothly over the field. Of coarse wide tyres help too when it is possible to use them with out too much damage of the crop.

To find out how low the tyre pressure can be in the field you need data from the tyre manufacturer. The needed minimum pressure is depending on forward speed and total load. It is of coarse extra work to take out some air once in the field and add air before going on the road again but many farmers find it worth the effort.



Checkpoints for ensuring a uniform distribution

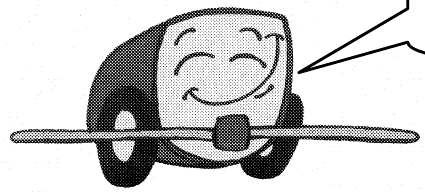
	Before spraying	**While spraying**
Nozzles	Calibrate to check nozzles are not too worn. (p 25)	Make sure no nozzles are damaged or blocked
Wind drift	Spray early mornings (or evenings) when the wind speeds are normally low. Choose nozzles according to wind speed. (p13)	If you see wind drift from the sprayer you know that the wind is moving the droplets around, leaving a poor distribution over the crop. Either adapt to the situation, by changing spraying parameters (p 13 and 21) or postpone the application.
Speed	Slower travel speed means less turbulence around the boom. Make sure the boom has been adjusted to the intended travel speed.	Reduce speed along sensitive areas
Pressure	Choose a working pressure within the recommended range for the chosen nozzle Under windy conditions, a low pressure is preferable.	Never let the pressure drop below the minimum recommended
Boom stability	Lubricate and adjust boom for minimum boom movement. Wider track width when possible. Lower tyre pressure when possible.	Check the adjustment in the field at the relevant chosen forward speed.
Terrain	An even seedbed helps boom stability – a good reason for a good soil preparation.	
Plant density	It is very hard to adopt to the needs of uneven plant density when spraying - one more reason for a good seed bed.	If larger areas in the field are much more dense or open than the rest of the field you can try to match the volume rate by adjusting speed with a gear change. With some fungicides or insecticides a denser patch may need more volume, but a herbicide may tolerate less because of better competition from the crop (site specific spraying).

How to reduce drift

Wind drift – not only an environmental concern

There are two very good reasons to minimise wind drift. The most obvious is to avoid crop damage on neighbouring crops and other damages caused by plant protection products drifting out of the field.
But, also very important, is that wind drift is a clear indication of a poor spray job and loss of efficacy.

When there is wind drift, the droplets staying within the target area are being pushed around by the wind resulting in a poor liquid distribution and reduced efficacy.

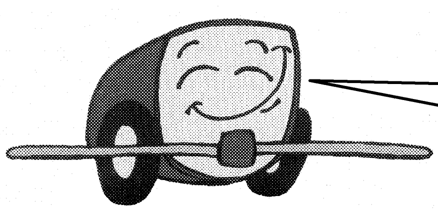


Wind drift conditions can reduce efficacy dramatically!

How to reduce wind drift

When you make the decision to spray
(before making the tank mix)

Early morning spraying	Often there is no or very low wind speeds early in the mornings (Note that in still air conditions, the spray cloud may appear to 'float' behind the sprayer – not a favourable condition) Spraying early mornings at low wind speeds usually will allow good efficacy with low volumes and fine atomisation.
Nozzle type	Either use or be ready to change to lowdrift or INJET. The choice depends on wind speed and spray job (see p. 21).
Nozzle size	Choose a bigger size nozzle. This will increase the water volume rate and apply larger/faster drops. The increased volume rate can compensate for the reduced coverage from bigger droplets.
Spray pressure	Use a lower pressure since this produces larger drops
Driving speed	Slower speed means less disturbance of the spray pattern and also less turbulence around the boom and thus less drift
Boom height	If the boom is stable enough it can be lowered to 40 cm (allowing +/- 5 cm vertical movement at the tip of the boom)



You can increase the volume rate to compensate for the poorer coverage of bigger, less driftable droplets – if you need to spray under less favourable wind conditions

If the wind speed goes up after you have started spraying

Nozzle type	Change to a coarser atomisation: lowdrift or INJET nozzles –remember that minimum pressure for INJET is 3 bar, so you may have to go down one size to maintain flow rate.
Spray pressure and Driving speed	If your spray pressure will allow a reduction then simply 'throttle back' and reduce both pressure and speed (without changing gear). If spraying in head and back wind, and timing is very important, the operator can choose to spray only driving down wind where the speed may off-set the effect of the back wind.
Boom height	If the boom is stable enough it can be lowered to 40 cm (allowing +/- 5 cm vertical movement at the tip of the boom)
Add more water	This allows you to choose a bigger nozzle producing bigger drops and less drift
Stop spraying	Flush pump and pipes with clean water, leave the agitation on and wait for better weather (keep an eye on the sprayer).

Drift reducing agents are seldom the solution

The use of a drift reducing agent is not a simple matter of applying an additive and reduce drift.
A drift reducing additive works by increasing drop size by changing liquid properties such as viscosity. This may have several consequences: the spray angle is often reduced at the same time and the liquid distribution is affected. Some drift reducing agents are sensitive to shearing through a pump and may even end up producing smaller droplets than if the product had been left out. To be on the safe side it is better to minimise drift by the right nozzle choice rather than work with such unknown variables. (Hewitt and Bagley 2000)

Buffer zones

When agrochemicals are Approved, one level of assessment that is made, concerns the products risk to the environment. In particular, there is increasing concern at the unintentional contamination of surface water such as streams, ponds and rivers. Disturbances to these delicate ecosystems is one issue but, so too, is human water consumption. Water supply authorities are being told to ensure the supply of clean water – that is judged by an ever decreasing contaminant limit – and they have the responsibility and costs of removing any agrochemicals that it contains to these enforced limits. Some agrochemicals, are therefore only Approved subject to the use of a so-called Buffer or No-Spray Zone; it is a distance that has been judged adequate enough to minimise the level of contaminant over these protected areas from downwind fallout.

Not all agrochemicals demand a Buffer Zone; the products label or special regulations will specify if it exists and what it should be. In practice, the option to not spray in some crops is not a commercially viable proposition and the Authorities now recognise Low Drift Equipment which may be used with a reduced Buffer Zone Width. Already, some Northern European countries have introduced this scheme; there are nozzles and complete sprayers that have been independently validated and listed by governments to permit this use.

Hardi sprayers and nozzles are currently the most comprehensive package of Low Drift Equipment.
The level of drift reduction offered by a recognised Low Drift nozzle or sprayer will influence the width that a specified Buffer Zone may be reduced. Hardi Twin Sprayers, Injets and Defender booms are in the highest drift reducing category and permit spraying very close to the protected area or water. Hardi Border Jets (see nozzle chapter) produce a half-pattern on the downwind swath edge and these replace the conventional Injet which have double overlapping swaths that may directly spray beyond the intended cut-off point for the swath.

How to increase deposit and coverage

Deposit

When a droplet hits its target, it will either stay, run off or split into several smaller droplets. This fate depends on drop size, drop speed, leaf surface and the physics of the spray liquid.
If the droplets are small (fine and medium atomisation) they will normally stay on the leaf. For larger droplets (coarser or bigger), the deposit very much relies on a slow droplet speed or a good adhesion between leaf and droplet.
Large droplets from conventional nozzles often shatter when they hit. If there is a high leaf density the new small droplets are likely to be deposited further down in the crop.

Leaf inclination also influence liquid deposit. Vertical leaves tend to retain less spray from bigger drops than horizontal leaves.

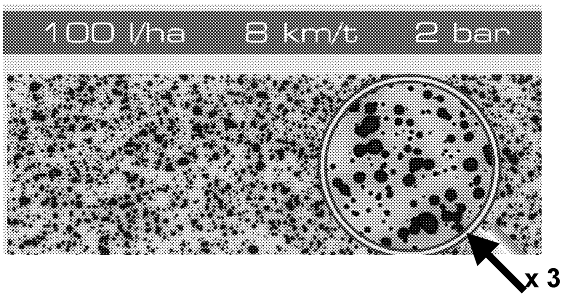
Retention is easier if there is only little or no wax on the leaves. But if the liquid surface tension is low then even larger droplets may deposit well on waxy leaves – providing their speed is not too high.

Usually the chemical manufacturer has already included surface tension regulating additives in the formulation. However, sometimes the label recommends the addition of additive on the farm.

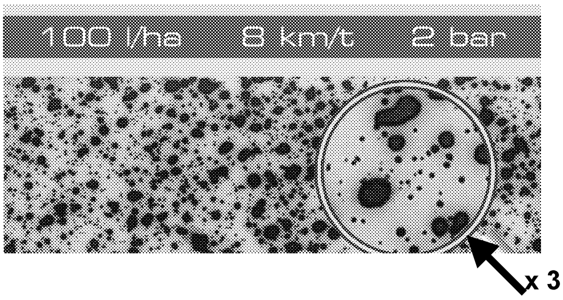
Coverage

The smaller the droplet then the larger is the surface area of that droplet - relative to the volume – so many small droplets can cover a bigger leaf area than a big droplet of equal volume.
If the drop size is halved, 8 times more droplets are produced - and in theory - the area that can be covered is doubled. This is why, if drift can be controlled (minimal wind or by using Twin air assistance), the water rate can be reduced with the use of finer droplets. The small droplets can compensate for a reduction in water rate.

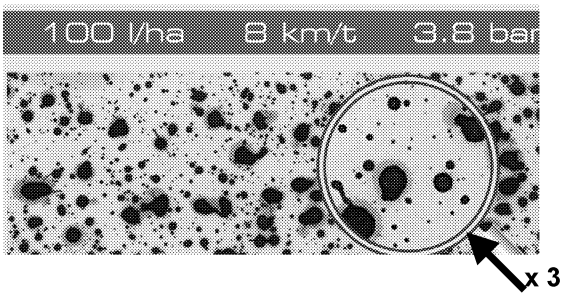
Flatfan F 02

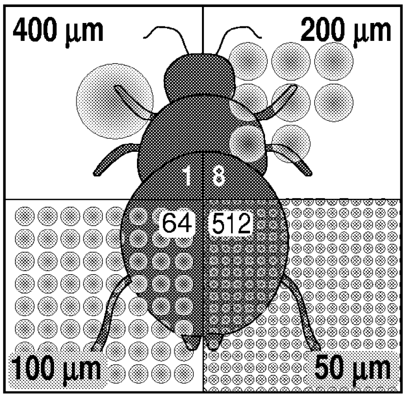


Lowdrift LD 02



INJET 015



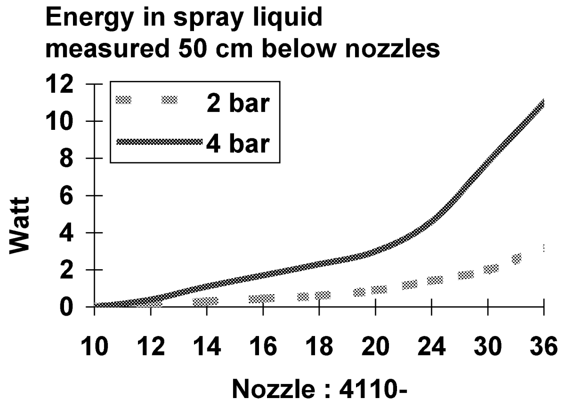


On the sketch the droplets in each square represent the same volume. Every time the drop diameter is halved there will be 8 times more droplets.
The water sensitive papers to the left show the same picture: the smaller the droplets the better the coverage if the volume rate remains the same.
As can be seen on the water sensitive papers it is possible to adapt to specific application needs by choosing the right nozzles. The right choice is usually a compromise of weather, spray purpose and timing. In the chapter “Choosing nozzles for arable crops” are some guidelines to be used unless a nozzle choice is already defined on the agrochemical label.

How to increase crop penetration

Slower driving speeds of 3 to 5 km/h reduce the turbulence around the boom and thus the droplets maintain a more vertical trajectory.

Larger nozzles
Big droplets have relatively less surface area compared to smaller droplets and are of coarse heavier. Thus - with a conventional sprayer -the best way to get good penetration into a dense crop is by combining the use of larger conventional nozzles and a relative coarse atomisation with a higher pressure that will increase the droplet speed. But as always the weather conditions need to be considered especially at higher pressures.



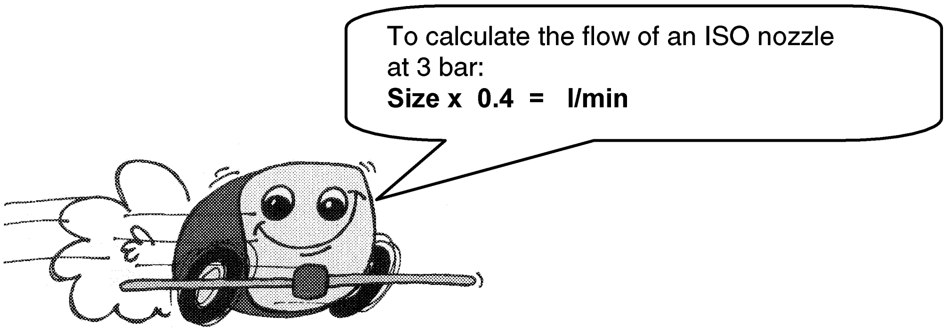
Droplets need energy to reach and penetrate into a crop. The graph shows how this energy can be increased with a higher pressure (the black line of 4 bar is at a higher level than the 2 bar stippled line). The graph also shows that the larger the nozzle the more energy the droplets have. If the nozzle size is above 4110-20 (equal to ISO F04) a higher spray pressure is more valuable.

Nozzles

International Standardisation

ISO nozzles are standardised with regards to: Coding, Flow, Colours and Outer dimensions. The nozzle type and flow are identified on the nozzle together with the spray angle. The flow is in Gallon per minute measured at 3 bar, but by multiplying the printed flow with 0.4 you get the flow in l/min.

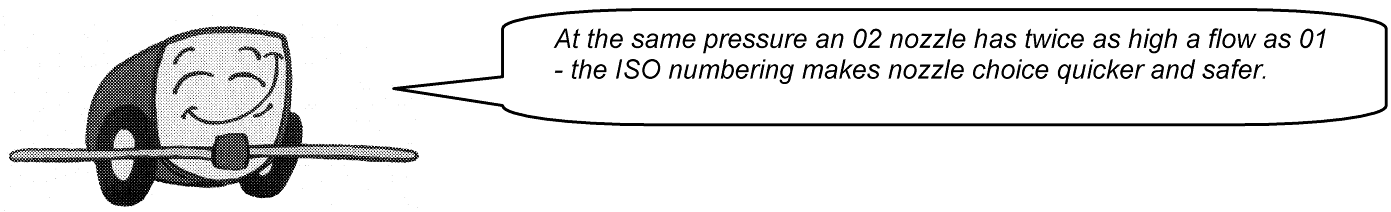
Example: **F-03-110**
F = flatfan
03 refers to the flow at 3 bar: 03 x 0.4 l/min = 1.2 l/min
110 is the spray angle: 110°



ISO nozzles of the same colour give the same output at the same pressure as long as they are not worn. This important Standard ensures that if accidental mixing of nozzle makes or type on the same boom occur, water volumes and therefore dose are not likely to be seriously at fault in the field.

Flowrate at 3 bar l/min	Colour	Coding	Type*
0.3	Pink	0075	F
0.4	Orange	01	F, LD, AI
0.6	Green	015	F, LD, AI
0.8	Yellow	02	F, LD, AI
1.0	Lilac	025	F, LD, AI
1.2	Blue	03	F, LD, AI
1.6	Red	04	F, LD, AI
2.0	Brown	05	F, AI
2.4	Grey	06	F, AI
3.2	White	08	F, AI
4.0	Light blue	10	F

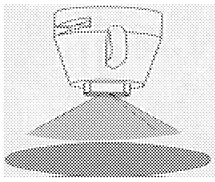
* F = flatfan, LD = low drift and AI = Air injection nozzle (INJET)

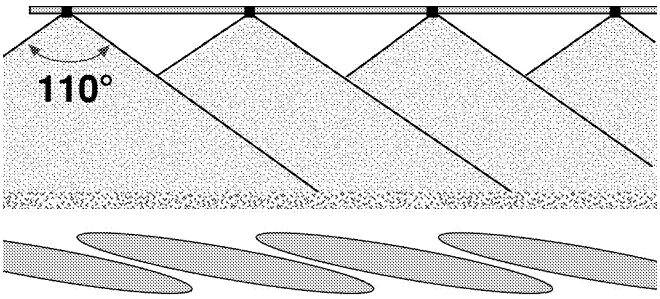


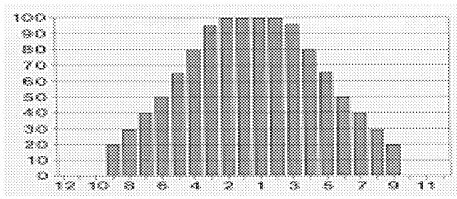
Nozzle types

There are 3 types of flat fan nozzles available for field crop spraying: standard – flat fan - nozzles, low drift and air inducing nozzles. Further the 5-hole nozzle for liquid fertiliser is also related to the flat fan nozzles offering the same type of distribution advantages. Cone nozzles are now rarely used for field spraying because the flatfan ensures a more uniform distribution and is less sensitive to wind; particularly at the more favoured, low pressure, uses today.

Flatfan nozzles are the most commonly used nozzles for arable spraying. They produce –
as the name indicates - a flat fan of droplets with an elliptical "foot print" applying most liquid right under the nozzle and less to the sides. Overlapping from the neighbour nozzles ensure that the liquid distribution can be even under the whole width of a boom.







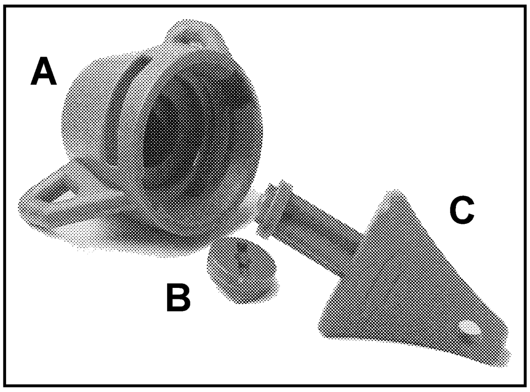
It is important that the nozzles are mounted off-set at an angle of 8° to the boom.
This is automatically done for COLORTIPS nozzles, where the nozzles are locked into the right position in the Snapfit nozzle cap. Failure to off-set nozzle patterns may cause disturbances in distribution from adjacent nozzles.

Standard flatfan nozzles have been used as the general purpose nozzles for almost all types of field spraying.

Standard flatfan nozzles are available with either 110° or 80° spray angle. 110° is most commonly used but 80° nozzles are gaining more interest as booms get wider and have to be used at heights more than 50 cm.

Boom height: 50 cm for 110° nozzles and 70 cm for 80° nozzles.
Pressure range: 1.5 to 5 bar. Recommended range: 2 – 2.5 bar.

Lowdrift nozzles are a newer development and popular where drift is a fear. If using a lowdrift nozzle instead of a conventional nozzle of the same size the application will tolerate some more wind. Spraying under windier conditions with theese nozzles will often be just as efficient as a standard nozzle where the wind has worsened the distribution. Volume rate reductions are important such as in sugar beet spraying where a small standard flat fan would much increase the risk of drift when working with conventional nozzles. If changing from a conventional nozzle into a smaller lowdrift nozzle it will be safer to work with the reduced volume rate but there will be no gain in safe wind speed limits compared to the larger conventional nozzles.
A restrictor plate, placed just before the liquid reaches the nozzle opening, reduces the spray pressure in the chamber of the nozzle. (Without the restrictor the flatfan nozzle part of a lowdrift nozzle has a higher flow than the same size conventional nozzle.) The lower pressure together with a larger orifice results in a thicker spray sheet emerging from the nozzle. A thicker spray sheet breaks up into bigger droplets. Hence the lowdrift nozzles produce a droplet spectrum with less of the finest droplets but still comparable to conventional nozzles.



A: Flat Fan nozzle.
B: Restrictor plate.
C: restrictor removal kev.

Boom height: 50 cm for 110° nozzles.
Pressure range: 1.5 to 5 bar. Recommended range: 2 to 2.5 bar.

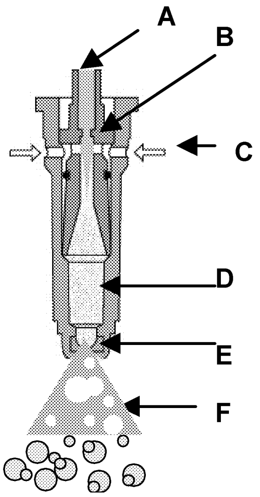
Air Induction: INJET is an air induction nozzle and – as the name indicates - there are little air inlets on the side of the nozzle. INJET nozzles also have a built-in restrictor right before the air inlets, which - together with the air - reduces the liquid pressure inside the nozzle.

When air is sucked into the nozzle it is mixed with liquid in the mixing chamber just before leaving the nozzle orifice. The mix of air and liquid creates a thick and unstable liquid sheet. The bubbles of entrained air perforate the sheet before it would normally break up to form droplets. Thus the spray becomes very coarse.

INJET nozzles are very efficient for drift reduction. With induction nozzles, drift can typically be reduced by 50 to 90% compared to standard nozzles at the same flow. However the very coarse atomisation gives a poorer coverage and a reduction in efficacy has been reported from early herbicide treatments applied under optimal conditions.

This need for good coverage is not yet fully understood, but in some situations may be vital. For example, spraying very small broad leaf weeds and grasses, a reduction in efficacy could be expected.

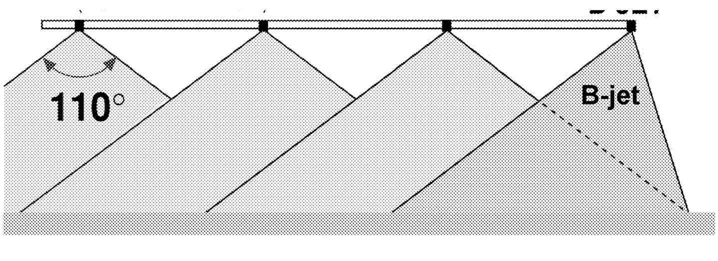
However, the advantage of spraying at the right time (even if windy) can sometimes be higher than to have the optimum coverage. It is also worth noting that an increase of the volume rate can often compensate for less coverage due to increased droplet size. This is particularly important when spraying broad leaf weeds and when using contact pesticides. But when spraying very small weeds -, including grass weeds, research has shown that more water does not solve the problem of less coverage.



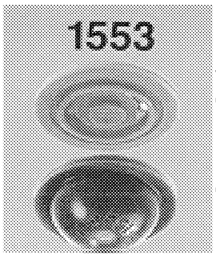
A: Liquid inlet.
B: Restrictor.
C: Air inlet.
D: Mixing chamber.
E: Flat Fan orifice.
F: Liquid sheet

Boom height: 50 cm.
Pressure range: 3 to 8 bar. Recommended range: 3 - 5 bar.

B-jet nozzles are INJET nozzles that only produce a half spray pattern. B-jet (border-jet) are used as the last nozzle on the downwind edge of the boom whilst spraying alongside a drift sensitive area. A well-defined cut-off of the spray pattern reduces unwanted contamination of the neighbouring area. Using B-jets is mandatory in the Netherlands, when spraying next to environmentally sensitive areas such as canals.
Boom height: 50 cm.
Pressure range: 3 to 8 bar. **Recommended range**: 3 - 5 bar.

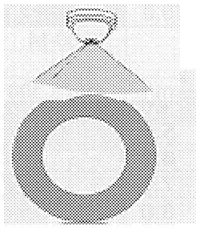


Cone nozzles consist of a solid stream nozzle that regulates the flow and a swirl plate, that ensures the required spray quality (Very fine, Fine or Medium spray) is produced. The swirl plate also distributes the spray in a hollow cone/ring shaped pattern under the nozzle or as a full cone (solid circle).
Before flat fan nozzles were introduced, cone nozzles were widely used on boom sprayers. Due to a poorer distribution and high wind sensitivity they are not recommended anymore. Only for special purposes, such as gaining an under-leaf deposit with high volumes of Fine sprays, are they now used on conventional sprayers; a need that should only be met in very low wind speeds and with a very stable boom.

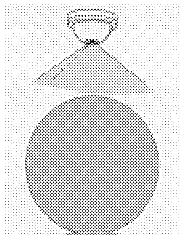


Swirl plate (hollow cone)

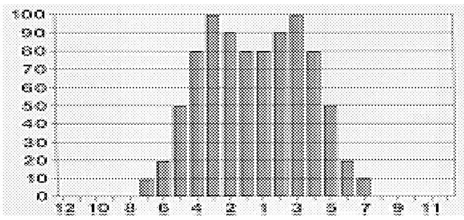
Calibration nozzle

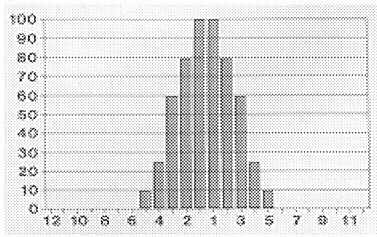


Hollow cone



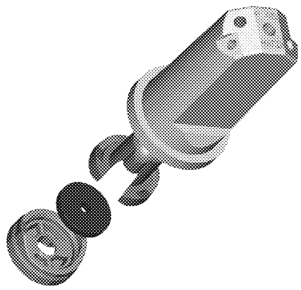
Full cone





Boom height: Variable, depending on spray pressure (spray angle). Boom height must be fixed so the neighbouring cones meet just above the crop.
Pressure range: 2 to 10 bar.

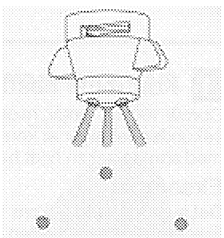
5-hole nozzle for liquid fertiliser (Quintastream). The Quintastream is a major refinement to the 3-hole nozzle. It produces 5 solid streams with each angle and capacity optimised in a way that allows overlapping - just like for flat fan nozzles. This ensures a much more even distribution of the liquid fertiliser yet without compromising on the need for big, fast droplets that easily bounce and run off the plants to minimise scorch.



With 5 hole nozzles it is quick and easy to convert the sprayer to a fertiliser applicator since they are also spaced along the boom at the normal 50 cms.
Quintastream follows the ISO colour coding so the calibration disc can be used when calibrating the nozzles with water – just remember to adjust the pressure according to the density when actually spraying (p 8)

Boom height: 50 cm
Pressure range: 1.5 to 5 bar.

3-hole nozzles for liquid fertiliser. The 3-hole nozzle applies liquid fertiliser in three solid streams, which help to minimise crop scorch. With 3-hole nozzles it is quick and easy to convert the sprayer to a fertiliser applicator since they are also spaced along the boom at the normal 50 cms.



Boom height: The optimum boom height can vary a little depending on spray pressure and density but it must be set to a height that ensures an even spacing of the solid streams normally 40 to 50 cm above the crop.
Pressure range: 1.5 to 5 bar

Solid stream nozzles for liquid fertiliser. Solid stream nozzles at 25 cm spacing with or with out dribble hoses are also a possibility to use when applying liquid fertiliser. Boom tubes with 25 cm nozzle spacing are available as an optional extra.
If working with hoses that can reach below the crop's canopy, you get the ultimate scorching reduction. However, in very dense crops the forward speed might have to be reduced to keep the hoses down into the crop.
Boom height When working with the solid stream nozzles alone you have full flexibility.
Pressure range: 1 – 10 bar

Spray quality (drop size)

The droplet spectrum

All agricultural nozzles produce a range of drop sizes. This is a useful feature as the crops to be sprayed always present a 3-dimensional target that have contrasting leaf surfaces and angles. Hence, in a crop canopy, for example, finer droplets are likely to be deposited in the top and larger droplets lower down.
Drop sizes are measured in micron (μ). 1 μ = 1/1,000,000 metre.
To describe the median droplet sizes produced from a specific nozzle, the term VMD is used.

<u>VMD = Volume Median Diameter</u>
VMD is the mid-way drop size that is reached when the accumulated volume of smaller drops accounts for 50% of the sprayed liquid leaving the nozzle; half the volume is atomised into droplets smaller – and the other half of the volume is larger - than the VMD.

Wind drift has in the past been regraded as being mostly caused by droplets below 150 micron in diameter. Nozzles that specify a VMD <150 are very likely to present an increased drift risk if they are to be used on conventional sprayers. These and other drift related parameters are now being further investigated.

Spray quality – BCPC

The British Crop Protection Council (BCPC) has made a useful guideline that segregates the spray from nozzles into groups according to the drop size (VMD) they produce: Very fine, Fine, Medium, Coarse, Very coarse. These sizes are often referred to as spray quality and are based on relative comparisons using special, internationally agreed, nozzles. These descriptive terms for drop size are more easily recognised and practical in use.

BCPC reference nozzles

Reference nozzle – ISO	BCPC threshold	VMD - measured with Aerometrics	VMD measured with Dantec
BCPC 01	Very Fine – Fine	139 μm	164 μm
BCPC 03	Fine – Medium	237 μm	238 μm
BCPC 06	Medium – Coarse	317 μm	297 μm
BCPC 08	Coarse – Very coarse	359 μm	353 μm

More and more manufactures of plant protection products now give a recommended spray quality on the label.

Spray quality for HARDI ISO 110° flat fan nozzles

<table>
<tr><th>ISO</th><th colspan="4">01</th><th colspan="4">015</th><th colspan="4">02</th><th colspan="4">025</th><th colspan="4">03</th><th colspan="4">04</th></tr>
<tr><td>Pressure (bar)</td><td>1.5</td><td>2.0</td><td>2.5</td><td>3.0</td><td>1.5</td><td>2.0</td><td>2.5</td><td>3.0</td><td>1.5</td><td>2.0</td><td>2.5</td><td>3.0</td><td>1.5</td><td>2.0</td><td>2.5</td><td>3.0</td><td>1.5</td><td>2.0</td><td>2.5</td><td>3.0</td><td>1.5</td><td>2.0</td><td>2.5</td><td>3.0</td></tr>
<tr><td>Standard</td><td colspan="4">F</td><td>M</td><td colspan="3">F</td><td colspan="2">M</td><td colspan="2">F</td><td colspan="4">M</td><td colspan="4">M</td><td colspan="4">M</td></tr>
<tr><td>Lowdrift</td><td colspan="4">M</td><td colspan="4">M</td><td colspan="4">M</td><td colspan="2">C</td><td colspan="2">M</td><td colspan="4">C</td><td colspan="4">C</td></tr>
<tr><td></td><td>3.0</td><td>4.0</td><td>5.0</td><td>6.0</td><td>3.0</td><td>4.0</td><td>5.0</td><td>6.0</td><td>3.0</td><td>4.0</td><td>5.0</td><td>6.0</td><td>3.0</td><td>4.0</td><td>5.0</td><td>6.0</td><td>3.0</td><td>4.0</td><td>5.0</td><td>6.0</td><td>3.0</td><td>4.0</td><td>5.0</td><td>6.0</td></tr>
<tr><td>INJET</td><td colspan="3">VC</td><td>C</td><td colspan="4">VC</td><td colspan="4">VC</td><td colspan="4">VC</td><td colspan="4">VC</td><td colspan="4">VC</td></tr>
</table>

F	M	C	VC
Fine	Medium	Coarse	Very Coarse

Choosing Nozzles for arable crops

Define the needs
Spray quality selection must be taken from the plant protection product label. In general, where no guidelines are offered then for most fungicide, insecticide and Graminacious [grass] weed applications, choose the Fine or Medium spray for optimum coverage. For broad leaf herbicide spraying choose a Medium or Coarse spray.
The coarse and very coarse spray should only be used when there is a real fear of drift. Very fine spray should only be used when spraying with TWIN air assistance, since this sprayer design has the unique ability to reduce drift without having to increase drop size.

Always follow label recommendation for spray quality – if nothing is stated you can use the tables below as a guideline

Optimum spraying conditions

	Conventional①					TWIN air assistance②		
Nozzle type	**Standard flatfan ISO FF 110**			**Lowdrift ISO LD 110**		Standard flatfan ISO FF 110		
Spray quality	***Fine***	***Medium***	***Coarse***	***Medium***	***Coarse***	*Fine*	*Medium*	*Coarse*
Herbicides - soil applied	❍	●	●	●	●	●	●	●
- grass weeds	●	❍		❍		●	❍	
- broadleaf weeds	❍	●	❍	●	❍	●	●	❍
Fungicides - systemic	●	●	❍	●	❍	●	●	❍
-contact	●	❍		❍		●	❍	
Insecticides – vapor action	●	●	❍	●	❍	●	●	❍
- contact	●	❍		❍		●	❍	
- systemic	●	●	❍	●	❍	●	●	❍

①At driving speeds >7 km/h always use Low drift nozzles
②At driving speeds > 12 km/h always use Low drift nozzles

● Best choice
❍ Useful alternative

Normal spraying conditions

	Conventional①				TWIN air assistance②		
Nozzle type	**Standard flatfan ISO FF 110**		**Lowdrift ISO LD 110**		Standard flatfan ISO FF 110		
Spray quality	*Medium*	*Coarse*	*Medium*	*Coarse*	*Fine*	*Medium*	*Coarse*
Herbicides - soil applied	●	●	●	●	●	●	●
- grass weeds	❍		❍		●	❍	
- broadleaf weeds	●	❍	●	❍	●	●	❍
Fungicides - systemic	●	❍	●	❍	●	●	❍
-contact	❍		❍		●	❍	
Insecticides - vapor action	●	❍	●	❍	●	●	❍
- contact	❍		❍		●	❍	
- systemic	●	❍	●	❍	●	●	❍

①At driving speeds >7 km/h always use Low drift nozzles
②At driving speeds > 12 km/h always use Low drift nozzles

● Best choice
❍ **Useful alternative**

When spray drift is a fear -but timing is critical

Often spraying at the right time makes it possible to reduce the chemical dose rate considerably, and postponing the application just a few days, can result in a need to increase the pesticide dose rate. Where drift can be controlled, much can be gained by spraying at the right time.
However, increasing the drop size to reduce drift may result in a poorer coverage on the target area if the water volume rate is not also increased. Only the TWIN can maintain efficient coverage, reduce drift and exploit best use of low water volumes at the same time.

	Conventional sprayer			*TWIN air assistance*			
Nozzle type	**Std. Flatfan ISO FF 110**	**Lowdrift ISO LD 110**	**Air Injection INJET 110**	Std. Flatfan *ISO FF110*	Lowdrift ISO LD110	Lowdrift ISO LD110	Air Injection INJET 110
Spray quality	*Coarse*	*Coarse*	*Very Coarse*	Fine	Medium*	*Coarse*	*Very Coarse*
Herbicides - soil applied	❍	❍	●	●	●	❍	●
- grass weeds	❍	❍		●	●	❍	
- broadleaf weeds	●	●		●	●	●	
Fungicides - systemic	●	●	❍	●	●	●	❍
-contact	❍	❍		●	●	❍	
Insecticides - vapour action	❍	❍	❍	●	●	❍	❍
- contact	❍	❍		●	●	❍	
- systemic	❍	❍	❍	●	●	❍	❍

* If spraying on bare ground or very low crop a medium drop size from lowdrift will help keep both volume and drift down

Please note that with TWIN air assistance the high coverage from a standard nozzle is still possible due to the efficient drift control.
● Best choice
❍ Useful alternative

Nozzle wear and maintenance

-Nozzles are vital, high precision components of a sprayer and, on which, the best spraying practice, relies.
-High precision and efficient performance is only maintained with frequent checks of the nozzles: they must be free of dirt and, as a set on the boom, have an average wear that is below 10%.

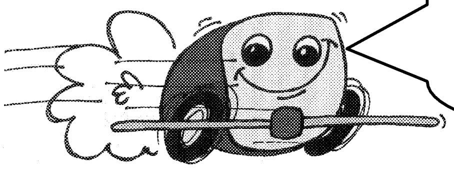
Rules for high performance nozzles:

Once a year (and before an independent inspection) Hardi recommends a thorough check:
Check all nozzles ➤ if average output is more than 10%, change all nozzles
➤ if there is more than +/- 5% deviation, change all nozzles

During the season, Hardi recommends frequent quick checks:
Check 2 nozzles per boom section:
➤ if one nozzle has more than 15% increase in flow, change all nozzles

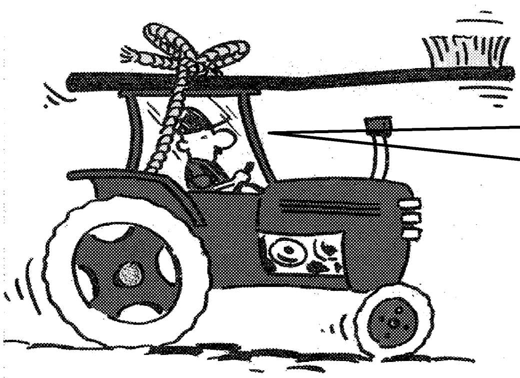
When the avarage nozzle flow has increased by more than 10% or there is more than +/- 5% deviation in the nozzle flow, the liquid distribution across the swath will get poorer. Furthermore, wear starts rounding the edges of the nozzle's opening and heavy stripes in deposits will make a further contribution to a poorer distribution.

It is not possible for manufactures to give a specific life time for nozzles because their wear is much dependent on individual use and exposure to certain formulation types, water quality, spray pressure and cleaning practice.



Synthetic nozzles offer the highest precision.
Ceramic nozzles have the lowest wear rate but are more expensive.
For general use on field sprayers, HARDI recommend synthetic nozzles.
Only if the spray product –such as some powders - is very abrasive, may ceramics come into consideration.
Always change all nozzles at the same time – a mix of old and new nozzles will lead to poor distribution.

A shortcut when checking nozzle wear
Use a new nozzle for reference – it saves any calculation to compensate for eventual pressure losses from pressure gauge to nozzle. If the nozzles are still performing well and not too worn then remember to put back the worn nozzle after checking and safely store the reference one for another occasion.



Use a soft brush or compressed air to clean nozzles. Never use hard material like a knife since the finely shaped nozzle opening can be damaged and cause poor distribution.

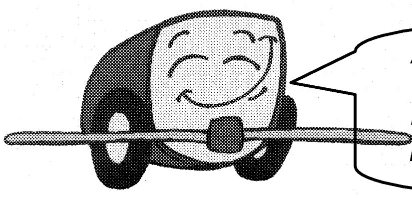
Spray pressure

Spray pressure and crop penetration
Spray pressure influences spraying effectiveness in crops by 2 ways:

1. Pressure influences the spray angle: the higher the pressure the wider the spray angle. If the pressure is too low (below 1,5 bar for flat fans and 3 bar for INJET) the spray angle is not wide enough to ensure full overlap on the boom and optimum liquid distribution.

2. Generally increased pressure helps penetration and also increases underleaf deposit.

3. The higher the pressure, the smaller the droplets. These smaller drops are also more sensitive to wind movement.



A glycerine pressure gauge only works if the “breather” is open.

NB After the spraying season: Remember to remove glycerine filled pressure gauges and store them frost free in upright position.

Pressures recommended for field spraying with standard and lowdrift nozzles
Pressures of 2 to 3 bar for normal flat fan and lowdrift nozzles can be recommended for most applications.
Only for well developed dense canopies where penetration is needed - such as spraying weeds that are concealed at the base of a vigorous crop - the pressure could be increased to 5 bar with larger nozzles (03, 04 and bigger).

Note, that when working below 2 bar, there is very little tolerance for the Hardi Matic* system to compensate for any lowering of speed - which may happen, for instance, going up-hill or when turning.

Generally 1,5 bar is an absolute minimum pressure – at lower pressures the spray angle may be too small to provide the 110° spray angle (or 80° on 80° nozzles) that will produce its essential overlapping patterns.

Pressures recommended for field spraying with INJET nozzles
INJET nozzles require a minimum of 3 bar to have a full spray angle but are used up to 8 bars to induce more air.
Much research debate discusses whether the air trapped within Injet spray drops offer a ‘soft’ impact; an explanation that may make their use more effective than their very large drop size originally implied.

***HARDI MATIC means** linearity between pump flow and driving speed within same gear: increasing or lowering the speed 20-30% will not change the volume rate.

Water Volume rates

On the plant protection product label the spray volume rate is often specified or given in a range like 150 to 200 l/ha.
It is important to note that, if the label recommendation is not followed, the chemical company may not support Warranty claims.
The suggested volume rate may not always express an optimised rate but some times one that tolerates a lot of variable conditions under which the product is likely to be used.
Because a lower volume rate offers increased spraying capacity/work rates (ha/h), many farmers choose to lower the volume rate to a specific spraying situation – knowing and accepting that it is their own responsibility – but gaining the important advantage of high spraying capacity and better field timing.

Several factors must be considered when choosing volume rate:

1. ***Mode of action and coverage***
   Generally a good coverage increases the efficacy of most pesticides. However, soil applied and systemic chemicals are less dependent and tolerate lower volume rates and coarser sprays.

2. ***Target height***
   Taller vegetation may need higher water volumes if the target sites are in the lower areas of the canopy. In contrast, with ear protection in wheat, for example, a very small area of the plant has to be covered, there is little loss by interception of spray by the canopy and less water can be used.

3. ***Crop density***
   The denser the crop, the more water is needed. Usually the need for water will increase with growth stage as the crop grows denser; there may be much more vegetation [a higher leaf area index] that has to be adequately covered with spray deposit. There may be 5 ha of potato leaves to spray on just one ha of cropped land!

4. ***Mixing Plant protection products***
   If more than one plant protection product is applied at the time, the water volume rate that must be adopted is that for the product which demands the higher water rates.

5. ***Wind speed, humidity, temperature and dew.***
Generally early morning spraying favours reduced volume rates with low wind speeds, high humidity and low temperature.
Dew is essentially water already distributed on the plants, and to avoid run off, the water rate should not exceed 150 l/ha.
However, dew can be so heavy that spraying should be avoided but normally it is just an advantage that will help to reduce the water rate.

Water rates for field spraying.

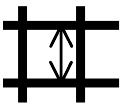
Traditionally water rates may vary from country to country. For instance in Germany it is seldom below 200 to 300 l/ha, whereas in Denmark, UK and France many of the same applications take place with 100 to 150 l/ha. Even 100 l/ha is used more (ear spraying and some herbicide applications), but when going below 150 l/ha special care must be taken.
Over the years there has been a tendency to reduce water rates. This development has happened along with the introduction of new nozzle types and more advanced spraying equipment to meet the growing needs for higher field work rates on larger farms. It could however be questioned if maximum efficacy is acheived when reducing both agrochemical dose rates and water rate – research work indicate that if the aim is to use an absolute minimum dose rate - it is often an advantage to be above 150 l/ha volume rate.

Filters

In addition to the tank sieve, there are, in general, 3 further points of filtration (if line filter used - then 4 points) on the sprayer:

Suction filter → self cleaning filter → line filter (optional) → nozzle filter

The fineness of filters is described as “mesh”, where the number of mesh is equal to the number of threads per inch. The higher the mesh – the finer the filter. To help choose the right filter size, the mesh is colour coded.

Color coding	**Green**	**Blue**	**Red**	**Yellow**
Mesh	**30**	**50**	**80**	**100**
 mm	0.58	0.30	0.18	0.15

Suction filter
On most HARDI sprayers, the suction filter is placed on top of the spray tank. This filter housing is automatically emptied if you remove its sealing cap to check the filter - even if the tank is not empty.

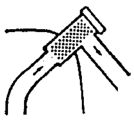
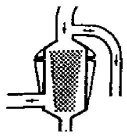
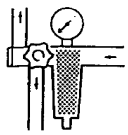
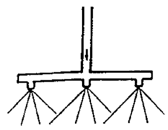
Self cleaning filter (pressure filter)
The self cleaning filter is designed with an internal flushing filter that returns dirt and agglomerated particles to the spray tank. The amount of spray liquid returning to the tank is on some sprayer models controlled by a color coded restrictor that is chosen according to the pump size and nozzle choice.
IMPORTANT !
Make sure that the right restrictor is used in the filter to benefit from its selfcleaning action and build-up sufficient pressure. When you know your volume rate, you can choose the right restictor.

Line filter
To avoid build up of dirt or chemical on the nozzle filters, a larger and finer filter – a line filter - can be mounted in the spray line just before the boom sections.
If line filters are mounted, then nozzle filters can be coarser. It is much quicker to clean a few line filters instead of all nozzle filters.
After each spray job, it is good practice to thoroughly clean the sprayer and remove any deposits that may have built up in the spray booms. There is less need for nozzle filters when there is a line filter for each boom section instead.

Line filters may again be a better choice when working at low volume rates (without a re-circulation system) for the low flow in the boom tubes may encourage powder formulated agrochemicals to more rapidly build up on nozzle filters.

If you choose to work without nozzle filters, remember that the filters have an integral seal. To seal nozzles without their filters, you can either use an o-ring or the filterbody that is also used with the fertiliser nozzles.

Nozzle filters
These are the last-chance filters that protect the nozzle's opening. The finer the filter, the higher is the risk of powder chemicals building up on the screen. Consequently a lower mesh filter is often mounted with the sole purpose of catching those few impurities that may have been loosened from the boom pipes; a much smaller risk today with modern sprayers, better formulations of plant protection products and the practice of rinsing the sprayer immediately after spraying – whilst still in the field.

	Filter size mesh **(standard in fat types)**				
Flat spray ISO Nozzle size	Suction filter 	Self cleaning filter 	Pressure filter 	In line filter	Nozzle filter 
0075 – 02	50	100	80-100	80-100	50*-100
025 – 03	50	**80**	80	50-80	50*-**80**
04 or bigger	**30**	**80**	50	**50**	**50**
Quintastream	50	80	80	50-80	**

*If working with line filters you can choose coarser nozzle filters

**Liquid fertiliser nozzles: work best without nozzle filter – use filter body with gasket for sealing: order no. 725737

Spraying speed

For many years, 7 to 8 km/h [and 4 to 6 km/h in dense crops where canopy penetration is needed] have, in general, been considered good practice. It is an option that is still of value for, increasingly, it is recognised that the slower the boom moves then less is the turbulence around it and hence less drift and less disturbance to the quality of spray distribution.

Some important considerations needs to be made before choosing a higher tractor speed:

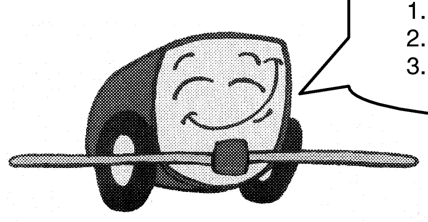
Side effects from higher speed	**How to deal with the side effects**
More turbulence / more wind drift	Bigger droplets / TWIN air assistance
More boom movement	Often the boom should be readjusted for optimum performance at a higher drivning speed

Recommended spraying technique – resume

Water rate	150 - 300 l/ha
Driving speed	(4) 7 - 8 km/h
Nozzle	according to label, weather and volume rate
Spraying pressure	2 to 2.5 bar for flatfan and lowdrift and 3 to 5 bar for INJET
Boom height	40 - 50 cm for 110° nozzles

Weather conditions

Weather conditions before, during and after spraying are very important to the performance of plant protection products. How a product will respond-, will depend on the characteristics of the formulation itself, the local climatic conditions as well as the application method used. Note that plant protection product labels often state the climatic restraints under which more care should be taken when using the product. Local Authorities may also offer special guidance e.g. tolerated wind speed limits.



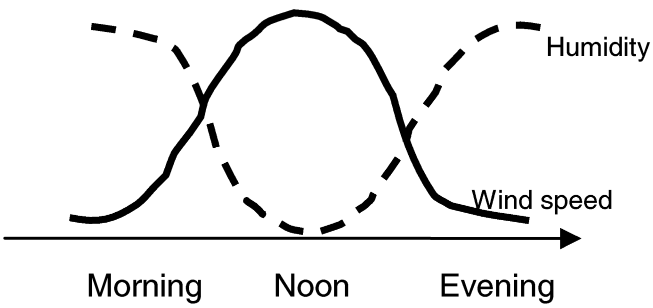
Rise with the sun - or even earlier !
Early morning spraying usually offers many advantages:
1. low wind speeds
2. high humidity
3. a full day of light and warmth that follows the application, may increase efficacy

Weather conditions before spraying

Drought and wind If plants have been exposed to dry or windy conditions for a longer time they will be stressed and the leaves may develop a thick wax-layer to protect against further evaporation. This makes pesticide penetration difficult and can result in loss of efficacy.
Spraying at good growing conditions tends always to give the best result.

Weather conditions during spraying

Wind often follows a diurnal pattern being low during the evening, night and early morning. Under these conditions humidity may be high; this is a combination that is frequently claimed to optimise biological effect of foliar applications.



Wind speed is often included under weather conditions to consider whilst spraying. In particular, there is much emphasis on preventing downwind damage to adjacent crops or contamination of crops ready to be harvested. Most Codes of Practice and Rules suggest a maximum wind speed of 4 or 5 m/sec measured 2 m above the ground. The appropriate maximum wind speed is closely linked to the drift characteristics of the spray being applied; especially their spray quality (drop size).

Wind speed m/s	Conditions for spraying	Recommended drop sizes
0 – 0.5	Inversion risk	Fine, Medium or Coarse
0.5 – 2	***Ideal***	***Fine, Medium or Coarse***
2 – 3	Acceptable	(Fine) Medium or Coarse
3 – 5	Less good	Medium or Coarse (Very Coarse)
> 5	Unfavourable	Only with drift reducing equipment

Temperature often has a pronounced influence on the efficacy of foliar pesticides. Many herbicides perform better at higher temperatures [for temperate crops up to 25-30°C] while others notably –round-up (glyphosate) and many of the sulfunylurea herbicides are not influenced by temperature or even work better under cooler conditions.
Light intensity and duration have been recognised to have some effect too; paraquat, for example, showing quicker symptoms when a period of bright light follows spraying.
Air humidity. Generally high air humidity is an advantage because it minimises evaporation. Moreover water - soluble pesticides penetrate the plant surface more easily at high humidity. If possible spraying at RH lower than 50-60% should be avoided.

Soil moisture is very important for translocation within the plant. High soil humidity usually promotes the pesticide efficacy and is especially very important for soil-applied herbicides – Soil applied products may rely on some re-distribution in soil, and it is not possible to compensate with higher volume rates.
Dew. It is possible to apply plant protection products to plants with dew but only in lower volume rates (maximum 150 l/ha); too high volume rates may result in product being lost due to foliar run-off. Dew can promote performance of plant protection products at low volume rates. In some situations dew can be so heavy that spraying should be avoided.
Rain. If rain occurs during spraying most spray jobs will have to be discontinued; hoses and nozzles flushed with clean water if possible and the agitation left on until spraying can be continued. In this case the sprayer should not be left unattended.
Liquid fertilisers and soil-applied herbicides will tolerate some rain.

<u>Weather conditions after spraying</u>
Rain. Some plant protection products are very rain-fast i.e. the speed of leaf uptake is so rapid that no product is lost. Other products are very sensitive to rain and a rain-free period may be required after spraying. Additives or mixing with other plant protection products may change these properties. Such conditions will be stated on the label.
Temperature. It is generally beneficial if temperature remains optimal for at least some days. For some pesticides efficacy will be reduced if frost follows the application.

Protecting the Environment when
- filling
- spraying and
- cleaning

Check that you are very familiar with the machine, the weather and that you know how to apply the plant protection product and what to do in an emergency. Wherever sprayer loading may take place - in a dedicated area or in the field – the objectives are the same; do not let any plant protection product be spilt such that it can contaminate the machine, the operator or the work environment.

Safe handling of the sprayer when filling and cleaning.

- Guidelines: The instruction book supplied with your HARDI sprayer describes how the equipment must be used. Do follow this guidance and also any that may be offered on the chemical label.

Research shows that a great proportion of agrochemical pollution may originate from filling and cleaning. These activities often take place on the same spot year after year and so does the contamination. Thus it is very likely that the plant protection products will be present deep into the soil. By following good practices, this risk can be minimised.

Protecting the environment when
Filling the sprayer.

Water filling
When filling the sprayer with water, avoid any risks of "over flow" or back siphoning. At the same time, special care must be taken that no spillage could end up in drains, wells, ditches or surface water unless the filling takes place on a special concrete area with efficient drainage to a safe container.

In practice it is safer to fill the sprayer from a separate water tank – or if filling directly from a public or private water supply - make sure that the end of the filling hose is positioned a minimum of 10 cm above the sprayer filling hole.

The sprayer should not be left unattended whilst filling – to avoid over flow or other spillage.

Sprayer filling may not take place anywhere near wells or drills – please look up local guidance (In Denmark a distance of minimum 25 m is recommended by the "Landbrugets Rådgivningscenter "(Tjekliste for håndtering af bekæmpelsesmidler på landbrugsbedrifter, 2000).

To minimise the impact on the environment due to smaller spillages or dripping always on the same spot, the water filling should preferably take place in the field. If filling water at the farm, an area covered with grass is preferred to that of stones or gravel.

Loading Plant Protection Product
Plant protection products should also be loaded into the sprayer at varied places in the field. Transportation of the concentrated products between farm and field must be safe and according to the local rules. In practice, it is recommended to transport plant protection products in a locked box where it is possible to contain any spillage that may occur (like the lockers on CM+). A shovel and plastic sack may also be a wise precaution for they can be used to pick up any spillage of concentrated product if lost on the ground.

When loading plant protection products at the farm it should take place on a concrete area where it is possible to pick up any spillage using special absorbent granules. If this is not possible then use a dedicated grass area that will help to bind and degrade any spillage. The sprayer pump should be off when transporting the sprayer from farm to field – to ensure the system is not under pressure.

Avoid contamination of wells and drillings.

- ✓ Do not fill, rinse or clean the sprayer close to a well or well boring.
- ✓ The water supply must have a one-way valve to prevent back siphoning of water to the source.
- ✓ The filling hose must be kept at a minimum 10 cm above the filling hole to prevent back siphoning if the pump stops.
- ✓ Always stay by the sprayer when filling and prevent overflow
- ✓ Keep minimum 25 m away from wells and well borings if applying herbicides to yards etc.
- ✓ Make sure that the well cover is tight and that no water from any treated area could run down and contaminate it

(Arne Helweg 2001)

Reduce risks when adding plant protection products

✓ Add the agrochemicals to the sprayer in the field.

This way you
- avoid using the same spot every time you handle concentrated chemicals
- benefit from an active soil breakdown of minor spills
- avoid any risks from transporting a full tank of spray solution

✓ Carry the agrochemicals in safe lockers on the sprayer. It must be possible to collect any spillage that may occur from the containers.

When the agrochemical container is empty it must be rinsed either with the rinsing nozzle in the chemical filler or with 3 lots of clean water. In both cases it is important to move the container to make sure the rinsing is fully efficient. If using a rinsing nozzle - the time used for rinsing a container - must be adjusted to the container size. An extra rinse with clean water afterwards will ensure that the container is clean as can be. The rinsing water must be added to the main spray solution. The rinsed containers are stored upright and securely in a locked cupboard or compound with their lids replaced.

Bio beds for filling and cleaning
A bio bed is a pit lined with clay and having a water-proof membrane in the bottom. It is filled with a mix of fine cut straw, peat mould and high organic soil. Covering the pit is turf and there is a driving ramp for access.
The purpose of the biobed is to optimise the degradation and binding of spillages.
It has yet to be clarified how efficient the biobed is and how to handle the contents after due time.

Protecting the environment when
Spraying

A wind streamer mounted in front of the tractor will help to show the operator which way the wind is blowing and its likely force. It will help you to know when to be extra cautious and maybe react by using coarser nozzles.
Plan ahead for any emergency and try to anticipate problems. For example, if the wind speed is currently acceptable but is forecasted to rise then consider spraying the downwind swath edges first.
Avoid over spraying for it is wasteful and puts your crops at risk as well as posing a hazard. Use the boom section valves for areas, which are less wide than the swath. If treating an “angled” field it is worth the effort to turn off the boom sections as the boom passes over the already sprayed area close to the headland. Hardi Triplets have an ‘off’ position for you to use if you need to control swath widths by 0.5 m sections; in particular, when next to water ways.

Protecting the environment when
Cleaning the spray equipment.

Label guidance
If a specific cleaning method is given on the label then this must be followed. Below you find more general guidance. Always remember to wear gloves, face shield and plastic apron/appropriate waterproofs when cleaning.

Residual volumes within the sprayer
The cleaning of the sprayer starts already when calibrating: if calibration is done correctly, there will be very little spray solution left in the tank after spraying. The emphasis today is to encourage in-field cleaning using dedicated equipment on the sprayer.

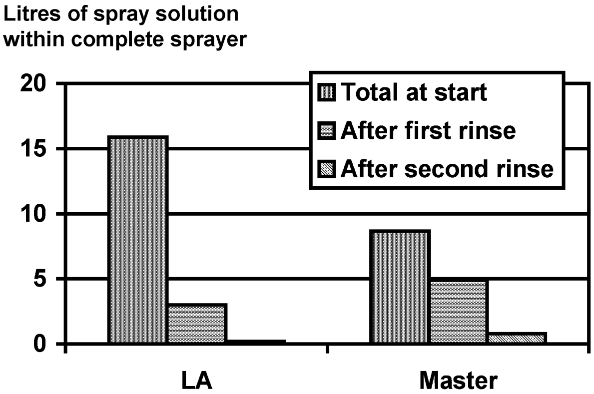
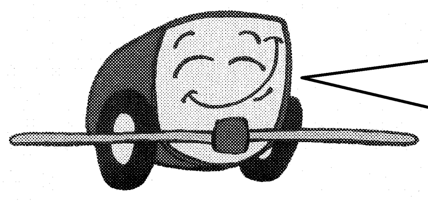


Figure 1.
Rinsing in the field is very effective when using dedicated clean water tanks.
Although the LA and Master may have retained 17 and 8 litres of solution, the final volume is substantially less after this cleaning process.

In some instances, small residual volumes of spray solution have been drained from the machine and disposed using the services of an authorised company.
More often, the practice is to dilute the remaining liquid and spray this out over an area which would comply with its Approved use. Avoid exceeding it's maximum dose. Diluted 10 times with water and sprayed out over the just treated area or similar will often meet that need simply and effectively.
A dedicated rinsing tank mounted on the sprayer is the first important requirement for quick and easy field cleaning.



Keep the sprayer clean
Never postpone cleaning for later. Once the plant protection products have dried out onto the sprayers surfaces then cleaning will be much harder work and more time consuming. Keeping clean is quicker, easier and more efficient.

Infield rinsing with rinsing tank *(a daily routine)*
The most efficient use of the water in the rinsing tank is achieved if the water is used in 2 to 4 lots; using half, one third or one fourth of the water for each rinsing. It is important that all valves are operated whilst rinsing so that trapped spray solution is removed from everywhere in the system.
If the sprayer is equipped with a rinsing nozzle this should be activated during each rinsing to achieve the most efficient cleaning of the internal spray tank. It is important that the sprayer is emptied as much as possible after each rinsing to ensure maximum dilution with each new introduction of rinsing water. The rinsing water is sprayed in an area of the crop just treated.

Rinsing without rinsing tank (daily !)
To minimise the amount of rinsing water that has to be used and then, disposed, the tank is flushed internally using the equivalent of 10% of the tank size. This is repeated twice. A high-pressure cleaner is a useful help. After each rinsing stage, the rinsing water is sprayed over an area of low environmentally-valued vegetation that will not be damaged near the farm; the just treated crop or similar is preferred. Before applying the rinsing water over the crop, all valves must be activated for a complete rinse. Do remember that whichever way you dispose of agrochemicals, the procedure used must comply with your local rules and regulations. In particular be aware that no rinsing water ends up in ditches, drains or sewages.

An absolute cleaning of the sprayer following one type of crop use ready for another.
To be able to confidently treat crops that are very sensitive to the plant protection product that has just been used in an earlier application, it may be necessary to chemically breakdown even traces of the active compound that are stuck to the inside of the sprayer. If a method is written on the agrochemical label - this must be followed! Otherwise there are 2 possibilities:

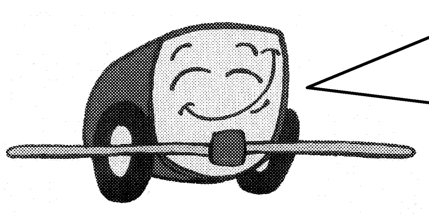
Cleaning without rinsing nozzle: Fill the spray tank with water and an approved cleaning agent like ammonia, bleach or a product marketed for sprayer cleaning. Turn on the pump and let the solution circulate through the whole system for 15 minutes. Do operate all valves – on sprayers with selfcleaning filter: increase the pressure until the safety valve is activated, then reduce the pressure again. To ensure that the tubes and hoses on the boom are also cleaned, remember to let the nozzles spray for a while during the process onto grassland or the just treated crop. Leave the sprayer for a couple of hours to ensure that any residues of chemicals are de-activated. This cleaning solution may be sprayed over the just treated area or grassland.
Dismantle and remove all filters and nozzles and place them in a container of the same cleaning solution as used in the spray tank. After a while they are given a final clean with a brush and rinsed with clean water and fitted back on the sprayer again. Finally the whole sprayer is rinsed with clean water that is also sprayed over the just treated crop or grassland – somewhere with vegetation where it does no harm.

Cleaning with a rinsing nozzle: Fill the tank to 1/10 of the capacity with water and cleaning agent. Activate the rinsing nozzle and let the liquid circulate in the whole liquid system for 15 minutes whilst operating all handles and valves. Then follow the procedure as described for "Cleaning without rinsing nozzle"

External cleaning
An area covered with low value, unused grass may be an appropriate “filter” for distribution of rinsing water from the sprayer and an appropriate place to clean the outside of the sprayer and tractor. The grass hinders the plant protection product solution from moving away and encourages it to be chemically bonded to soil particles and subsequent degradation. Therefore it is advisable to have such an area - moved every year - nearby the farm.
A new possibility for most sprayers involves having supplied or fitted, special equipment for external cleaning of the sprayer in the field. This - to be preferred - procedure is still being developed but some of the clean water in the dedicated rinsing tank has to be reserved for this extra purpose. Hoses with a high pressure supply are being used to rinse those areas of the machine that get the greatest level of contamination; the rear of the tank, the booms and wheels. The frequency at which external cleaning takes place will depend on factors such as spray quality and wind direction as well as exposure time and temperature. Today’s evidence suggests that infield cleaning is likely to be a routine that should be done at the end of every spraying day. It is an activity that is of great importance for both personal and environmental safety when storing the sprayer.

Personal safety

Always follow the safety instructions on the agrochemical label and use all personal protection equipment as stated.



When working with plant protection products, do remember that the safety equipment that you wear is there to avoid last chance contamination. Think safety and work with care!
Never reuse a pair of damaged or contaminated gloves. Check that they are suitable. Research with plant protection products show that they penetrate the cheapest gloves within minutes. Some of the more expensive qualities can last up to 4 hours: all gloves are disposable gloves !

Typically, the operator is at a greater risk when filling the sprayer and handling the concentrated product than when actually spraying. The hands are - not surprisingly - the most exposed part of the person.
Figure 2 comes from a Danish test that evaluated chemical exposure during the spraying operation (Kirknel and Thellesen 1989).

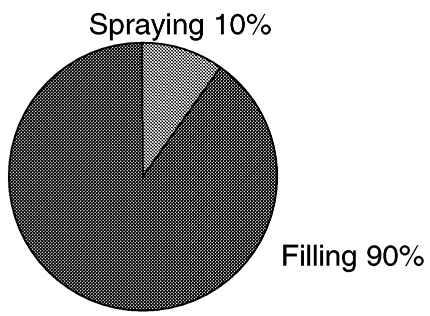
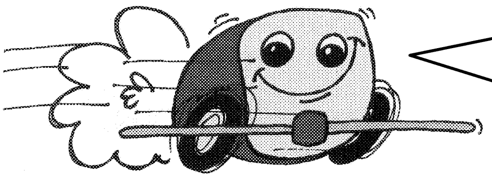


Figure 2
Filling poses a far greater risk than spraying to the operator. Distribution in percentage of the total load on the operator when working with pesticides.



Personal protection equipment is no guarantee for safety if it is not combined with a good practice.
Good practise and full attention combined with appropriate safety equipment especially when handling the concentrated products can almost eliminate operator contamination.

Optimal use of gloves. What is good practice? Good practice is a lot of things most operators already know: do not pull out the container seal with your hands, do not touch the sprayer without gloves, do not walk in just sprayed crop etc. However there are details that might be new also to experienced operators, like the significance of "optimal use of gloves". Using gloves is of course, a very good way of protecting the hands, but investigations have shown that many users are contaminated when taking off the gloves. ***It is very important to rinse the gloves before taking them off (and immediately after spilling on them) – also when using disposable gloves. And try not to touch the outside of the gloves when taking them off.***

The graphs in the box below indicate the differences between normal use of gloves and rinsing the gloves before taking them off.

The following are trends showing up in a research project not yet completed, but the results are expected to be validated very soon.

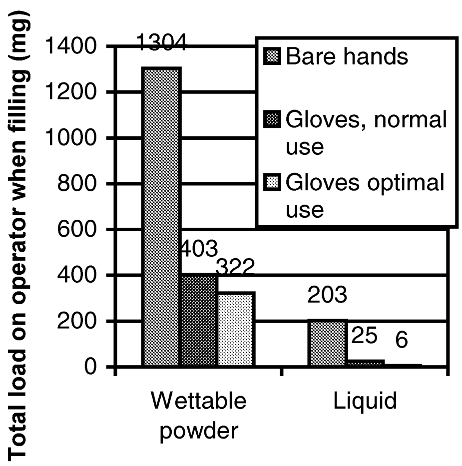


Figure 3.
Wettable-powders need extra attention when filling
Preconditions: Normal cotton coverall, closed cabin.
The big difference in operator contamination when working with wettable-powders speaks for it self and so does the advantage of gloves.
Rinsing the gloves reduces the contamination with an extra 10 % for liquid formulations.

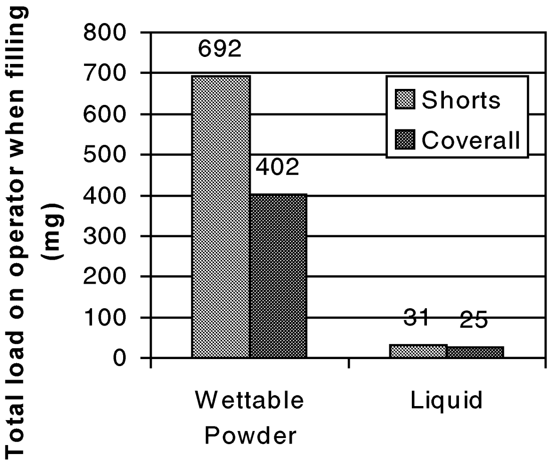


Figure 4.
Shorts or coverall ?
Precondition: Normal use of gloves and closed cabin.
Again it is especially the wettable powder that shows the highest level of contamination – and just changing to coverall instead of shorts when filling will reduce contamination with more than 40%.

Disposable nitrile gloves seem to be a very good choice if being careful that they do not break and as long as they cover the wrist:

- **they are very efficient keeping out the product**
- **they are cheap enough to be disposable in practise**
- **disposable gloves are very much easier to take off with out contaminating the hands.**

Soruce:www.agrsci.dk/plb/eki/exposure/exposure.html

During the actual process of spraying, the main source of contamination is changing nozzles - where again the hands are highly exposed. The legs are also at risk if the operator has not remembered to drive out of the just-sprayed crop a little. Walking in the field just sprayed – must be avoided.

Where boom lift and/or folding is still manual, this is of course, also a glove job.

To reduce operator contamination, extra equipment like remote sprayer control, quick filler, hydraulic boom lift, hydraulic boom folding, chemical filler, non drip valves, self-cleaning filter, Triplet nozzle holders and Snapfit bayonet couplings, tank rinsing nozzle, rinsing tank and high pressure cleaner can all contribute to lessen operator exposure levels. To day more and more of this equipment is standard.
Keeping the tractor cabin closed and using remote controls and extra equipment means a total reduction of more than 70% on the operator exposure whilst spraying (Fig 5).

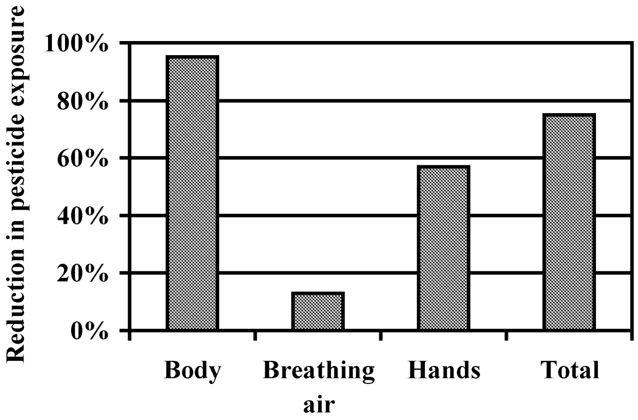
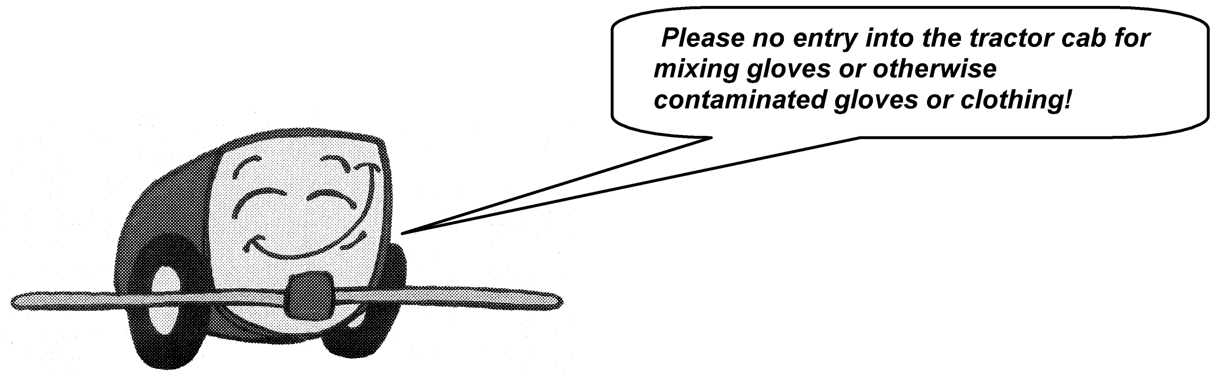


Figure 5.
Likely reduction in pesticide contamination - when starting to use remote control and extra equipment - instead of a fully manual sprayer.



Fault finding

Problem	Probable cause
No suction from pump	• 3-way valve not open/wrong setting • hoses not mounted correctly • leakages on suction side • pump valves not mounted correctly • pump valves blocked • pump needs priming • suction filters blocked
Insufficient pressure	• Suction filter partly blocked • Too little distance between yellow suction pipe and tank bottom • Plugged pressure filters • Pump sucks air • Leakage at 3-way valve • Faulty pressure gauge – check for dirt at inlet • Restrictor in selfcleaning filter too big or missing • Safety valve spring for self-cleaning filter not tight • Pump valves not mounted correctly • Pump valves worn – check by demounting them and pour water into the valve with the valve pointing downwards – if water runs through then the valve is worn.
Pressure is dropping	• Filters are clogging • Tank is air tight – check vent in lid is functioning • Sucking air towards end of tank load – lower rpm
Pressure increases	• Pressure filters are beginning to block
Pressure pulsating at nozzles	• Air on suction side • Broken diaphragm in pump • Broken valve in pump • Faulty pump assembly (all diaphragms activated at same time) • Too high pressure in the pressure damper • Broken diaphragm in pressure damper
Nozzles are dripping	• Anti drip valve not tightened • Diaphragm or spring in anti drip valve defect or missing
Spray liquid is foaming	• Too much agitation if - rpm too high - safety valve for self-cleaning filter not tight - return pipes and hoses inside tank not present • Check/ tighten gaskets/O-rings of all fittings on suction side
Liquid leaking from drainage hole in pump	• Damaged diaphragm(s) in pump
Leakages at fittings	• Damaged hoses • Seals missing or insufficient tightening • Damaged seals • Dry seals – lubricate with oil
A nozzle is not spraying	• Nozzle plugged • Nozzle filter plugged
Sedimentation in tank	• Dirty water • Wrong mixing technique • Insufficient agitation – too little pump capacity • Plugged agitation nozzles

Prepare your sprayer for inspection

More and more countries have their own independent sprayer checks; in some countries it is mandatory i.e. every second year, whilst in other countries it is optional or just carried out as a random check.

The tests have not yet become standardised so it is advisable to check the rules in your own country. The following list may not be complete for all countries, but it identifies the most important points that need to be checked before an official test.
As the purpose of the checks is to ensure safe and optimum use of agrochemicals then these same checkpoints can also be used as part of a good routine for efficient and responsible plant care.

Start with a clean sprayer	-clean the sprayer internally -remove all nozzles and filters and soak in a bucket with soap and water – rinse and refit -clean the sprayer externally
Check all hoses for external wear Check that no hoses are squeezed when boom is folded Check that no hoses are hit by spray and thus interfering with the spray pattern	If a hose is worn it must be changed. Make sure that the new one is mounted in a way that avoids “kinks” and rubbing against sharp edges.
Check the pump	Check that drainage hole in pump is dry Check that the pressure is stable
Do a thorough calibration	Check speed Check all nozzles flow and wear Make a visual check of spray distribution Check for leakages, incl. anti drip valves are functioning by spraying at about 7 bar.
Check agitation	Clean agitation nozzle if blocked.
Check lubrication scheme	Lubricate if necessary
Check the boom	Loose joints must be tightened or changed. The centre section must be adjusted so the boom can move freely with out being loose: the boom must be stiff along the whole length and when raised at one end and released then it must return to horizontal without further vertical movements.
Check lights and brakes	

Spraying record Crop______ Field__________ ha________

Operator, Time & Weather

Operator				
Date				
Start				
Finish				
Crop stage				
Wind (m/s)				
Wind direction				
Temperature				
Humidity				

Plant protection products

Spray task/s								
1. Chemical								
Dose rate/ha								
l or kg/tank								
T l*								
2. Chemical								
Dose rate/ha								
l or kg/tank								
TI*								
3. chemical								
Dose rate l/ha								
l or kg/tank								
TI*								
Volume rate								
Sum TI *								

*TI is the treatment index, meaning the number of full reccommended dose rates.

Sprayer

Nozzles				
Flow l/min				
Pressure (bar)				

*Tractor:*___________

Speed (km/h)				
Gear / motor rpm				
Tyre size				

Useful formulae

Speed check

$$\frac{\text{Distance driven (m)} \times 3.6}{\text{Time (sec)}} = \text{km/h}$$

Calibration formula
– nozzle spacing 50 cm

1. Calculating the necessary nozzle output per nozzle (l/min) with known water rate (l/ha) and speed (km/h):

$$\frac{\text{Speed (km/h)} \times \text{Water rate (l/ha)}}{1200} = \text{nozzle output (l/min)}$$

2. Calculating the water rate (l/ha) with known nozzle output per nozzle (l/min) and speed (km/h):

$$\frac{1200 \times \text{nozzle output (l/min)}}{\text{Checked speed (km/h)}} = \text{water rate (l/ha)}$$

3. Calculating the necessary speed (km/h) with known nozzle oputput (l/min) and water rate (l/ha):

$$\frac{1200 \times \text{nozzle output (l/min)}}{\text{Water rate (l/ha)}} = \text{speed (km/h)}$$

-nozzle spacing not 50 cm:

$$\frac{\text{Nozzle spacing (m)} \times \text{Speed (km/h)} \times \text{Water rate (l/ha)}}{600} = \text{nozzle output (l/min)}$$

Relation between output (l/min) and pressure (bar)

$$\left(\frac{\text{New output (l/min)}}{\text{Measured output (l/min)}}\right)^2 \text{X Measured pressure} = \text{New pressure}$$

or

$$\sqrt{\frac{\text{New pressure (bar)}}{\text{Measured pressure (bar)}}} \text{ X measured output (l/min)} = \text{New output (l/min)}$$

Adding agrochemicals

1. Calculating the necessary amount of agrochemical per tank:

$$\frac{\text{Tank volume *(l) x dose rate(l/ha or kg/ha)}}{\text{Water volume rate (l/ha)}} = \text{(l/ha) or (kg/ha) agrochemical per tank}$$

*If you do not need a full tank then you enter the actual volume you will be using.

2. Calculating the total amount of agrochemical needed for the area to be treated:

Dose rate (l/ha or kg/ha) x area to be trated (ha) = total amount of agrochemical (l or kg)

3. Calculating the total needed spray solution (l):

Water rate (l/ha) x Area to be treated (ha) = Total spray solution (l)

Notes from your own calibration

Date:__________

Spraying parameters to be checked:

	Intended values	Checked values
Driving speed	km/h	km/h
Volume rate	l/ha	l/ha
L/min/nozzle	l/min	l/min
Nozzle		
Pressure	bar	bar
Gear / rpm	/	/

Check Speed

Distance driven (m) x 3.6 / Time (sec) = km/h

m x 3.6 / sec = km/h

Gear:

rpm:

Sec/100 m	**40**	42 44 46 48 50 52 54 56 58	**60**	62 64 66 68 70 72 74 76 78	**80**
Km/h	**9,0**	8.6 8.2 7.8 7.5 7.2 6.9 6.7 6.4 6.2	**6.0**	5.8 5.6 5.5 5.3 5.1 5.0 4.9 4.7 4.6	**4.5**

Use the nozzle calculator to choose nozzle size and pressure

Check liquid system for leakages and check agitation

Check nozzle output (Quick test)

- Adjust working pressure and measure at least 2 nozzles for every boom section.
- Check that the average flow (l/min) is the same as the intended

Nozzle	l/min	l/min (2nd check)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
Average		

Check wear – Quick test

- Mount a new nozzle of same size as on the boom
- Check flow at working pressure and use as reference
- Check that no nozzle flow is higher than reference nozzle flow + 15%.

Pressure:____bar

L/min for reference nozzle	Maximum flow (l/min) = l/min for reference nozzle x 115%

Previous calibrations

Plant protection products

Volume rate l/ha	*Nozzle type*	*Speed km/h*	*Gear & rpm (Tyres*)*	*Pressure bar*	*Date of calibration*	*Wear rate*	
						Quick test %	*Thorough test %*

Liquid fertiliser

Volume rate l/ha	*Nozzle type*	*Speed km/h*	*Gear & rpm (Tyres*)*	*Pressure bar* *Calibration pressure x density = application pressure*		*Date of calibration*	*Wear rate*	
				Calibration	*application*		*Quick test*	*Thorough test*

**** If changing tyres during the season it is important to state what tyres were mounted for a specific calibration***