Potential Operator Exposure when Spraying in a Strawberry and Raspberry Tunnel System

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ABSTRACT

The pesticide exposure of the operator during the spray application in strawberries and raspberries was measured in a tunnel and a conventional 'open field' cultivating system. When spraying strawberries a front mounted spray boom using four nozzles per row and three rows per swath was used. When spraying raspberries a rear mounted mist blower on a tractor and a trailer sprayer pulled by an ATV were used.

A quick and easy passive sampling method was developed in order to get a sensitive and exact measurement of the potential exposure. The samplers consisted of transparent overhead sheets cut to a 10 x 10 cm^2 standard size.

The potential operator exposure was significantly higher for a tunnel system compared with the conventional open field system for strawberry as well as for raspberry.

Keywords: pesticide, equipment, samplers, nozzles, environment, safety, wind velocity

1. INTRODUCTION

In order to obtain a better crop quality, higher yield and lower number of spraying applications, an increasing number of the Norwegian growers cultivate strawberry and raspberry in a tunnel system instead of using the conventional open field method. Questions have been raised if there are any disadvantages when using pesticides in a tunnel system from an environmental point of view. Thus, the Norwegian Food Safety Authority founded a project in order to document if there is a difference in the operator exposure of pesticides influenced by a tunnel system versus an open field arrangement. Only a few previous studies have focused on operator exposure when spraying strawberry in the open field (Bjugstad and Torgrimsen, 1994; Jensen and Spliid, 2005), and none of them studies the effect of cultivating systems in raspberries nor strawberries.

In earlier exposure measurements active as well as passive samplers have been used (Bjugstad and Torgrimsen 1996). However, the use of active samplers like filter pumps are time consuming to set up and normally need a longer exposure time than passive samplers to ensure detectable exposure values, mainly because these samplers measure the respiratory fraction. Furthermore the respiratory exposure caused by hydraulic nozzles normally is very low compared with dermal exposure measured by the passive sampling method (Bjugstad and Torgrimsen, 1994; Chester, 1993). Passive samplers have been used in a large variety of sizes and structures (Kramer *et al*., 2002; Miller, 1993). Among others, an advanced sampler type has been developed in greenhouses consisting of three layers; an outer cotton layer, filter paper and a dense plastic foil as the inner layer (Nuyttens *et al*, 2004). The cotton layer should catch the large droplets and the dense inner layer should prevent drops to contaminate from the coverall below. However, such a filter is complex to attach and collect quickly in the field. Thus, a simple passive sampler was wanted in order to increase the number of measurements without major changes in meteorological conditions.

2. OBJECTIVES

The main goal of this project was to examine the effect of the difference in cultivating system (open field versus tunnel) on potential operator exposure when spraying in strawberries and raspberries.

The total exposure is not important in this context, because that exposure will contain exposure also when stopping at the end, when turning, exposure depending of field shape etc., i.e. other factors than caused by the cultivating system alone. Thus, the measurement only could be carried out for single track(s) inside the tunnel and for the similar length outside in the open field. To avoid measuring failures like those explained above, the time carrying out the experiments were only 1-2 min. Pre studies showed that if the samplers were fixed inside a closed cabin for such a short time of application, the amount of exposure was negligible. Thus, in order to obtain any possible significant difference in potential exposure between the two application situations, the samplers had to be position outside the tractor cabin in the open area in order to be able to catch possible droplets drifting away against the operator. Analogous to the phase I and phase II drift described for drift measurements (Herbst and Ganzelmeier, 2002), we can define phase I (outside the cabin) as potential exposure detected closer to the nozzles depending only on spraying equipment and tunnel vs open field, and phase II as the total exposure measured on the operator inside a closed cabin including the turnings, stops and other situations of exposure in addition to the factors causing the phase I potential exposure. Because the spraying equipment, adjustment, sampler position, operator and plants were similar, the only influence on the measured potential exposure was the cultivation system as pointed out in the objectives.

3. MATERIAL AND METHODS

3.1 Passive samplers

After some pre studies, a simple conventional overhead sheet, black & white copier transparency film *(3M, PP2500)*, cut to a 10 x 10 cm^2 standard size (WHO, 1982), proved to be a very simple and well suited passive sampler. The sampler was tested at different vertical positions and loads of exposure. The drifting droplets were caught by the sheet without any risk of run-off also when positioned vertically. However, the exposure time had to be taken into account in order to avoid overload and run off of droplets. By visual control the run off limit could easily be detected. The time carrying out the final experiments was even shorter than in these pre studies in order to ensure that no run off would occur. Every sampler was fixed, by using a piece of transparent tape on the corners, on a similar clean, but larger OH-sheet with a size of approx. 12 x 12 cm^2 in order to prevent any contamination from the earlier exposed operator coverall from the bottom. Some positions of samplers are shown in figure 1. All the samplers including supporting layers were prepared in advance in order to reduce the total experimental time. Unexposed samplers were controlled for any backup residues and proved to be clean. After exposure, the passive sampler was removed from the supporting surface and stored in a pre numbered plastic bag for later analysis. Normally, setting up the samplers, performing the spraying operation (1-2 min) and collecting the samplers took approximately 15-20 min.

As shown in table 1 - 2 and figures 2 – 4, totally 10-12 passive samplers were put out for every trial. All the trials were repeated four different days in strawberry and two days in raspberry. Five replicates were carried out every day. The applications in the tunnel and in the open field were run every other time to obtain approximately similar meteorological conditions each day for both trials and to ensure that the tunnel was well ventilated before the next replicate was carried out.

Figure 1. Passive samplers, size 10 x 10 cm^2 fixed on a 12 times 12 cm^2 layer. Dotted lines show edges of the samplers and supporting layers. The tank on sprayer pulled by the ATV for raspberry (picture to the right). An inner tape was used to fix the clean layer at the bottom.

3.2 Spraying equipment

Because the goal of this project was to examine any difference in potential exposure between a tunnel and an open field system, a spraying equipment causing a certain amount of drift and operator exposure was needed to obtain significant values. Thus, the most conventional spraying equipment for each crop was selected, in spite of the fact that equipment producing a lower potential of spray drift did exist (Bjugstad and Hermansen, 2008).

When spraying against fungus in strawberry, a front mounted spraying boom with four nozzles per row and covering three single rows per swath, was used. One application consisted of spraying only one swath of a length of 54 – 100 m. The doors on the tractor cabin were opened in order to get droplets into the cabin as well as impact the passive samplers fixed inside on the doors. In this way any difference in potential operator exposure between the two different cultivating systems could be stated. An overview of different equipment, nozzles and set up is shown in table 3.

Figure 2. Front mounted spraying equipment (LTI boom) on a MF 360 tractor in strawberries. Position of samplers.

When spraying raspberry in a tunnel arrangement, two types of equipment were used. A small trailer sprayer, Hardi, equipped with a vertical boom spraying only to one side, was pulled by an ATV in order to treat the outer rows closely to the tunnel walls. In the interrow, a tractor mounted mist blower, Hardi Mini Variant, with vertical booms to both sides, was used. In the open orchard only this sprayer was in practical use. However, both kinds of sprayers were tested in the tunnel and the open field situation in this project. One application consisted of spraying two different rows back and forth, approx. 2 times 100 m, in the field in order to compensate for variations in the wind direction. To reduce random errors, the operators were only spraying in the swath during the measurements. The nozzles were shut off in good time before any turning was needed.

Table 1. Position of samplers Exposure Raspberry Mist blower and tractor Fiat 50-66.

Main position	Position	Distance from nozzles (cm)	Height above ground (cm)
Tractor	inside cabin front	280	220
Tractor	inside cabin side	210	150
Tractor	outside tractor left high	210	210
Tractor	outside tractor left low	210	150
Tractor	outside tractor rear high	180	210
Tractor	outside tractor rear low	180	150
Tractor	outside tractor right high	210	210
Tractor	outside tractor right low	210	150
Sprayer	outside tank left	120	130
Sprayer	outside tank right	120	130

Figure 3. Hardi Mini Variant mist blower for application in raspberry. Nozzle height above ground in cm. Spraying simultaneously to both sides. ½ + ½ = 1 row treated per swath. Positioned in the interrow in the tunnel.

Table 2. Overview of sampler position. Raspberry ATV and trailer sprayer

Sampler No.	Position	Distance to nozzles (cm)	Height above ground (cm)
1	Operator, chest, right side	240	120
2	Operator, chest, left side	240	120
3	Operator, forehead	240	150
4	Operator, right glove	280	100
5	Operator, left glove	280	100
6	Operator, back, left side	210	120
7	Operator, back right side	210	120
8	Operator, back of head	215	150
9	End side of sprayer	25	70
10	Along side of tank, behind	35	70
11	Along side of tank, centre	70	70
12	Along side of tank, front	110	70

Figure 4. ATV and Hardi trailer sprayer with Unigreen nozzles spaced vertically every 50 cm, for application in raspberries, spraying horizontally to the left hand side only. One side = ½ row treated/swath. Here used in order to threat the outer row in the tunnel.

Table 3. Technical factors for the equipment used in strawberry and raspberry

Equipment	Driving speed km/h	Nozzles	Pressure MPa	Flow rate l/min nozzle	Volume rate l/ 100 m row
Strawberry Front mounted boom	1.8	4xTJ 80 015/row 3 rows/swath	0.7	0.9	12.0
Raspberry ATV- Hardi Trailer	4.7	4 x orange Unigreen nozzles to one side only	0.7	1.71	17.5 (8.7 -one side)
Raspberry Fiat tractor & Hardi mist blower	4.7	5 ATR yellow hollow cone nozzles per side	1.0	1.0	12.8

3.3 Crops and Cultivating System

Because of the use of a fluorescent tracer, the measurements were carried out after the berries were harvested. The strawberry field of *Korona* was planted in a single row system. The row spacing, 1.25 m, and the plant size were similar in the tunnel and in the open field. The average plant width and height were 0.40-0.50 m and 0.30 m respectively. The tunnel experiments were carried out in one single 54 m long tunnel only open at the ends. The maximum tunnel height was 4 m and the width 7 m. The tunnel system is shown in figure 1.

The raspberry field was also similar outside and inside the tunnel. The plant size was approximately similar for all the experiments. The tunnel width and height were 4.5 m and 8 m, respectively. The lower sides of the walls were open approx. 1.0 m from the ground. The raspberry, type Glen Ampel, was cut to a 2 m height and had approx. a width of 0.70 m at the top. The row spacing was 4.0 m, which means that the distance from the centre of outer row to the tunnel wall and construction was 2 m.

Figure 5. Strawberry tunnel to the left. Normally, a transparent cover is used. This cover was only used in the experiments. Raspberry block tunnels to the right.

3.4 Tracer and analysing method

Fluorescein was used as tracer in a concentration of 0.1%. Because the tracer is sensitive to sunlight, the samples were collected immediately after the exposure and put in pre numbered transparent plastic bags. The samples were stored dark and chilly until the analysis was carried out the following day. The samples were washed by adding 40 ml distilled water into the bags and the concentration of the fluid was analysed with a fluorimeter (10-AU-005-CE Turner, measuring range of 0.001 – 100 ppb). Based on a normal pesticide concentration of 3% the pesticide exposure per cm^2 surface and 100 m row could be calculated in order to visualize the potential exposure of pesticides, as shown in figure 11 -14 for raspberry. The values were analysed by a statistical program (Statistix). Totally, approximately 800 samples were analysed. Several samples of the tank concentration were taken for every experiment. The spray volume was added a surfactant of 0.1% alcohol- etoxylate (DP).

3.5 Meterological parameters

Wind vector, relative humidity and air temperature were measured inside and outside the tunnel before every application. The wind direction was observed by using light tread indicators guided by the airstream. The wind velocity was measured by using a hot anemometer. The replicates were carried out at so similar meteorological parameters as possibly. However, the wind vector was normally significantly reduced and more or less harmonised in a tunnel system as described in figures 15 and 16.

RESULTS AND ANALYSIS

The vertical lines in the figures 7-14 denote the standard error (SE). L is left and R is right.

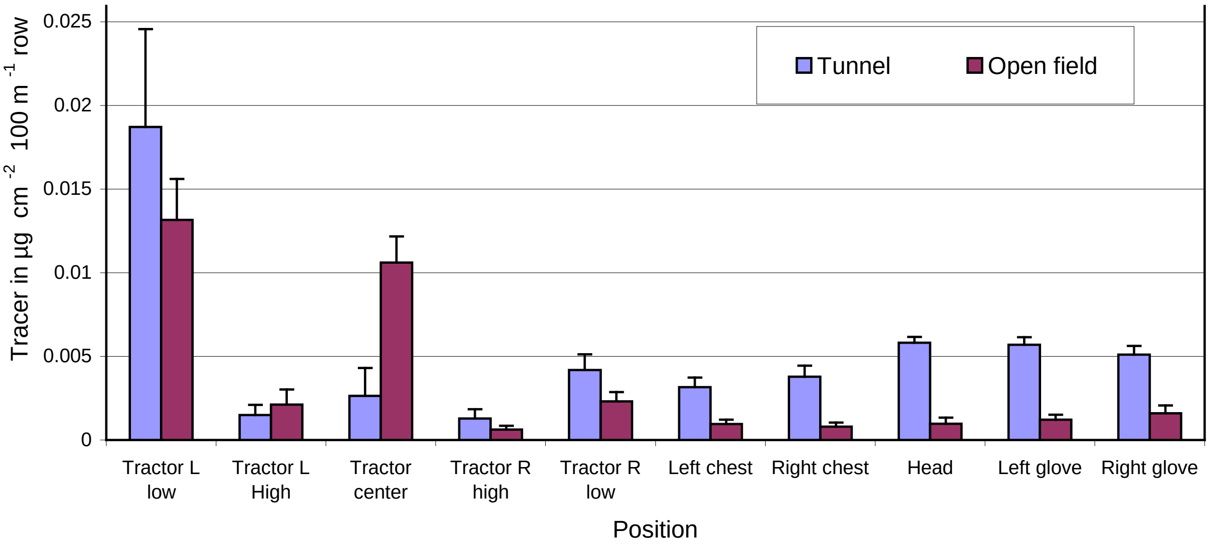

Figure 7. Exposure measurements in **strawberry**, tracer in µg/cm^{2}100^{-1}m. 1 run. LTI boom. Wind: Open field; from right /behind 0.8-3.5 m/s. Tunnel; from behind 0.2-1.8 m/s.

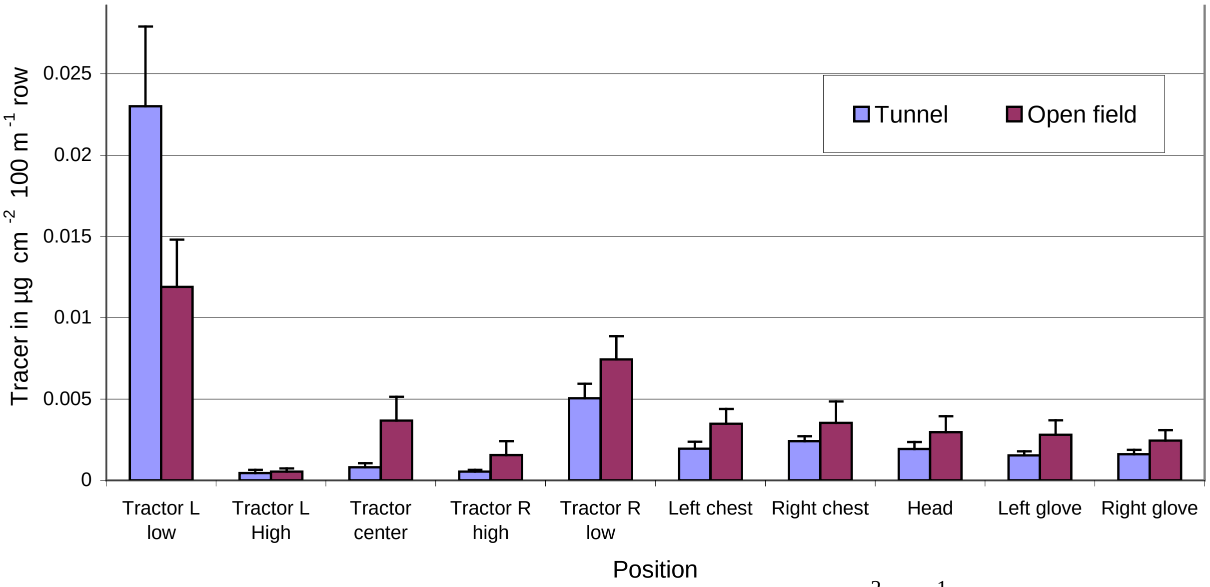

Figure 8. Exposure measurements in **strawberry**, tracer in µg/cm^{2}100^{-1}m. 2 run. LTI boom. Wind: Open field; from right /front 0.1-0.75 m/s. Tunnel; front 0.1-0.95 m/s.

A wind speed direction from right&behind and higher than the driving speed causes a lower exposure in the open field, fig. 7. In the tunnel the wind speed slows down and the operator gets more exposed because the saturated air will be less diluted. Generally, a wind from the right will increase the exposure found to the left. The higher exposure for open field in fig. 8 is probably caused by a wind turbulence which visually occurred in the 3'rd replicate this day. Changing in wind conditions may occur more frequently in an open area. Both diagrams show that the mass flux is mostly concentrated near the ground at the beginning and needs time and distance to move upwards, thus resulting in higher exposure at lower positions.

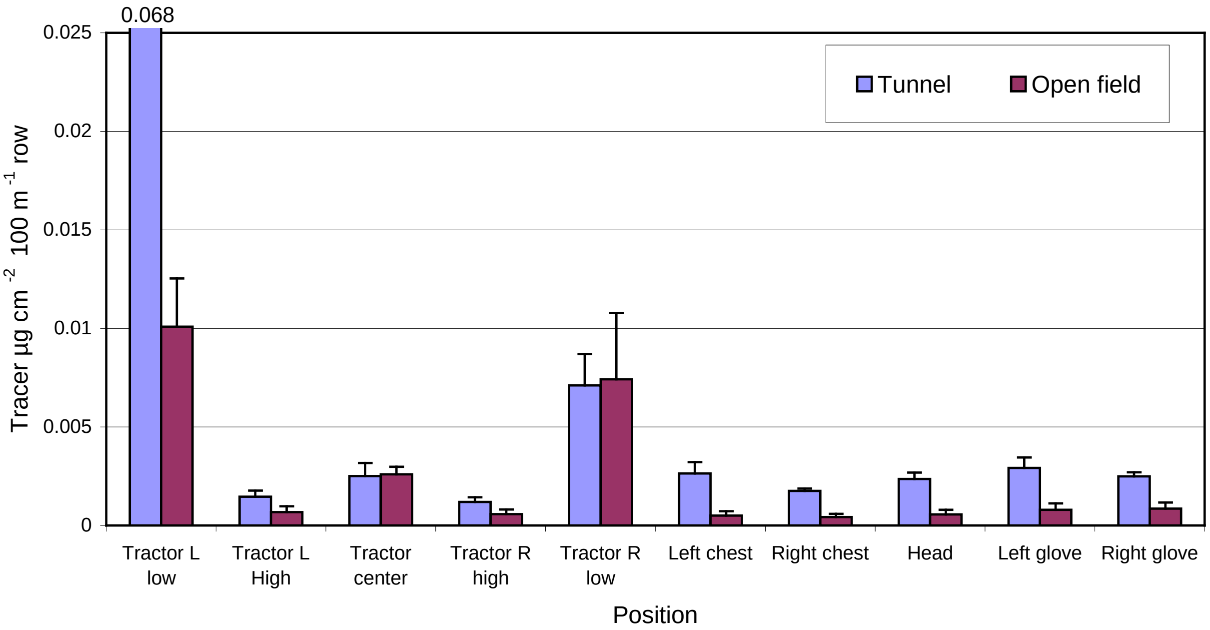

Figure 9. Exposure measurements in **strawberry**, tracer in µg/cm^{2}100^{-1}m. 3 run. LTI boom. Position tractor L (left), low and open field has an exposure of 0.068 (drift).

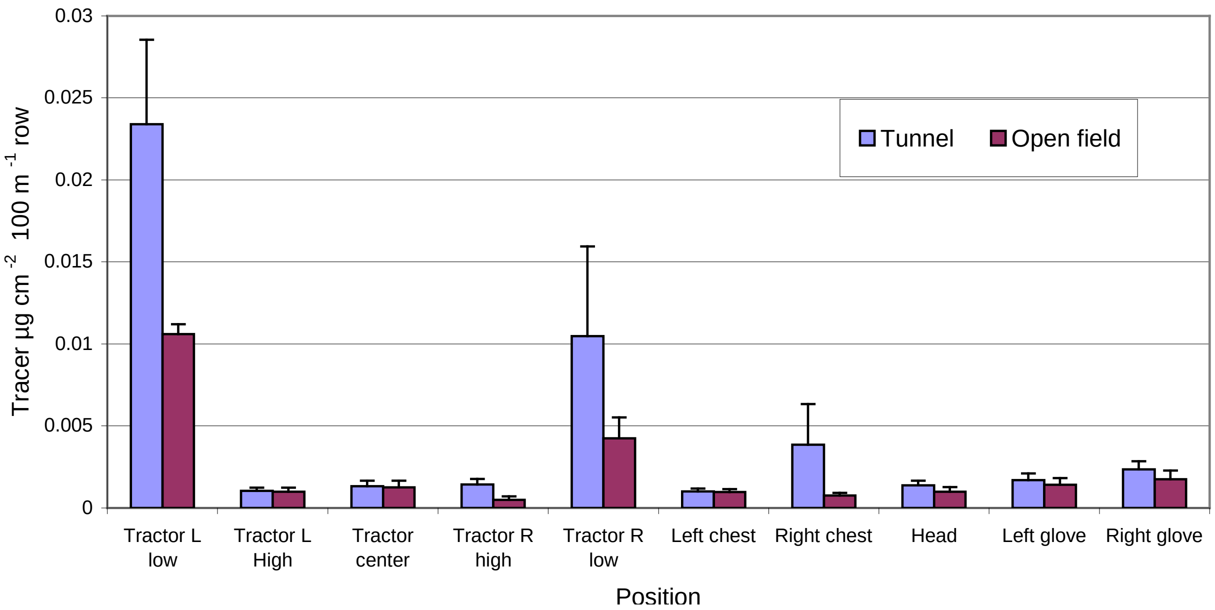

Figure 10. Exposure measurements in **strawberry**, tracer in µg/cm^{2}100^{-1}m. 4 run. LTI boom Wind: Open field; from right /front 0.2 - 1.7 m/s. Tunnel; front 0.1 - 0.6 m/s.

The wind in the tunnel mainly goes parallel along the tunnel walls and is weaker than in the open field. The wind component in the open field from the right may push a part of the saturated air away from the operator and samplers. Thus the potential exposure of the operator at these conditions is lower in the open field than in the tunnel.

Because the samplers positioned around the operator got significant exposure values, only these results were analysed in the statistical tests in order to avoid random failures. The results of some range tests are presented in table 4 and 5.

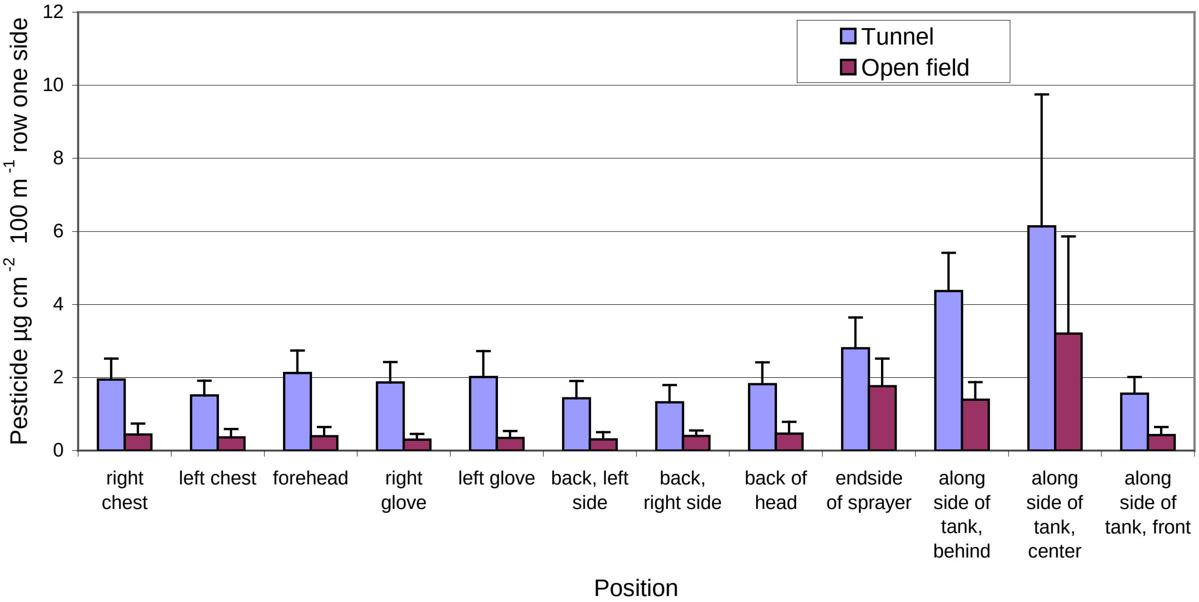

Figure 11. Exposure measurements in **raspberry** expressed as pesticide in µg/cm^{2}100^{-1}m Vertical boom trailer sprayer to one side pulled by an ATV. 1 run. Wind: East perpendicular to rows. Open field; 0.1-2.4m/s. Tunnel; 0.1-0.8 m/s.

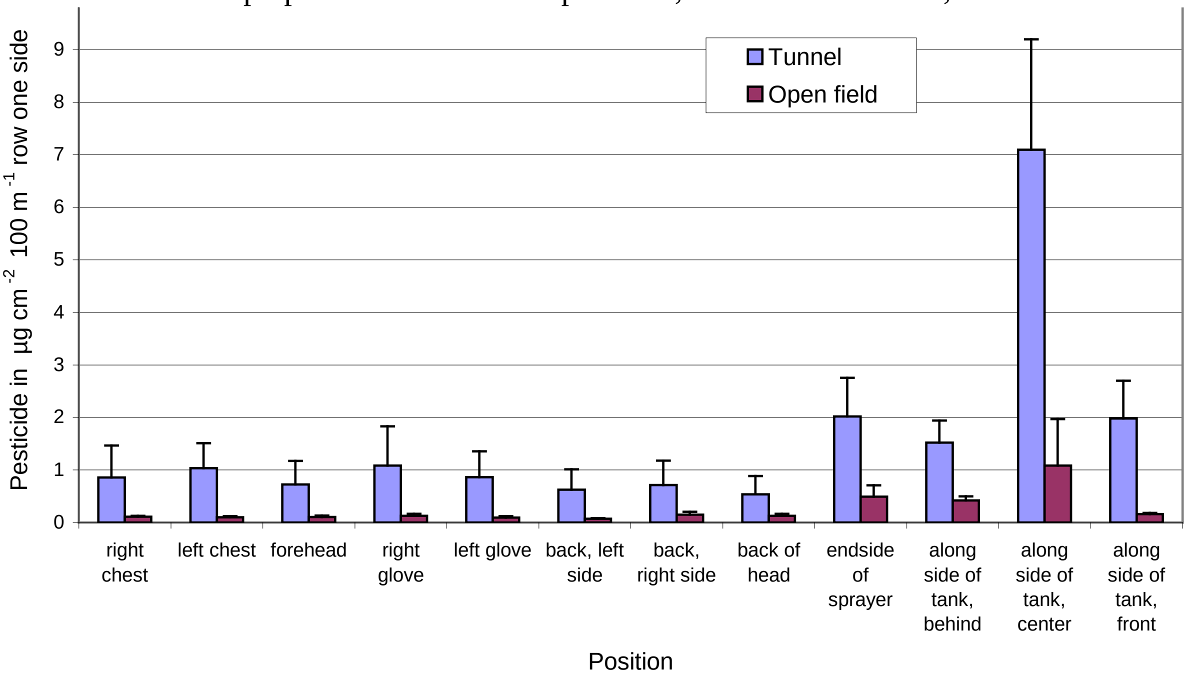

Figure 12. Exposure measurements in **raspberry** as pesticide in µg/cm^{2}100^{-1}m. Vertical boom trailer sprayer to one side pulled by an ATV. 2 run. Wind: North East. Open field; 1.0-1.5 m/s. Tunnel; 0.1-0.8 m/s.

When spraying with the trailer and the ATV only the outer row in the tunnel was sprayed to one side. The distance from the operator to the nozzles is longer than for the rear mounted Hardi Variant later presented. The samplers positioned on the tank side closely to the vertical boom got the highest values as expected. Because of the fluctuation and high values found on the tank, these samplers were not included in the statistical range test. The higher amount found in the tunnel is probably caused by the reduced air dilution effect of the mass flux in the tunnels.

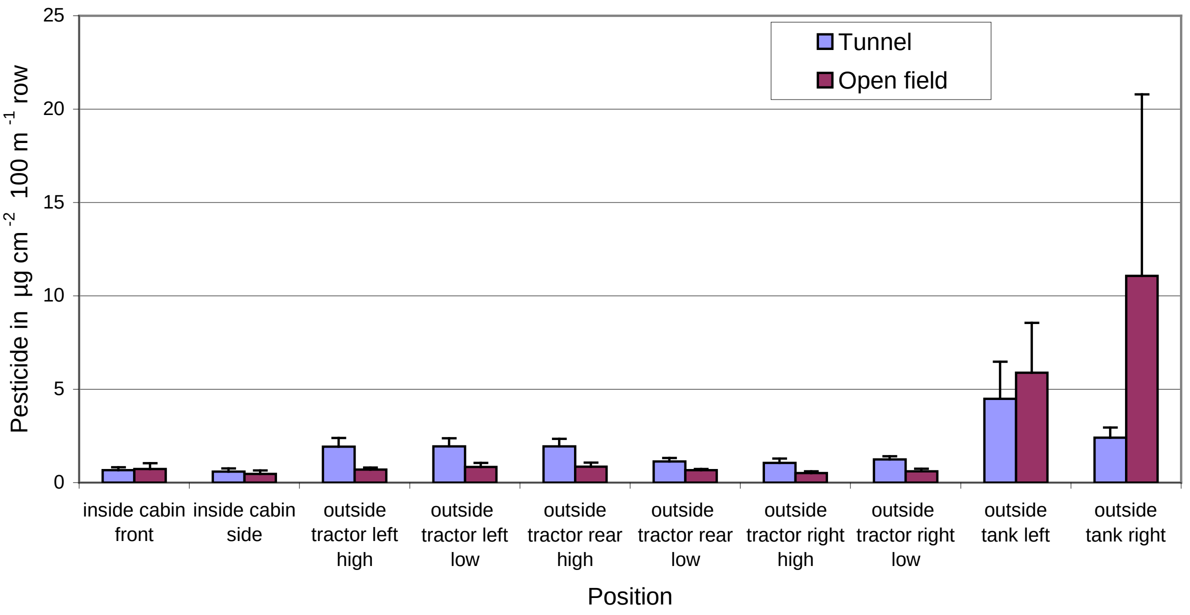

Figure 13. Exposure measurements in **raspberry** expressed as pesticide in µg/cm^{2}100^{-1}m.
Mist blower direct mounted on a tractor. 1 run.
Wind: South East. Open field; 0.7-1.8 m/s. Tunnel; 0.2-1.0 m/s.

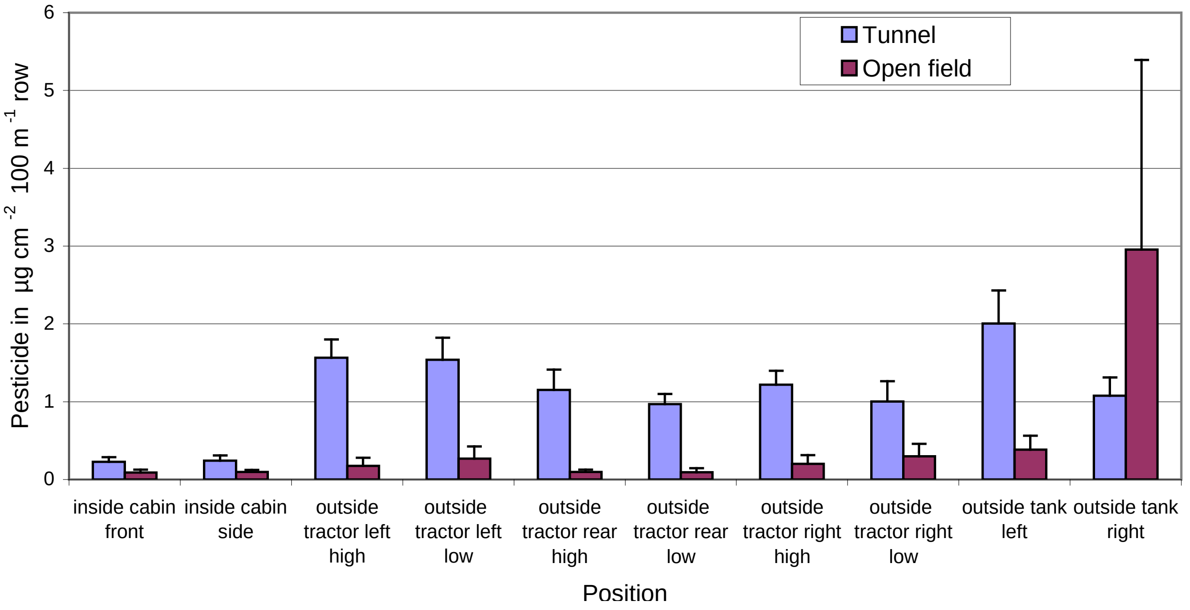

Figure 14. Exposure measurements in **raspberry** expressed as pesticide in µg/cm^{2}100^{-1}m.
Mist blower direct mounted on a tractor. 2 run.
Wind: South East. Open field; 0.5-1.2 m/s. Tunnel; 0.4-1.0 m/s.

When spraying with a Hardi Mini Variant sprayer directly mounted on the tractor, all samplers were included in the statistical analysis. In figure 13, spraying in the open field had a tendency to get higher values than the exposure from the tunnel. Probably more turbulent wind in the open field caused the higher exposure on the spray tank. If the samplers on the operator and tractor only were included, the tunnel exposure would have been highest also in this case.

Table 4. Range test of potential operator exposure for tunnel (trial 1) and open field (trial 2) when spraying in **strawberry**. In right column average exposure only for samplers fixed around the operator are expressed as tracer in µg cm $^{-2}$ 100 m $^{-1}$ row (p<0.05)

Crop and equipment	Rang test for tunnel (trial 1) and open field (trial 2)
	Trial
Strawberry 1 Run LTI-boom	1 4.71E-03 A (tunnel significantly higher)
	2 1.10E-03 B
	Trial
Strawberry 2 Run *) LTI-boom	2 3.04E-03 A (open field significantly higher)
	1 1.89E-03 B
	Trial
Strawberry 3 Run LTI-boom	1 2.44E-03 A (tunnel significantly higher)
	2 6.31E-04 B
	Trial
Strawberry 4 Run **) LTI-boom	1 2.06E-03 A (no significance)
	2 1.18E-03 A

*) not significantly if all samplers (also the samplers outside the tractor) are included
**) tunnel system significantly higher if all samplers were included.

Table 5. Range test of potential operator exposure for tunnel (trial 1) and open field (trial 2) when spraying in **raspberry**. Average exposures for samplers fixed around the operator are expressed as tracer in µg cm $^{-2}$ cm $^{-2}$ 100 m $^{-1}$ row in the right column. Samplers from 1 to 8 were used for the ATV experiments. When using the Mini Variant all the samplers were used because the samplers were fixed further away from the nozzles. (p<0.05)

Crop and equipment	Rang test for tunnel (trial 1) and open field (trial 2)
	Trial
Raspberry 1 Run ATV	1 2.63E-03 A (tunnel significantly higher)
	2 8.93E-04 B
	Trial
Raspberry 2 Run ATV	1 5.74E-03 A (tunnel significantly higher)
	2 1.64E-04 B
	Trial
Raspberry 1 Run Mini Variant	2 1.51E-03 A (open field tendency to be higher)
	1 1.17E-03 A
	Trial
Raspberry 2 Run Mini Variant	1 7.66E-04 A (tunnel significantly higher)
	2 3.24E-04 B

When spraying in strawberry, a tunnel system caused a significant higher operator exposure level in two experiments and a tendency of a higher exposure in one experiment. In one case the open field exposure was significantly higher than in the open field. This may be due to a higher influence of turbulence in the open field, visually observed in one replicate.

When spraying in raspberry, a tunnel system caused a significantly higher operator exposure level in three out of four experiments. One experiment showed a tendency of a higher exposure for the open field system caused by a higher exposure on the tank of the sprayer. This is due to the extra high exposure on the sampler closest to the nozzles illustrating the higher drift potential in the open field. Most of these drops are so large that they are going to sediment on the ground and not reach the operator. Thus, if this sampler had not been included in the test, then the tunnel exposure would be significantly higher also in this case.

A probably reason of increased risk of exposure when spraying in a tunnel compared with spraying in an open field may be that the air saturated with small droplets from the nozzles in tunnels will be more slowly diluted with dry and clean air because of the slower wind velocity caused by the tunnel cover. This is stated in figure 15, and shown theoretically in figure 16.

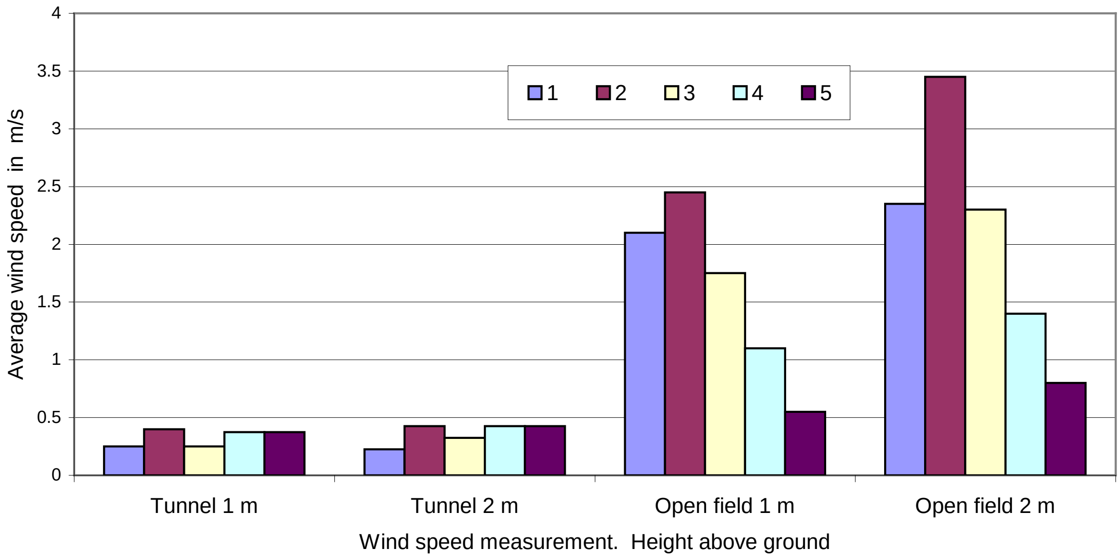

Figure 15. Average wind speed in the tunnel and the open field measured simultaneously 1 and 2 m above ground for five replicates. Spraying in strawberry. 1 run.

Another factor, in particular for the tunnels where the side walls are closed, is that the tunnel itself could act like an equalizer by decomposing non-parallel wind vectors into smaller vector components running inside and parallel to the tunnel direction. Depending on the driving direction and position of equipment, this may cause the saturated air to remain for a longer time around the spraying equipment and the operator. The wind along the inside tunnel wall furthest away from the outside incoming wind direction will also be larger than along the opposite wall. This may be the reason why the exposure is higher on the left side also in the tunnel for strawberry. When spraying in raspberry the internal walls are open along the ground, which will reduce this effect. However, such a house of block tunnels will also decrease the wind speed compared with an open field system. When spraying in the open field it is recommended to spray perpendicular to the wind direction and at a low wind speed. In this case the drifting droplets may pass the rows before the operator reaches the sprayed area. However, if the wind is directed perpendicular to the outer tunnel wall, only a minor component may be transformed as a vector running inside parallel to the tunnel as described in figure 16. If the internal walls in the strawberry tunnel are open as for raspberry, the rows inside the wall may be more exposed from the incoming wind. This influence may be decreased by planting trees or using an artificial shield outside (Richardson et al, 2004). Normally, the use of such a block tunnel also is common for strawberry tunnel systems.

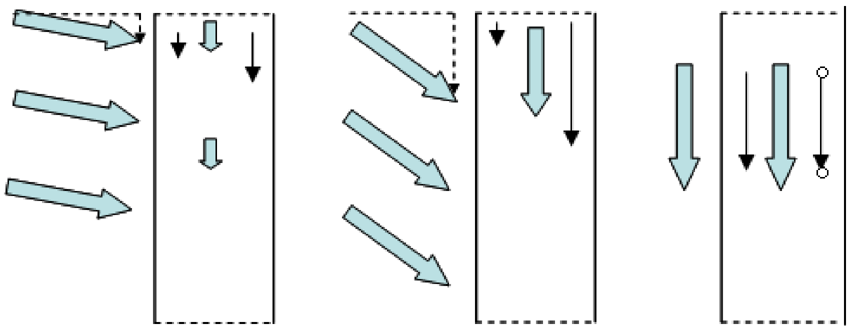

Figure 16. Visually demonstration of changing wind vectors inside a tunnel in the length direction as a function of incoming wind from the open field.

However, the drift of pesticide to the environment is expected to be higher when spraying in an open field system compared with tunnels, which also could be visually seen for the strawberry as well as for raspberry application. An example of this situation is shown in figure 17. In the open field the impact of droplets on the tank samplers could change very quickly because of the changing wind turbulence. Thus, the samplers positioned on the tank for this type of equipment were not included in the statistical model. However, the values are presented in the graphs.

Figur 17. Spraying with ATV and trailed sprayer to the left side only. In the tunnel (left) and in the open field (right). Drift of droplets can be visually seen in the open field situation (wind direction from the left side).

If extremely high temperature should occur in the tunnel compared with the air outside, there may be a risk of enabling convective air streams or ventilating effects which may cause a convective drift. However, the tunnels in Norway are normally well ventilated also in the summer time and therefore this will only be a minor problem.

These experiments are carried out at certain conditions and for limited use of spraying equipment. The potential exposure may differ when using other equipment and other tunnel systems. More experiments are needed to determine the potential exposure for other application conditions.

4. CONCLUSIONS

In order to be able to measure the small differences in exposure caused by the tunnel versus the open field cultivating systems, samplers had to be positioned closer to the nozzles and outside the cabin and/ or in an open area towards the nozzles. This examined exposure is called the drift potential, i.e. amount of droplet approaching the operator area. The potential operator exposure in strawberry and raspberry in these experiments was significantly higher in most of the applications when spraying in a tunnel system compared with an open field system

However, the real exposure will be on a much lower level than the potential exposure because of a longer distance to the operator and the protective cabin.

The total exposure may be higher when spraying in an open field, depending on the wind vector, especially because of a higher risk of wind turbulence and drift of droplets. This could be visually observed during the experiments.

Other parameters not measured in these experiments will also influence the total exposure. Factors like length of rows, topography and number of turnings will influence the exposure, i.e. turning against the wind direction when using rear mounted equipment and in the wind direction when using front mounted equipment will decrease the operator exposure as well as starting the application as far away from the wind as possible and moving row-wise against the wind.

Inside contamination of the tunnel walls may also cause an environmental problem.

5. ACKNOWLEDGEMENTS

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7. REFERENCES

Bjugstad, N., Torgrimsen, T. 1994: Exposure of operators to pesticides during spray application. XII Joint Int. Symp. Kiev 1993; Health, Safety and Ergonomic Aspects in Use of Chemicals in Agriculture and Forestry, Institute of Occ. Health, Kiev, printed by the *World Health Organisation*, Geneve, ISBN 951-802-062-0: 110-117 pp.

Bjugstad N., Torgrimsen T. 1996: Operator safety and plant deposits when using pesticides in greenhouses, *J.agric, Engng* Res, 65: 205-212.

Bjugstad N., Sønsteby A. 2004: Improved spraying equipment for strawberries; International Advances in Pesticide Application, *Aspects of Applied Biologist*, No. 71: 335-342

Bjugstad, N., Hermansen, P. 2008: Field measurements of spray drift in strawberry, *Agricultural Engineering International: the CIGR Ejournal*. Manuscript PM 1048. Vol. XI. August, 2009.

Chester G. 1993: Operator Exposure of Pesticides, Application Technology for Crop Protection, *CAB International*, ISBN 0 85198 834 2: 123-144.

Herbst A., Ganzelmeier H. 2002. Classfication of sprayers according to drift risk- a German approach. *Aspects of Applied Biology* 57, ISSN 0265-1491: 35-40.

Jensen, P. K., Spliid, N. H. 2005. Comparison of drift from spray equipment used for control of diseases in strawberry. Book of Abstracts, *8'th Workshop on Spray application techniques in fruit growing*, June, 2005, Barcelona: 131-133.

Kramer H., Kleisinger S., Czaczyk Z. 2002: Emission of fluorescent dyes, - influence of time, exposure and collector materials; International Advances in Pesticide Application, *Aspects of Applied Biologist*, No. 66: 421-426.

Miller P. C. H. 1993. Spray drift and its measurement. Application technology for crop protection, *CAB International*, ISBN 0 85198 834 2: 101-122.

Nuyttens A., Windey S., Braekman P., De Moor A., Sonck B. 2004: Comparison of operator exposure for five different greenhouse spraying applications; International Advances in Pesticide Application, *Aspects of Applied Biologist*, No. 71, vol II: 349-356

Richardson G. M., Walklate, P. J., Baker, D. E. 2004. Spray drift from apple orchards with deciduous windbreaks; International Advances in Pesticide Application, *Aspects of Applied Biologist*, No. 71, Vol I: 149- 156.

WHO Standard *Protocol. 1982.* Field surveys of exposure to pesticide**s**. Ref. VBC/82. Geneva: WHO.