When Efficiency Matters…
Can organic fruit production benefit from "Low Loss Crop Protection"?

P. Triloff[1]

Abstract

Official drift reduction with air induction nozzles is not an option for most of the professional fruit growers since large droplets and high water volumes prevent the utilization of modern, highly efficient spray application methods with all their advantages.

Low Loss Crop Protection as a solution combining all the advantages from small droplets and low water volumes with a drift reduction in the range of air induction nozzles comes as a package of

a) *orchard sprayers with optimized air distribution, providing uniform horizontal reach and adjusted to farm specific tree height. The adjustment of a rectangular air distribution at a test bench and its adaptation to canopy width during spraying is the key for making use of essential advantages from small droplets and low volumes of which especially an increased efficiency of spray cover formation, a reduced risk for phytotox and minimized fuel consumption can be most interesting for organic production.*
b) *an electronic field book calculating all parameters required for dosing and application of the selected pesticides in the desired orchard blocks, runs a pre spray check of any electronically surveillable statutory requirement from registration for any product in any orchard block and after the treatment documents the spray complying with all current quality assurance systems,*
c) *training for all participants of "Low Loss Crop Protection" as for*
   i. *the staff doing the air distribution measurements with the test bench*
   ii. *the manufacturers through a close cooperation and an annual workshop where new developments are discussed and decided upon mandatory implementation*
   iii. *the grower who is trained continuously at any occasion as meetings, workshops, seminars, before purchasing a new sprayer, during the air adjustments, farm visits, etc..*

Since for organic fruit production all the advantages of "Low Loss Crop Protection" are even more important - especially fuel consumption and phytotoxicity - than for conventional production it is assumed that organic fruit production can substantially benefit from this technique.

Keywords: top fruit, spray application, air distribution, low loss spray application, low volume

Introduction

In the early 1990ies low volume spray application with less than 250 l/ha and small droplet nozzles has become standard in some large fruit growing areas in Europe (Austria, The Netherlands, United Kingdom, Germany). The reasons for a rapid spread of this technique amongst professional fruit growers have been the high work rate, which allows utilizing limited time windows with suitable climatic conditions for spray application on a large acreage, a good coverage with no visible deposits, low risk for phytotoxicity and the potential for reducing dose rates. This technique has increasingly been threatened as

[1] Marktgemeinschaft Bodenseeobst eG, Friedrichshafen, Germany

spray drift became an issue during the 1990ies and high volume spray application with large droplets from air induction nozzles has officially been introduced as the exclusive way to reduce spray drift. Today spray application technique in top fruit is narrowed down to only drift reduction with the exclusive use of large droplets from air induction nozzles ignoring any new developments in application techniques and drift reduction.

Based on the spray drift reduction obtained by air induction nozzles and deflector plates to shut off or redirect the air stream on the down wind facing fan side, buffer zones to water courses can officially be reduced by the operator according to registration. This technique, resulting in water volumes of approximately 500 - 600 l ha^{-1} may create advantages for growers using higher water volumes before but cause severe problems for growers using low volume spraying techniques of less than approximately 250 l ha^{-1} since many years. The paper describes the components of a method combining the advantages of small droplets for spray application with the demands of autorities and the society to reduce pesticide consumption and the side effects odf their use.

Results

a) Effects of an optimized air support system

Spray drift: To maintain this highly efficient spray application technique for tree fruit growers, an alternative method of spray drift reduction has been developed which allows a classification at least in the 75 % drift reduction class according the German drift reduction classes. It combines fans with cross flow characteristics, a mixed set of nozzles with four low flow rate air induction nozzles (Albuz AVI 8001 or Lechler AVI 9001) at the two top most nozzle positions of the fan and hollow cone nozzles (Albuz ATR purple) at any other positions. For spray application the fan speed has to be adjusted at any forward speed in any orchard block to a value where the spray mist just slightly leaves the canopy at its broadest position into the next alley way. From drift trials with these settings an average spray drift reduction of approx. 83 % was obtained in a range of forward speed from 6 to 12 km h^{-1}, allowing a classification in the German 75 % drift reduction class (figure 1).

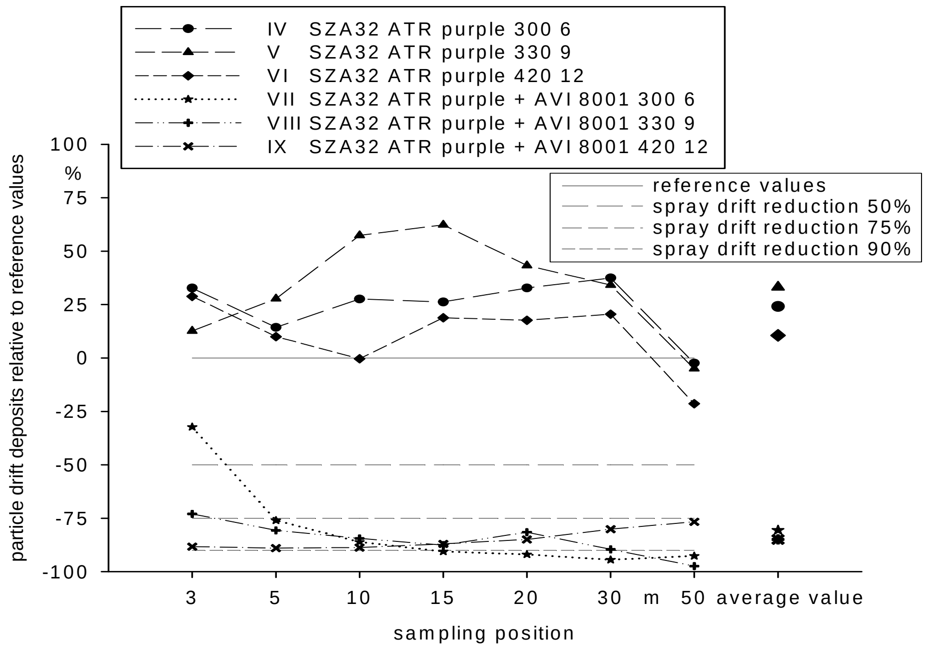

Figure 1: Relative changes of spray drift of an axial fan with cross flow characteristics at various forward speeds and canopy adapted fan speed with a full set of 16 hollow cone nozzles (full lines) and a mixed set off 4 air induction nozzles and 10 hollow cone nozzles (dotted lines) (Triloff, 2011).

Repeating the trials with the same settings under hail netting increased the spray drift reduction by approximately 10 %, leading to an average reduction of about 94 %. The results clearly proved that an almost horizontal air stream adapted to canopy width at any forward speed, in combination with a mixed set of hollow cone / air induction nozzles leads to a spray drift reduction equivalent to orchard sprayers equipped with a full set of air induction nozzles. The method developed is a chance to combine the enormous advantages of small droplets and low water volumes for the growers with the demands of the authorities for the reduction of spray drift. It is an answer to growers needs since for many growers relying on low water volumes it prevents the serious problems arising from a change towards classical spray drift reduction with a full set of air induction nozzles and high water volumes. Therefore this officially registered method has to be considered in future regulations concerning spray drift reduction in tree crops.

Spray application efficiency: Cross flow characteristics and canopy adpated air support at any forward speed are not only the keys to reduce spray drift of small droplets but also increases spray deposition on the target. Since mall droplets follow air streams because of their low weight and even deposit at the rear side of leaves, twigs and fruits, a reduction of the horizontal reach of the air stream through increased forward speed and/or reduced fan speed penetrating the canopy but not extiting it into the opposite row, keeps much more droplets within a disintegrating, turbulent air stream inside the canopy, increasing the number of droplets depositing at the target area. Depending on the canopy width, spray deposit may increase up to 35 %, relative coverage and droplet deposit density on the upper leaf surface up to 67 % and 55 % respectively per litre of spray liquid applied, compared to a classical application with full fan speed and relatively low forward speeds (Triloff, 2012).

Fuel consumption and noise emission: For assessing the energy consumption and noise emissions of fans from orchard sprayers, standardized measurements have been carried out at various fan speeds. Four axial fans with cross flow characteristics at 540 PTO and high fan gear yielded fuel consumptions from 7,7 to 13 l h^{-1} while at 300 PTO and low fan gear consumption decreased to approximately 2 l h^{-1} (Lind K., pers. comm. 2013), a reduction of 74 – 85 %.

However the energy efficiency of a fan is not only depending on the fan speed with its non-linear relationship, but also on the fan type and the usable air volume – the fraction of the total air volume produced by a fan reaching the target during spray application. This ratio varies from below 50 % to approximately 90 %. When calculating the specific energy consumption per m^3 usable air volume per hour, various fans vary by a factor of more than five, meaning that in the worst case a fan consumes five times more energy per m^3 usable air volume per hour than in the best case (figure 2).

Standardized measurements of noise emissions on a 36” axial fan with cross flow characteristics showed a decrease of noise emissions from 95 to 85 dB A, meaning a reduction of 50 % in terms of loudness, respectively 87.5 % in terms of acoustic pressure.

Vertical air distribution: An adapation of the fan speed to the canopy width requires a reasonably even horizontal reach of the air stream over working height to guarantee a uniform penetration of the spray mist into the canopy system. Unfortunately the vast majority of fan types with cross flow characteristics showed a very uneven vertical air distribution unsuitable for adapting fan speed to canopy width.

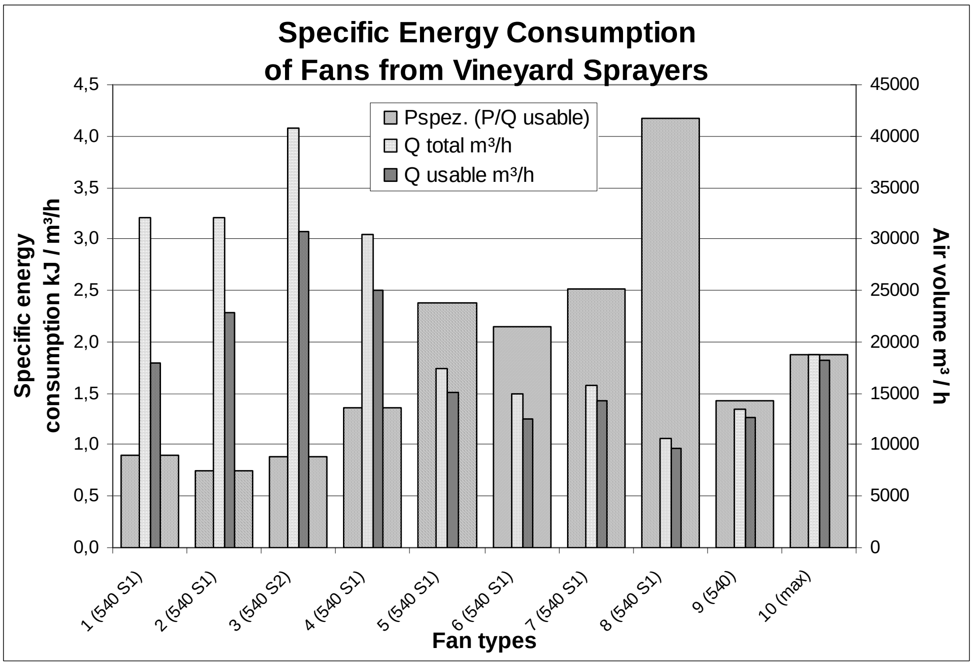

Figure 2: Parameters of fans for vineyard sprayers for total and usable air volume and specific energy consumption per cubic metre of usable air volume per hour (from Bäcker & Koch, 2009; modified)

As this appeared to be a wide spread and severe problem preventing the introduction of “Low Loss Spray Application”, a joint venture of advisory services in Austria (Verband der steirischen Erwerbsobstbauern), Italy (Südtiroler Beratungsring für Obst- und Weinbau) and Germany (Marktgemeinschaft Bodenseeobst eG) for testing, adjusting and improving the air distribution of orchard sprayers with an air distribution test stand has been founded. The equipment used is based on ultrasonic sensors measuring air speed and direction from which any other data are calculated as there are the usable air volume (minimum volume and speed and direction to penetrate the canopy sufficiently) and creates a two page protocol.

On page two the air distribution is shown graphically as vertical and cross distribution with total and the usable air volume with its target corridor, air stream directions and maximum working height (figure 3). Page one contains general data about the sprayer, environmental data like fan-type related specific energy consumption and CO_2-emissions as well as noise emissions at various PTO speeds. This page is completed by an automated assessment of the air distribution according to predefined parameters (figure 4) from guidelines developed by the cooperation. These guidelines define the requirements for a vertical air distribution suitable for canopy adapted spray application as the basis of “Low Loss Spray Application”. As a result after two years of measurements may be concluded that a uniform vertical air distribution is severely impaired by smallest obstacles (in the range of millimeters) in the air support system of a fan like reduced pipe diameters from a too small bending radius, rough surfaces of air ducts, defectively adjusted deflection plates, uneven cross sections of deflection systems and air ducts and others and may not at all be adjusted without a test bench! The system of “Low Loss Spray Application” is completed by a semi public positive list with the fan types suitable for this technique where growers may preselect fan types which potentially meet their requirements as working height and others. The cooperation also recommends to add a supplement to the contract of purchase that it will be void, if the sprayer did not pass the air distribution test with the working height being adjusted to the buyers needs.

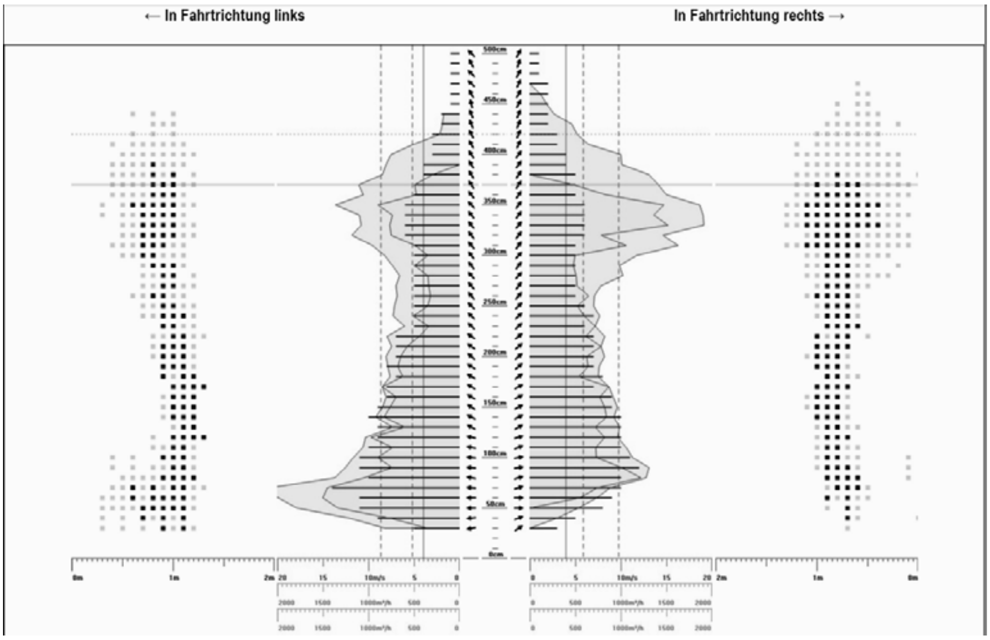

Figure 3: Detail of page two of the air distribution protocol graphically displaying measured parameters of the air distribution.

Ergebnisse Gebläseprüfung

vor durchgeführten Änderungen

Flügeldrehzahl (Prüfdrehzahl):	1650 U/min	
Maximal behandelbare Baumhöhe (=Arbeitshöhe):	3.7 m	Kat. I: ≤3m; Kat. II: 3-3,5m; Kat. III: 3,5-4m
Strömungsrichtung auf Arbeitshöhe:	l: 58° r: 60°	Höchster Wert: < 40° = Querstrom; 40° - 65° = Schrägstrom: > 65° = Axial

Teilbreite (in Fahrtrichtung)	links	rechts	Grenzwerte (eingehalten / nicht eingehalten)
Luftvolumen insgesamt:	38983 m³/h	41095 m³/h	
Nutzbares Luftvolumen bis zur Arbeitshöhe:	24287 m³/h 62.3%	25088 m³/h 61.1%	≥ 2 Messpositionen/Messhöhe bei ≥ 4.0 m/s Luftgeschwindigkeit = Mindest-Luftvolumen
Schwankungen des nutzbaren Luftvolumens	43.3 %VK	35.1 %VK	Höchstwert Schwankung: 25 % VK (VK= Variationskoeffizient)
Ausreißer bei der mittleren nutzbaren Luftmenge	51.4 %	45.7 %	Max. 15 % pro Teilbreite außerhalb des Toleranzbereiches von ± 25 %
Nicht-nutzbares Luftvolumen bis zur Arbeitshöhe	11174 m³/h 28.7%	10419 m³/h 25.4%	Aufgrund zu niedriger Luftgeschwindigkeit (< 4.0 m/s). Höchstwert: 15 %
Nicht-nutzbares Luftvolumen von 3.7 m - 4.2 m Höhe	3151 m³/h 8.1%	4492 m³/h 10.9%	Höchstwert: 12.5 % — Beide Werte bestimmen im Wesentlichen das Abdriftrisiko!
Nicht-nutzbares Luftvolumen über 4.2 m Höhe	372 m³/h 1%	1095 m³/h 2.7%	Höchstwert: 2.5 %
Luftgeschwindigkeiten bis zur Arbeitshöhe	7.4 / 13.8 m/s	7.4 / 11.8 m/s	Durchschnitt und Maximum
Schwankungen Luftgeschwindigkeit bis zur Arbeitshöhe	32.9 % VK	28.3 % VK	Höchstwert Schwankung: 30 % VK

	gesamt	gesamt nicht nutzbar	gesamt nutzbar	Differenz links/rechts nutzbares Luftvolumen
Luftvolumen	80078 m³/h	30702 m³/h 38.3%	49376 m³/h 61.7%	3.2%
		Grenzwert: 25 %		Grenzwert: 15 %

Figure 4: Detail of page one of the protocol on air distribution with the results of the automated assessment of the measured air distribution according the guidelines of the “Cooperation of the Regions” for “Low Loss Spray Application”

b) Electronic field book

Canopy adapted dosing and spray application according the MABO-dosing model requires the calculation of forward speed, water volume and pesticide dose rates according to canopy and orchard block parameters for any orchard block of a farm. Since the model is more complex than others, a fast and secure electronic system is necessary to proivide the grower faultlessly with the required data. Therefore originally an internet spray program was developed by Marktgemeinschaft Bodenseeobst eG (MABO) guiding the user through a spray round by planning it with a recipe of selected orchards and pesticides, carrying it out according the MABO-dosing model and finally documenting it in compliance with all current quality assurance systems. Because of a strong demand of safety in crop protection it has been extended it to an electronic field book (“XComply”), providing all services for actual documentation requirements in fruit growing (Matzer & Lind, 2013). A special feature is the safeguarding of the application of pesticides by potentially monitoring any electronically surveillable statutory requirement from registration for any product in any orchard block individually before a spray is put on, preventing the misuse of pesticides at a level never achieved before. Documentation finally fulfills all requirements of any actual quality assurance system.

c) Training

“Low Loss Spray Application” differs significantly from any other dosing and application system and historic assumptions requiring good knowledge about its principles. Therefore training is necessary for all its participants as for

i) the staff doing the air distribution measurements at the test bench which are trained on demand, e.g. when a new versions of the test software is to be released.

ii) the manufacturers who are already optimizing and developing their fan types from experiences made in the past years. Therefore the “cooperation of the regions” keeps close contact with the manufacturers through the regular testing and organizes an annual workshop where new developments are discussed and mandatory changes as e.g. securing deflector plates from changes after the adjustment on the test stand are decided upon.

iii) the grower who is trained continuously at any occasion as newsletters, meetings, workshops, seminars, before purchasing a new sprayer, during the air distribution adjustments, farm visits, etc..

Discussion

With „Low Loss Crop Protection“ a technical package for the application of pesticides in top fruit growing is available, the very first time juggling the demands of fruit growers like time, energy and fuel efficiency, optimal spray cover, reduced pesticide consumption, low risk for phytotox and visible deposits with the demands of authorities and the society for a reduction of negative side effects of pesticide usage as spray drift and residues as well as a general reduction of pesticide consumption.

This is achieved by a package of technical solutions beginning with the optimization of the air support system of the sprayers as the key to a range of benefits from canopy adapted dosing and spray application, incorporating drift reduction and the use of small droplets with low water volumes. An aerodynamically improved fan and the canopy adpated spray application result in an enormous reduction of fuel consumption of up to approx 50 % on a farm scale and noise emissions which is of greatest importance for organic production to improve energy and CO_2 balances. An optimized air distribution with an almost horizontal direction of the air flow and its adaptation to canopy width is the key to increase forward speed in slim orchard systems to up to 12 km h^{-1}, reducing time consumption, thus allowing a better use of limited time windows with suitable climatic conditions for spray application.

Small droplets have many advantages over large ones as more uniform spray cover, better rear side deposition, suitablity for electrostatic charging, easy controllability through a rectangular air distribution produced by a sprayer and its horizontal reach adjusted by the grower during spray application. In conjunction with a canopy adapted air stream the efficiency of the spray deposition is increased remarkably, allowing the reduction of pesticide dose rates without reducing biological efficacy through canopy related dosing or use the effect to raise biological efficacy without increasing dose rates of certain pesticides showing non satisfying efficacy with traditional spray application. For organic production the use of this effect of canopy adapted fan speed in conjunction with small droplets might allow a stronger variation of dose rates of e.g. sulfur as is already done with copper.

Small droplets provide even more positive effects of great importance for organic fruit production. They drastically reduce the risk for phytotxicity because it needs spray cover staying wet for a longer time, allowing penetration of substances into the fruit skin that should not get there. This effect is very much reduced by small droplets that dry off within only a few minutes.

As visible deposits appear as an effect of large, coalescing droplets, the small droplets of hollow cone nozzles prevent visible deposits effectively and thus provide another excellent means for improving crop protection. Both these very positive effects of small droplets may just by nozzle selection minimize two frequently appearing problems from the use of critical products like copper and bicarbonate in organic fruit production.

The low water volumes arising from small droplets are a basic key for the reduction of time consumption since they maximise the number of hectares per vat to be treated, reducing travelling on public roads and the chances for contamination of the operater when preparing the spray liquid by less fillings per spray round.

The electronic field book “XComply” is necessary for the correct usage of the canopy related dosing and application according the MABO-dosing model and mandatory to officially make use of reduced buffer zones to water coarses when using low volumes and small droplet nozzles with the sprayers registered for this method in the JKI list of drift reducing devices. It is finally a very usefull tool for the correct use of pesticides in fruit growing because it monitores any electronically surveillable statutory requirements for the use of individual pesticides, preventing their misuse effectively before the spray is done.

As final component of “Low Loss Crop Protection” training of all participants of the system is an important tool too since the close contact of the testing centres of the “Cooperation of the regions” for air distribution with the manufacturers supports them in developing and optimizing their sprayers according the demands of fruitgrowers and the associated advisory boards and has already led to significant improvements on currently available sprayers.

Since “Low Loss Spray Application” in many aspects does not support traditional opinions of dosing and spray application, training of growers is an important part of the package and is implemented through all kinds of tools enabling the growers to get familiar with “Low Loss Crop Protection”, making this technique an interesting tool with some important benefits especially for organic fruit production.

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