Adjusting and Straightening the Air Distribution of Sprayers for Three Dimensional Crops: The State of the Art

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Professional growers of both organic and integrated fruit and grapevine growing demand for a highly efficient spray application that allows the treatment of an area as large as possible per vat filling. This is the crucial key parameter to utilize limited time windows with climatical conditions, as e.g. low natural wind, suitable for the application of pesticides. Another key for modern fruit farms is the minimization of total time consumption for spray application, because they increase in size but only a few are big enough to employ staff apart from the family members, creating a strong pressure to save time for spray application in general. The time consumption for spray application is split up into

a) the time required for the preparation of the spray liquid and cleaning sprayers,

b) the time for driving to and from an orchard resp. vineyard and

c) the time for the application itself.

To meet both demands, a minimization of the water volume per hectare and the maximization of forward speed during spray application are the points of interest. This aim basically can only be achieved by small droplet nozzles combined with an adaptation of water volume to canopy characteristics and a canopy adapted forward speed, increasing as canopy width decreases. Small droplets offer a range of other important benefits to the grower as there is the low risk for phytotxicity of pesticides and leaf fertilizers, the low risk for visual deposits on the target and the controllability of their behaviour by an air stream. Since small droplets contain a high risk for drift, means that successfully reduce spray drift of small droplet nozzles have been developed in recent years and have been officially registered by German and Austrian authorities. These means are a combination of

a) fans with cross flow characteristics to minimize vertical spray drift above the canopies into the atmosphere,

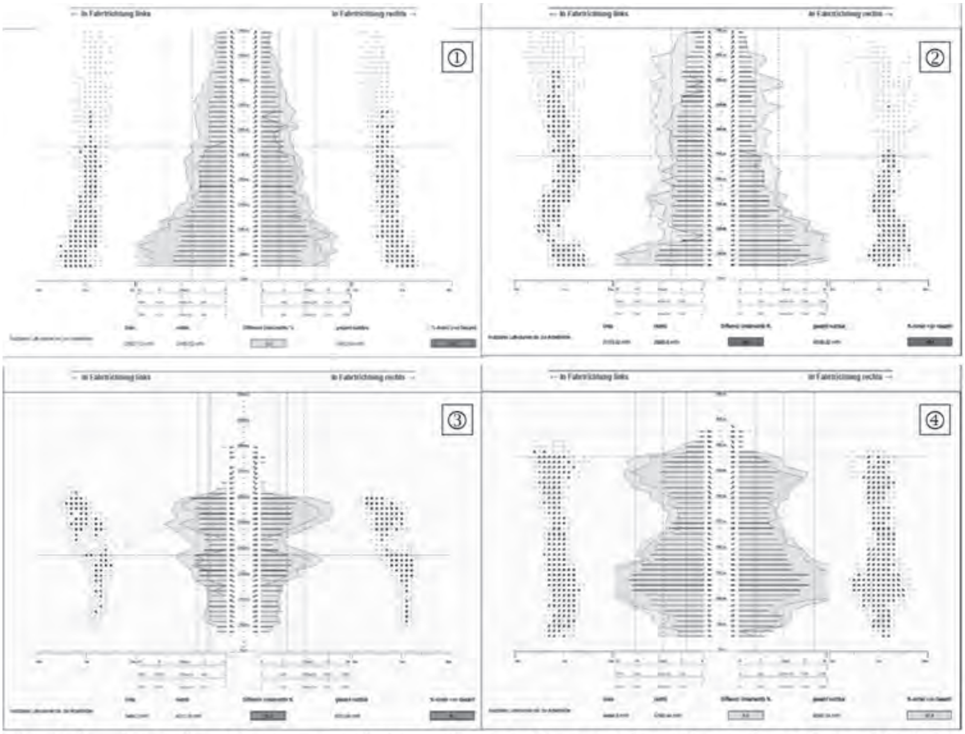
b) an adaptation of fan speed to canopy width at any forward speed in order to prevent the spray mist exiting the canopy at the opposite side and moving across the next alley way or out of the orchard,

c) a combination of air induction nozzles at the two top most positions and small droplet hollow cone nozzles in any other positions and

d) dosing models that calculate not only dose rate and water volume in relation to canopy characteristics, but also forward speed and in the future even fan speed.

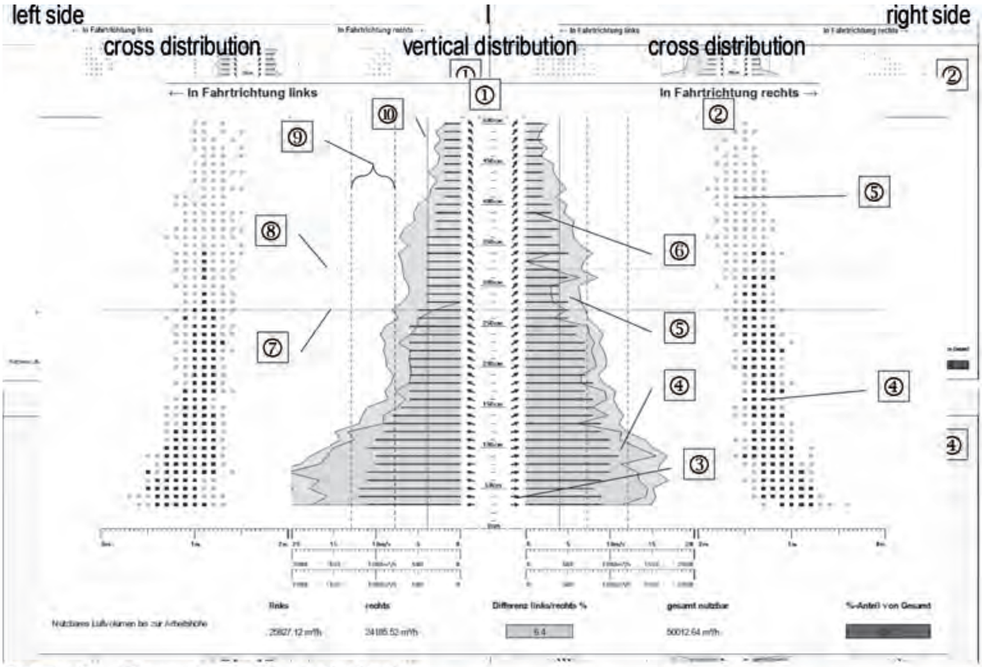
A basic obstacle for the adaptation of fan speed to canopy width has been the vertical air distribution of fans since in the past this was not taken into account at all for orchard and vineyard sprayers, because a high air volume and low forward speed have been assumed to be essential for good penetration into the canopy and good spray cover. Accordingly first measurements of the air distribution disclosed very uneven air distribution patterns which result in a very uneven horizontal reach of the air stream over working height. The result of such an uneven distribution is that in practice fan speed is increased until the spray mist from the section of the fan with the lowest horizontal reach sufficiently penetrates the canopy for the successful control of pests and diseases. At the other sections of the fan the horizontal reach consequently becomes far to strong, shooting the droplets through the canopy and high into the atmosphere. Keeping the droplets mostly inside the canopy by a canopy adapted fan speed, increases deposition efficiency significantly and offers the chance of reducing dose rates related to canopy characteristics without decreasing spray cover and a reduction of biological efficacy. Contrary to the wide spread opinion an excessive fan speed has remarkable detrimental effects on the efficiency of spray deposition in relation to water volume sprayed and the quantity and quality of spray deposits, is the main reason for avoidable spray drift from small droplets and increases fuel consumption and noise emission, of which at least the far distance visibility of spraying with an excessive air stream and noise are main causes for increasing complaints from bystanders and settlement areas. But also retailers and environmental organizations demand for the development and utilization of means to reduce contamination of non target areas and the CO_2-footprint of agricultural production. With a sprayer having an uneven air distribution, in the end fuel consumption and noise emission have to be raised in order to compensate a poor vertical air distribution, undoing all the benefits a canopy adapted fan speed offers for efficient and environmentally more friendly spray application.

As a defective vertical air distribution (**graph 1**) has been identified to be the key parameter preventing the introduction of a canopy adapted dosing and spray application, in 2010/11 the "Kooperation der Regionen", a cooperation for improving, testing and adjusting air distribution of orchard and vineyard sprayers has been founded by the "Styrian Professional Fruit Growers Association", the "South Tyrolean Advisory Board for Fruit and Vine Growing" and the "Marktgemeinschaft Bodenseeobst eG". Also a new air test bench using ultrasonic sensors has been developed and installed in the three regions at Gleisdorf, Austria, Lana, Italy and Friedrichshafen, Germany.



Graph 1: Examples of poor vertical air distribution: ①= axial fan, ②= tower sprayer, ③= tower sprayer, ④= twin fan

In 2013/14 the performance of the test bench itself has been improved to increase work rate and the two page protocol has ben reengineered. It now contains a graphical display of the vertical air distribution of both fan sides and a dot graph of the cross distribution based on a 100 x 100 mm resolution of the sensor. The graph of the vertical air distribution shows the angle of the air stream at each vertical measuring position, but also maximum speed and the air volume above a threshold level of speed and volume, defined as the usable air volume. The maximum variation of the usable air volume over working height is secured by a threshold value of a coefficient of variation. A second air volume between the threshold level for the usable air stream and a threshold for the speed of ambient air, defined as non usable air volume that does not reach the canopy during spray application is also displayed. To adjust the vertical air distribution as close as possible to a rectangular shape and to offer a guidance for the adjustment of the air distribution to maximum tree height to be sprayed with the indivdual fan, a corridor over working height is displayed in the protocol, calculated from the average value of usable air volume over working height, a threshold for maximum positive and negative deviation and a maximum percentage of measuring heights over working height with the usable air volume located outside the corridor. The working height is automatically calculated by the test bench as the height above which on either fan side on two or more neighbouring measuring heights a minimum of usable air volume has not been recorded, being marked by a first horizontal line. Half a meter above working height a second horizontal line is displayed, defining the upper limit up to which the air support should be cut off in order to keep the potential for vertical spray drift above the canopy as low as possible. Both values of non usable air volume above working height are secured by individual maximum percentages of total air volume. Additionally the difference of the usable air volume between left and right fan side should not exceed a certain threshold level as well as the ratio between non usable and total air volume (**graph 2**).

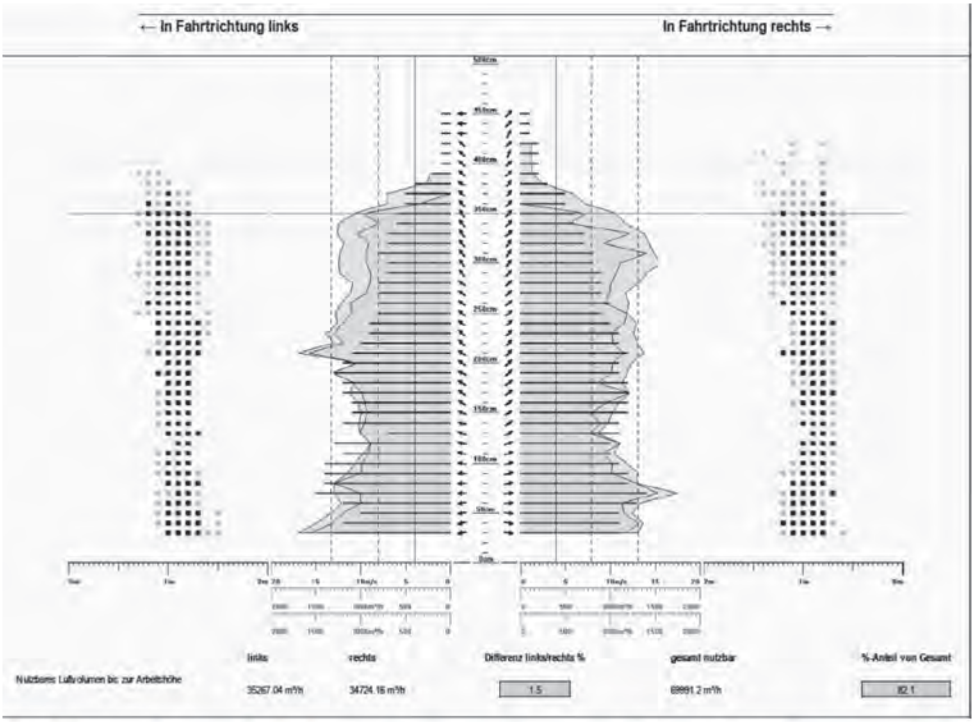


Graph 2: Protocol, page 2: air distribution

①= vertical distribution, ②= cross distribution, ③= angle air stream, ④= usable air volume, ⑤= non usable air volume, ⑥= maximum wind speed, ⑦= working height, ⑧= target vertical cut off air stream, ⑨= dynamic corridor usable air volume, ⑩= minimum speed usable air volume

Detailed information about the result calculated for any parameter is displayed on page 1 of the protocol and is coloured in green if the parameter meets the threshold value and in red if it does not. A fan has passed the test when all parameters stay within their threshold values resp. all fields are coloured in green (**graph 3**).

The threshold values for automated judgement of the air distribution are defined by the working group "Kooperation der Regionen" consisting of the three test bench operators, which developed guidelines of an air distribution suitable for "Low Loss Spray Application" in agreement with sprayer manufacturers participating in the "Low-Loss Spray Application" concept on an annual workshop. To enable potential customers finding out which fan types meet the demands of "Low Loss Spray Application" at the farm specific maximum working height, a positive list of fan types is published and updated according to demand. A fan type listed there is approved to meet the guidelines of "Adjusted Air Distribution " or "Low Loss Spray Application". Even when being listed in the positive list, any individual new sprayer with the same fan type as listed needs to be adjusted before purchase, because it is impossible to manufacture a series of fans with the same vertical air distribution. However, this is also not necessary, as long as the fan is adjustable – which is the case when the fan is on the positive list - because the air distribution anyways needs to be adjusted to the farm specific working height and then straightened to approach the rectangular vertical air distribution as good as possible.



Graph 3: Vertical air distribution of a tower sprayer meeting the guidelines of Low Loss Spray Application

The protocol also contains "environmental data" about energy consumption and specific energy consumption at three defined fan speeds from the fan type tests for the positive list, enabling the comparison of the energy efficiency of fans from various manufacturers. Environmental data are completed by noise measurements also at three fan speeds.

With the positive list and the environmental data potential customers are informed prior to ordering a sprayer about basic features of fans from various manufacturers. After a customer has chosen the fan type most suitable for this farm specific needs, the vertical air distribution is to be adjusted to farm specific working height and the air volume straightened before purchase. To avoid an accidental change of positions of deflection plates during delivery and use, they are permanently fixed after the adjustment. Fixing of deflector plates is absolutely necessary, since the vertical air distribution is extremely sensitive to even smallest changes of just millimeters of the orientation of the deflection plates and other obstacles in the air system. In case the fan cannot be adjusted to the desired working height or does not pass the test, it is returned to the manufacturer and the contract of purchase becomes void.

With this system of the three important fruit growing regions cooperating in testing and adjusting the vertical air distribution of sprayers for three dimensional crops, growers have the guarantee to buy a sprayer with a fully functioning air support that provides a uniform horizontal reach of the air stream over farm specific working height after successfully being adjusted to the tree height at the customer´s farm. With the uniform rectangular air distribution, proven by a protocol from before and after the adjustment the grower may make use of basic benefits of canopy adapted spray application, as there is an improved spray deposition and a reduction of fuel consumption and noise emission. When following the more strict rules of "Low-Loss Spray Application" the grower may additionally combine the high work rate of low volume spray application with an effective drift reduction enabling the utilization of reduced buffer zones to water courses, the reduction of pesticide consumption on a farm level by canopy adapted dosing and spray application, avoid visual deposits, minimize the risk for phytotoxicity and significantly reduce time consumption and costs of crop protection.