Test performance of handheld pesticide application equipment or knapsack sprayers in practical use in Norway

Bjugstad, N.[1]; Skuterud, M.[2]
[1]Department of Mathematical Sciencies and Technology, Postbox 5003, N-1432 Ås, Norway
[2]The Norwegian Food Safety Authority, Moervn.12, N-1430, Ås, Norway

Summary

In Norway the questions now are raised about testing handheld application equipment and knap sack sprayers i.e. in greenhouses and gardening. However, a detailed test of the equipment alone would not be able to ensure a good spraying result, correct dose and low risk of operator exposure. Additionally, such a test could be rather expensive for small sprayers and reduce the motivation for a proper use in the after hand. Correct calibration, movement of nozzle, nozzle position, spray coverage and correct pesticide concentration among others are also very important factors in order to ensure a good spraying quality. From our point of view a proper use may be solved by a simple test focusing on important factors like; no leaks, anti drip device, good operational functions and no damages. The nozzle should be renewed if the spraying picture is poor. The average capacity in litres/min should be measured. The operator should be skilled in how to perform a precise and safe application, how to avoid residues of spray volume and how to clean the equipment after use. This should be included in a test or control for such equipment. However, a standard for new sprayers should include other important aspects like testing equipment stability, weariness of straps, well functioning pump handle, low flow fluctuations, adapted manometer, low pressure drop, good agitation, low residue amount and no leaks when tilted etc. as described in the ISO19932-1. This paper will describe the Norwegian proposal of control of handheld spraying equipment more in details including the calibration of sprayer.

Introduction

In total there are almost 1,000 greenhouses in Norway and the average size is 2,000 m2. The number of greenhouses above 5,000 m2 has increased approx. 40% during the last 20 years (SSB, 2007). About the half is production of ornamentals, and the rest is different kinds of vegetables, mainly tomatoes, cucumbers and lettuce.

From 1997, all users of pesticides in Norway, including those in greenhouses, have to be educated in the correct use of pesticides. The Department of Mathematical Science and Technology at the Norwegian University of Life Sciences (MST) was responsible for the technical part due to spraying equipment and correct use. The specific equipment and methods for this application had to be studied carefully and adapted teaching material had to be developed. In Norway all users of pesticides are obliged to renew their spraying certificate every 10 years, therefore several users have already been updated.

For crop sprayers and orchard sprayers in use, a technical test, a so-called function test, is compulsory every five years (Bjugstad et al, 2004). During such a test, the user of the sprayer has to join the test, and the test operator normally goes out to the different farms or orchards in order to carry out the test together with the user/owner of the spraying equipment. In this way, the grower gets an increased knowledge and motivation, which make him able to perform the application correctly. Additionally, the grower/user is skilled about how to calibrate his specific sprayer(s) by the use of a certain check list. Hereby the grower/owner is able to fill in his own measurements and is encouraged to carry out this test by himself before every season. Additionally, an inspection is carried out by a testing operator every five years, and simultaneously the technical information may be refreshed and updated. Finally, the user should participate in the aforementioned authorisation course every 10 years, covering all aspects dealing with the use of pesticides.

When developing a test program for spraying equipment in greenhouses, the positive experiences from these tests and conditions ought to be implemented. Our experience is that when a grower meets the testing operator alone instead of attending a compulsory authorisation course where 20-40 people may be gathered, he gets a better adapted knowledge of spraying technique as well as an increased motivation to obtain a more precise and safer application. This is especially important in greenhouses, where the use and types of spraying equipment vary in a large extent as well as the type, size and density of the plant canopy.

Because of these positive experiences the MST and the Norwegian Food Safety Authority find it important to include the calibration process in a forthcoming test of spraying equipment in greenhouses. For these applications in particular, procedures to carry out a correct calibration are unavailable. Therefore the MST has studied the use of different spraying equipment in use for several years (Bjugstad et al, 2009) and suggested methods and procedures to ensure the correct dose. This paper will focus on what kind of sprayers which are in practical use in Norway, experiments carried out in order to study the differences in spraying quality and biological results, and finally how to obtain an easy and exact inspection including calibration of the sprayers used in greenhouses.

Spraying equipment in practical use and their limitations

High pressure spraying equipment: The high pressure system consists mainly of a trolley sprayer with a tank size from 25 to 300 litres, a drum with a 50-100 m long hose with a spray gun/ pipe/ boom and nozzle(s) at the end. The trolley is only moved at one end of the houses. Then the hose and spray gun is pulled out in the length of the house or row normally without spraying. Afterwards, the operator sprays the house, tables or rows when he slowly moves backwards with a minimum of resistance when pulling the hose back. The working pressure of the nozzles is normally 5 to 15 MPa which is almost up to 100 times higher than for a conventional crop sprayer.

The advantage of this equipment is the possibility to adapt a dose and amount of fluid according to different plant size, which often differ in each house. The extraordinary high pressure makes it possible to spray over a longer distance, which means that the operator does not have to move all over the house as much as for the low pressure equipment later described. The disadvantages are mainly that the operator may be highly exposed of pesticides and that the labour costs are high. This type of equipment is much in use in Sweden and Norway today.

Tab. 1 Estimated use of spraying equipment in greenhouses in Norway

Equipment	Pressure range	Estimated use
High pressure equipment	5.0 – 15.0 MPa	45 %
Low pressure equipment	0.5 – 5.0 MPa	30 %
Spraying booms	0.2 – 0.8 MPa	5 %
Knapsack sprayers, knapsack mist blowers, small pressure sprayers, others	0.1 – 1.0 MPa	20 %
Cold foggers		Minor use
Spraying robots		Minor use, but increasing

Low pressure spraying equipment: The low pressure sprayers are built in the same way as the high pressure unit, but the pump is smaller and the pressure range is normally from 0.5 to 1.0 MPa and in some extent up to 5.0 MPa. This equipment may also be used together with a spraying tower or vertical boom, i.e. in cucumbers, in order to get a more even distribution and easier handling of the equipment. Because of the lower pressure, the operator ought to walk between all the tables in order to achieve a proper distribution and penetration. The main advantages are low equipment costs and optimum adapted spray amount and dose due to plant size and type.

Spray booms: In large greenhouses several plants have installed horizontal spraying booms. The main advantages of this equipment are a more even distribution and reduced labour costs. Additionally, a higher capacity is important in order to spray the plants in time and make the area ready for other work needed. However, several growers point out that the lack of adapting the spray volume easily due to different plant height along the similar swath, insufficient penetration through plant canopy as well as unwanted sprayed areas i.e. in the inter row, empty parts of the tables, spots outside the tables etc. make these booms difficult to use properly for such conditions. For these reasons the MST has observed large plants where spray booms have been mounted in the house from the start, but are often not in practical use. However, if the problems mentioned may be solved easily, the spraying booms will be used more in the future than they are today.

Others (knapsack sprayers, knapsack mist blowers, small hand operated sprayers): The MST has carried out operator exposure measurements earlier, which proved that the use of knapsack mist blowers results in a very high operator exposure and should be avoided if possible (Bjugstad & Torgrimsen, 1996). In the '90s, the use of hot and cold fogging equipment was quite popular in Norway. Thus, the MST made several deposit and operator measurements as well as biological studies together with other institutions. In table 2 some biological results are presented (Stenseth, 1992).

Tab. 2 Biological results when using a cold fogger vs. a hydraulic sprayer (Stenseth, 1992)

Pesticide	Application	Dose/concentration	% dead nymphs
Applaud	Wanjet Tornado ULV	50 g per 1000 m2	32.0-82.0 %
Applaud	Hydraulic sprayer	0.05 %	100%
Thiodan 35	Wanjet Tornado ULV	200 g per 1000 m2	34.5 – 55.8 %
Thiodan 35	Hydraulic sprayer	0.15 %	94.0 - 100 %
Dedevap	Wanjet Tornado ULV	360 g per 1000 m2	15.8 - 29.9 %
Dedevap	Hydraulic sprayer	0.10 %	24.3-70.5
No treatment	Wanjet Tornado ULV		2.4-3.6 %

Experimental house size: 12 x 17 m2; Applaud buprofezin, 230 g/kg; Thiodan 35 – Endosulfan 357 6/l; Dedevap – Diclorvos 500 g/l; Nymphs: Bemisia tabaci

From the evaluation of hot and cold fogging machines and the biological results obtained, the following conclusions for such equipment were made compared to a conventional hydraulic sprayer:

- Lower effect when using contact pesticides due to a poorer coverage
- Higher risk of pesticide residues on plants/products
- Have to be tested for each pesticide, due to the high pesticide concentrations used
- More sensitive for break down/ disturbances than for the hydraulic sprayer
- Poorer deposit on the lower side of leaves and underneath tables surfaces
- Not possible to treat limited areas/ plants
- Deposit on greenhouse construction/ walls/ ceilings etc.
- Higher capacity due to higher concentration and lower volume rate
- Low weight
- Good effect where a vapour effect of pesticides is wanted, i.e. for diclorvos.
- Might be run during the night
- Good operator safety for stationary equipment, if not any drift problems occur

Additionally, the following problems/missing details were observed for the movable hot fogging equipment (Igeba 65):

- No agitation
- No visual scale of tank content
- No filtering
- Leaks of spray mix from the operating valve
- Motor stopped frequently when operating in the house
- Uneven flow of fluid
- Pesticide might react with the hot exhaust
- High noise (108 dB)
- Filling of gas near exhaust tube may cause hazards
- High risk of operator exposure if wearing the equipment

Thus, the use of fogging equipment is forbidden in use for food production in Norway, and only approved for a few pesticides for ornamentals, where conventional methods are not sufficient effectively. The movable hot fogging machine is not recommended to be used due to safety reasons.

Proposed content of a function test for spraying equipment in greenhouses

The proposed requirements are based on the EN-13790-1 and 2 from 2003 and own experiences made during the tests of the crop sprayers and orchard sprayers in Norway. Basic requirements as non leaking and a proper function are included for all kinds of equipment. However, the requirements, from our point of view, to some extent ought to be modified for different kinds of sprayers. I.e. when several nozzles are mounted very closely to each other and the distance from nozzles to the canopy is long, minor deviations between the nozzle flow rate capacities have minor negative influence on the biological effect.

The calibration of the flow rate as well as the volume rate and dose of pesticide are misleading in greenhouses in Norway today. Thus, the MST highlights the focus of exact calibration and proper use of all sprayers and the importance of implementing this calibration training into the test of the equipment. From our point of view, the correct use of equipment and dose of pesticide is often more important that the technical test itself, especially for small sprayers and low and high pressure sprayers, which are mostly in use in Norway. If these factors are not included, equipment which has passed a technical control could still cause large dosage failures. If this calibration should be carried out later by someone else, this would result in increased costs for the grower and possible misunderstandings. Probably the equipment then ought to be inspected again to ensure that it works properly before the calibration is performed.

The user will be instructed in how to move the nozzle(s) arrangement to obtain an even coverage and how to rapidly estimate the penetration and deposit. Additionally, the importance of walking backwards, where this is suited, is included, as well as other efforts to avoid a high risk of exposure which may occur during the spraying operations (Bjugstad & Torgrimsen, 1996). The spray result will be demonstrated by using water sensitive paper or non toxic dye stuff to examine how to obtain a good deposit and coverage.

On the label of the most fungicides and insecticides in greenhouses today in Norway, a concentration, i.e. 150 ml per 100 litres spray volume, is written. The original idea of this kind of labelling was that the operator was told to spray until run off. In this way, the volume rate and dose was easily adjusted for different plant sizes. However, this is correct only if different growers apply approximately the similar spray volume to the same plant type & canopy & density. During the last 15 years the MST has detected considerable variations in applied practical doses between different growers, in spite of carrying out the application at equal conditions due to similar pest attack, plant type and growth stage. In table 3 some results are presented (Bjugstad, 2007). The users of pesticide in greenhouses were randomly divided into two groups, A and B. One operator was chosen and asked to spray the plant canopy until run off. The trial included large plants covering a surface of 70 m2. The sprayer set up, nozzles, pressure used and other conditions were similar. Due to the wetness of the plants from the first spray application, the second group was expected to use a lower volume rate in order to spray until run off. In spite of this the second group used 77 % more fluid than the first group.

Similar experiments have been carried out for different plants and equipment. In all these experiments the volume applied differed in the range of 50 to 100 % or more between different groups. This is caused mainly by the different visual assessment of run off which is very difficult to evaluate in a uniform and proper way.

Tab. 3 Variations in dose caused by using different volume rates in similar conditions

	Group A **Low pressure sprayer**	**Group B** **Low pressure sprayer**	**Group C** **Knap sack blower**
Litres used	13.0	23.0	1.36
Plant surface	70 m2	70 m2	70 m2
Litres per 1000m2	185	328	19.4
Dose in %	100 %	177 % (+77 %)	10.5 % (-89.5 %)

Additionally, the movement of the nozzles, the distance from nozzles to plants, the walking speed or long/short legs/hands etc. may influence the applied rate and distribution. It is also important to highlight that the growers are taught not to use such a high amount of spray volume today, in order to avoid run off and get a better spray coverage. The users commonly also use a much lower volume rate in order to increase the spray capacity.

The third group in table 3 used a knap sack mist blower. They applied a volume rate of only 10.5 % of the rate of group A. This means that the average dose would vary from 10 % to 177 % if the concentration factor was not taken into account. Thus, a concentration factor for adapted recalculations was introduced. Additionally, we needed to implement a so-called normal volume rate corresponding to the factor 1.0, which was equal to the concentration on the label. However, this volume rate hardly did exist. Thus, the MST in 1993 introduced such rates in cooperation with a group of growers and biological experts in order to ensure that the use of different equipment and ways of application always resulted in an approximately similar dose. This was used by introducing the factors and values shown in table 4. The volume rates in the table are for large plants and high densities. For smaller plants, reduced pest attack and lower crop densities the volume rates have to be reduced.

Tab. 4 Concentration factor at different volume rates for selected crops

Concentration	Measured volume rate in litres per 1000 m2		
Factor	**Small flower plants/Lettuce**	**Roses**	**Cucumbers/Tomatoes**
0.25	400	600	800
0.3	333	500	667
0.4	250	375	500
0.5	200	300	400
0.6	167	250	333
0.7	143	214	286
0.8	125	188	250
0.9	111	167	222
1.0	**100**	**150**	**200**
1.25	80	120	160
1.5	67	100	133
2.0	50	75	100
2.5	40	60	80
3.0	33	50	67
4.0	25	38	50
5.0	20	30	40
6.0	17	25	33
7.0	14	21	29
8.0	13	19	25
9.0	11	17	22
10.0	10	15	20

However, when we evaluated the situation afterwards, we experienced that the growers did not understand how to use this concentration factor properly and more or less used their own empirical values, mainly because such rates previously had given good results. If we compare between different growers, they still use widely different volume rates for the same kind of application today which also result in large variations of the pesticide dose.

It is important to keep in mind that the biological efficacy depends on the amount of pesticide per area of the surface of the plant. The quantity of water acts only as a carrier to transport the pesticide towards the plants and to ensure a sufficient coverage, and might, as presented in table 3, vary widely between different kinds of spraying equipment and for different operators treating the same kind of plants at similar conditions. The label should give sufficient information to all the users in order to apply a correct dose. However, most of the users feel their conditions are normal and apply the concentration given on the label for the sprayer and nozzles used without adapting any changes in the concentration factor. Thus, the MST together with the advisory service and biological department in 1998 and again in 2005 proposed to introduce a dose also for spraying application in greenhouses. This is an important step in order to ensure a correct dose without any kind of misunderstanding. For hot and cold fogging machines an area or volume dose has existed for all pesticides during the last 20 years. Thus, an area dose may easily be calculated for practical use.

Professional greenhouse production results in a high number of applications on a limited area. Additionally, the floor may be of concrete and the risk of run off by dripping, cleaning or spraying outside the wanted area may cause a high risk of pollution. Thus, it is important to demonstrate by simple means how to avoid this kind of pollution. The solutions will depend much on the spraying system used, the building facilities etc. The testing operator has also to be aware of a possible contamination by the spray water used to carry out the test itself. If such a risk may occur, this water has to be collected back to the main spray tank. One problem is that long hoses are commonly used, which have to be proper cleaned before the testing can start. This is also a problem for the grower himself in practical use when a cleaning operation is needed. When using only a spray gun or similar device the rinse volume may be collected easily. However, when starting to spray again, the initial spray will be too much diluted because water may still be remaining in the system. This can be avoided by using a separate collecting tank, but this may cause much work. Another solution is to use a double hose recycling system, which will be rather expensive. However, a very simple and cheap method is only to put the spray gun into the opening of the main tank and recycle the flush water or spray fluid back to the tank directly. Depending on the kind of spraying equipment used, the best suited solution is to be demonstrated during the test in order to motivate and skill the grower in a proper cleaning procedure.

All growers get a four page check list enabling them later on to carry out a simple and quick control and calibration of their own spraying equipment and store the data. The list shall cover all potential equipment including examples of data and describing how to use water sensitive paper. Additionally, all the growers get a package of water sensitive paper included in the test for later use.

The proposed test for spraying equipment in Norway will include different high and low pressure equipment, knapsack sprayers, knapsack mist blowers, small pressure sprayers and spray booms. The fogging equipment is in minor use. If a test has to be carried out for such equipment, the spray volume has to include the pesticide itself in order to take into account its properties and high concentration. Thus, a test of fogging machines is not included in the test at this stage.

References

Bjugstad N., Sundbye A., Toppe B. 2009. Bruk av plantevernmidler.Sprøyteteknikk i veksthus. Fokus, Vol. 4, No 5, http://www.bioforsk.no/ikbViewer/Content/47424/2141_Bioforsk.pdf: 35 pages.

Bjugstad N., & Torgrimsen T. 1996. Operator Safety and Plant Deposits when using Pesticides in Greenhouses, Journal of agricultural Engineering Research 65, 205-212.

Bjugstad N., Hermansen O. P., Fridheim, D. F., 2004. Testing of sprayers in Norway, SPISE Workshop, Braunschweig, Germany, 8 pp.

EN 13790-1 2003. Agricultural machinery – Sprayers – Inspection of sprayers in use – Part 1: Field crop sprayers, CEN, 17 pp

EN 13790-2 2003. Agricultural machinery – Sprayers – Inspection of sprayers in use – Part 2: Air-assisted sprayers for bush and tree crops, CEN, 16 pp

Statistics Norway 2007. www.ssb.no, SSB

Stenseth, C. 1992. Virkning av kjemiske plantevernmidler ved kaldtåkebehandling, (Effects of pesticides when using cold fogging treatment). Gartneryrket 1, 17/1:21-22.