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Investigations into leaf deposit quality for plant protection in minimally pruned vineyards

With plant protection in hedgerow system vineyards (minimum pruning) the resultant foliage density hinders spray penetration to target surfaces with insufficient wetting of all parts of the plants. The investigation presented here tests the efficacy of different sprayer designs in these types of vineyards. Trial procedure is based on already existing methods of leaf deposit measurement in espalier vineyards and modified to account for the increase in leaf area and the specific leaf canopy geometry. Trial results show a very broad scatter of leaf deposit and a marked deficit of deposits on the foliage canopy roof area. The recorded data contribute to further development of application methods. Special attention is required in future investigations toward increasing the number of spot samplings.

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Hedgerow system, spraying, leaf deposit measurements, vineyard sprayers

Abstract
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Viticulture with any future potential must consider ways of growing vines with reduced labour input. Probably the most efficient of all growing systems in viticulture is the minimum pruning approach. This requires the lowest labour input per hectare. Minimum pruning systems can involve only 50 to 70 labour hours ha^{-1} [1]. This growing system has already been followed for 20 years in new wine production countries such as Australia [2], and is becoming more important in Germany too. Refraining from a winter pruning for early regulating has the result of vines bearing more grapes. This is compensated during the growing season through self-regulation of the vine and development of smaller single grapes. The resultant dense, bell-shaped foliage structure means the grape harvest can be carried out entirely by machine. Additionally, plant protection operations have to be very thorough because the dense vine row is more difficult to penetrate [1]. From the viticultural point of view, better treatment results were assumed for the radial fan sprayer design because of the comparatively high air velocities generated by this type of fan and the resultant more intensive penetration of the target areas. According to an empirical survey of plant protection in viticulture, out of 80 minimum pruning vineyards, 50 % used axial fan sprayers and 35 % radial fan sprayers [3]. So far, however, there have been no investigations into the real deposit quality resulting from the use of the different fan spray designs in this type of vine growing. To reliably identify the most suitable fan sprayer type for plant protection in minimum pruning systems, leaf deposit measurements were first taken following use of the most commonly applied sprayers, those with axial fans and those with radial fans.

Material

The field trials with two different fan spray designs took place in a Geisenheim minimum pruned vineyard representing the classic application of extensive vine cultivation with widely-spaced rows 2.8 m apart and dense foliage walls 1.6 m wide. The Wanner fan sprayer “SZA 24” (**Figure 1**) was selected as reference sprayer for the modern axial fan design. This type is used very often in German viticulture. The enclosed airflow system produces a comparatively precise horizontal demarcation of airflow in the upper and lower boundary zones of the foliage canopy wall. The fan blower is centrally situated in the fan casing. This positioning serves to counter the steep upward and downward movement (swirl effect) that occurred with older axial fan sprayers. Airflow deflector plates additionally guide the air stream in the horizontal direction, which results in a marked minimising of spray drift. The maximum air flow rate capacity of this type of fan measured 30,000 m^3 h^{-3} in the pre-

trial air distribution test stand, with a maximum wind velocity of 23.6 m s^{-1} (at 540 rpm pto speed). The sprayer, equipped with six external jets, had only one transmission position.

Investigated as representative of the radial fan technology was a new type of fan from viticulture machinery manufacturer KMS-Rinklin that has achieved satisfactory leaf deposit levels in steep vineyards, as well as in direct application in espalier systems (**Figure 1**). The low-pressure fan is situated at the upper end of a downward-tapered diffusion chamber.

The air, which is sucked in at right angles to direction of travel, flows through four rigid, V-form air exit openings onto the target areas. The upper air fans have a second jet attached that is activated when spraying the high foliage walls produced by the minimum pruning system. The maximum airflow rate of this fan is 19,000 $m^3 h^{-1}$, the maximum wind velocity 15.6 m s^{-1} (at 540 rpm). Other radial fan designs are equipped with forward-bending shovels and produce markedly higher wind velocities.

Methods

For investigating application results in minimum pruning, it was decided to separately record spray deposit on both sides of leaves. The colouring substance Brilliantsulfoflavin (BSF) was used for quantitative determination of leaf deposit efficiency. The target concentration of the tracer substance in the total container was 1 g L^{-1} BSF.

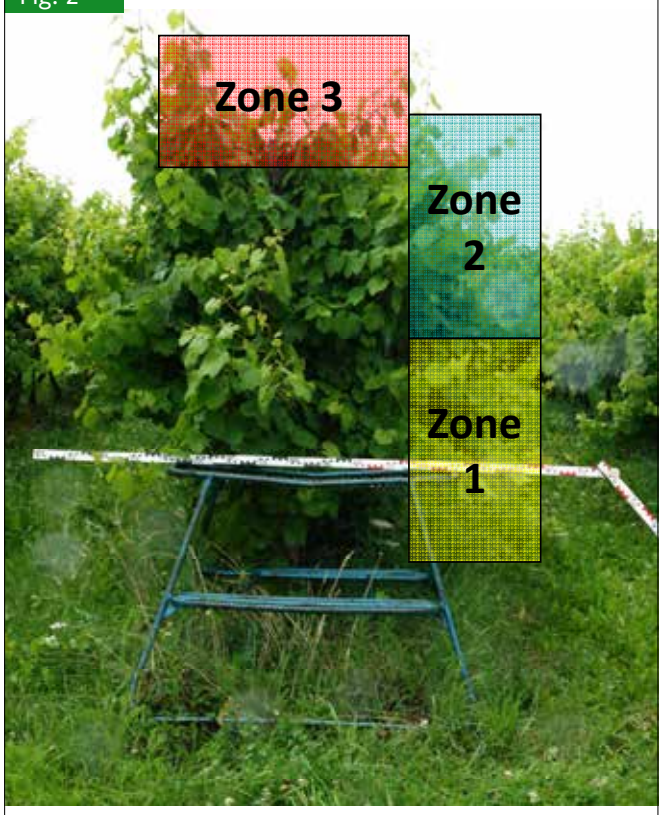
After application, a ten-minute drying period was allowed to avoid redistribution of spray liquid during sampling. Collecting leaves for sampling was started 15 to 20 meters after the beginning the rows because only from this point was a constant delivery of spray liquid and target sprayer forward speed able to be reliably recorded. The vine leaves were deposited in bowls of different colours to permit definite identification of the height zone from which the respective leaves were taken. They were then delivered to the wash table. There, each leaf was placed between a plastic platelet and a roll rim vial filled with 10 ml of distilled water. The roll rim vials have a defined opening surface area of 5 cm^2. During laboratory assessment, the concentration of the colouring substance in the liquid was measured with a fluorescence spectrometer and given in µg cm^{-2} as initial deposit in relation to the washed leaf surfaces.

The method described can already be found in the applicable literature with regard to leaf deposit measurements in espalier vineyards [4; 5; 6]. In order to meet the special challenge of spraying minimum pruned system vines, the respective sampling method was modified so that it was limited to three areas specific to minimum pruning. The height of the foliage wall at vine stage BBCH 75 was 250 cm above the ground on the sampling day whereby the bottom of the foliage was 70 cm above ground. The breadth of the foliage wall in the expansive areas reached from 160 to 170 cm. With minimum pruning, there is no localisation of the grape zone, this being spread over the entire foliage wall including the canopy roof of the foliage bell form. The three sampling zones were accordingly established as (**Figure 2**):

Fig. 1

Sprayers in the trial for measuring leaf deposits in minimum pruning system. Left: Wanner SZA 24 axial fan, right: Rinklin radial fan (Photo: Hochschule Geisenheim University)

Fig. 2



Spot sampling zones for leaf deposit measurements in minimum pruning system (Photo: Hochschule Geisenheim University)

- zone 1 = the area between 70 and 160 cm (the lower half of the foliage wall),
- zone 2 = from 160 to 250 cm (upper foliage wall half) and
- zone 3 = the roof of the foliage canopy.

Sampling zone 3 involved an elevation aid in the form of a fruit harvesting sledge. From each sampling zone were taken 30 leaf upper surfaces and 30 leaf under surfaces. This gave 180 leaf samples for each trial variant.

Because of the large vertical expansion resulting from the minimum pruning system, the lowest of the five jets on the Rinklin sprayer was positioned at 85 cm, 15 cm higher than with espalier systems. With the SZA 24 axial spray, the lowest jet was positioned at 75 cm, whereby six jets were opened. All trials were carried out at 6 km h^{-1} with a work pressure of 8.5 bar and injector jets. In order to compensate for the design-caused difference in the given number of jets, different calibres of jets were used on each sprayer giving a constant spay mix use of 400 l/ha^{-1}. As is usual in practice, the sprayers were first driven with a pto rpm of 540, with this being reduced to 400 rpm for a second trial variant. Hereby, the idea was to analyse whether a reduction of air volume and air velocity through reduced fan rpm had a positive or a negative effect on leaf deposit quality.

Observation of the spot sample scatter took place via creation of separate variation coefficients according to leaf upper surface or leaf under surface. In the presentation of the results the scatter of individual values is presented as percentages of the respective average leaf surfaces. In viticulture, variation coefficients of under 100 % are seen as acceptable values regarding uniformity of active ingredient distribution.

Another calculation method involved more qualitative assessments of the amount of individual distribution through generation of threshold value frequencies. The threshold value frequencies are always based on the common average value of all samples within a trial series. If the deposit mass on an individual leaf lay under 25 % of this average value, then the deposit on this particular leaf would be evaluated as insufficient. If the values of the individual samples fall under 10 % of the average, then the leaves in question would be seen as without any recognisable deposit. In this way, statements can relate to the procentual proportion of each leaf in a trial variant that has no deposit, or an insufficient deposit.

Results and discussion

First measurements of leaf deposits in minimum pruning show that the foliage roof level (zone 3) tended to be reached least of all by the active ingredient (**Figure 3** and **Table 1**). Even the more easily reached upper leaf surface in this zone was only slightly covered. In this respect, the reach distance of both sprayers appeared insufficient for application in the foliage roof level.

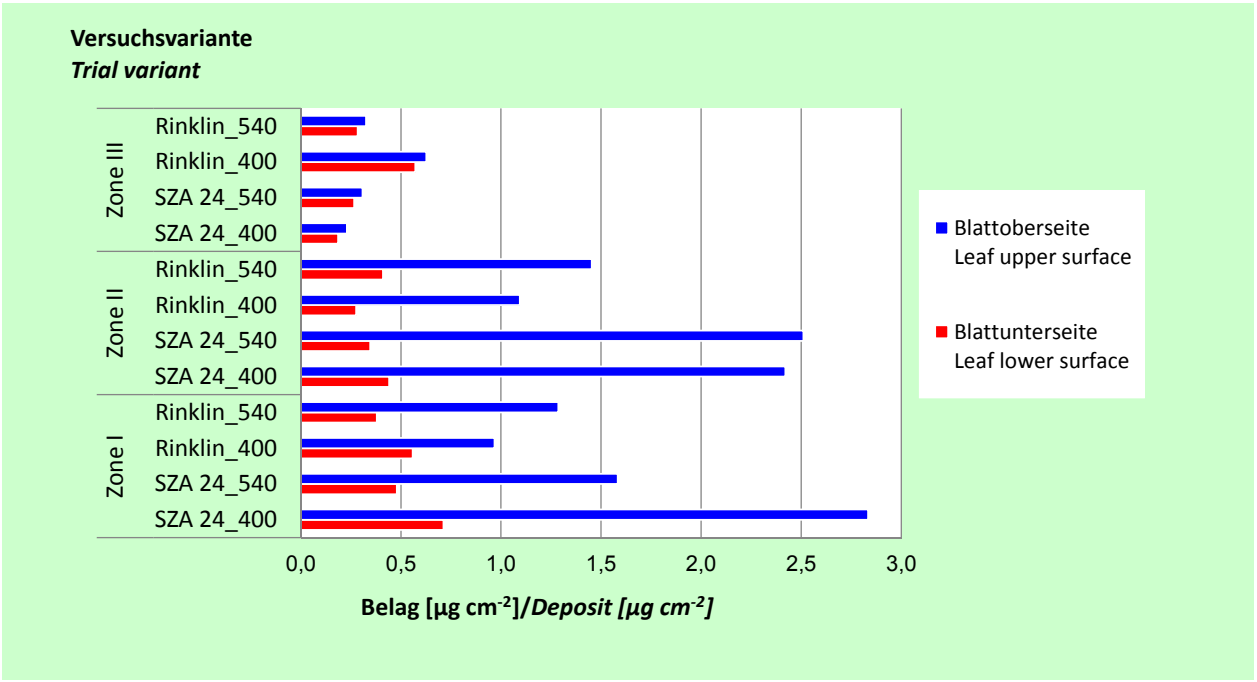
Of the two sprayers, the SZA 24 covered the large leaf areas of the zones 1 and 2 rather better in respect of leaf upper surfaces, possibly because of the higher air volumes produced by this model. Comparing performances of the fan designs and the effect of different pto speeds indicates that the radial fan deposited, with reduced rpm, a little more active ingredient on the leaf under surfaces in zones 1 and 3. With the setting for 400 rpm, the SZA 24 performed, on average, slightly better 0.1 µg cm^{-2} in the two lower zones.

However, the recorded results did not, in general, achieve the normal deposit levels on leaf under surfaces otherwise achieved in espalier systems. Experience has indicated that good deposits on the leaf under surfaces lie, with the given tracer application levels, in the area of 1 µg cm^{-2} or more. On the other hand, there is little experience to go by with minimum pruning vineyards. But it is important that the increase in leaf area be considered in future evaluations.

On top of this, the high scatter of deposit values achieved by both sprayers (**Table 1**) proves a characteristic of minimum pruning systems. With variation coefficients of up to 230 %, uniformity of active ingredient deposits on the leaf under surfaces is therefore very much poorer than the normal results in viticulture. On the other hand, the results on the leaf upper surfaces showed a marked improvement in variation coefficients although this is to be expected taking into account the special foliage wall geometry in minimum pruning systems.

With regard to threshold value frequencies, the high scatter of individual samples is also very marked. In the trials in the minimum pruning system, 10 to 20 % of leaves were identified as having no deposit. Trials carried out in parallel in espalier vi-

Fig. 3



Leaf deposits in minimum pruning with leaf upper surface and leaf lower surface results shown separately. The Rinklin and SZA 24 fan sprayers were powered with standard pto (540 min^{-1}) and at a reduced speed (400 min^{-1})

neyards showed only 0 to maximum 7 % leaves with no deposit. From 30 to 45 % of leaves in the minimum pruning system were identified as insufficiently covered, the respective figures for the espalier system were only 5 to 15 %. Especially the leaves with absolutely no deposits, or those with only very little deposit, represent a high infection potential within the dense, less aerated vine hedge formed by this extensive growing system.

Table 1

Average leaf deposits of all trial variants with results for leaf upper and lower surfaces shown separately, taken from results in the lower leaf wall half (zone 1), the upper leaf wall half (zone 2) and the foliage canopy (zone 3) with respective variation coefficients

Versuchsvariante *Trial variant*	**Stichprobenzone** *Sample area*	**Blattunterseite** *Leaf lower surface*		**Blattoberseite** *Leaf upper surface*	
		Blattbelag *Leaf deposit* [µg cm^{-2}]	**Variationskoeffizient** *Variation coefficient*	**Blattbelag** *Leaf deposit* [µg cm^{-2}]	**Variationskoeffizient** *Variation coefficient*
SZA 24 540 min^{-1}	1	0,5	99	1,6	97
	2	0,3	**170**[1)]	2,5	100
	3	0,3	**120**[1)]	0,3	79
SZA 24 400 min^{-1}	1	0,7	**154**[1)]	2,8	67
	2	0,4	**167**[1)]	2,4	73
	3	0,2	**230**[1)]	0,2	100
Rinklin 540 min^{-1}	1	0,4	108	1,3	90
	2	0,4	**176**[1)]	1,5	99
	3	0,3	**146**[1)]	0,3	**125**[1)]
Rinklin 400 min^{-1}	1	0,6	**166**[1)]	1,0	96
	2	0,3	**125**[1)]	1,1	88
	3	0,6	**141**[1)]	0,6	92

[1)] Streuung der Stichproben zu hoch/*Spot sampling scatter to high.*

Alongside the reported research, subsequent work should investigate the subjective experiences of German wine growers with different fan sprayer technology in minimum pruning vineyards. A self-conducted survey [3], as well as gathered statements of disease control experience, indicate that the widely accepted assumption in practical viticulture that a powerful fan with high wind velocities leads to better treatment results should be revised. 50 % of the radial fans applied led, according to statements by participants, to an infection situation over a five-year treatment cycle, in the case of axial fan sprayers there occurred an infection with peronospore only in 33–35 % of the cases. A greater air volume appears, in this relationship, to lead to better treatment results than through spraying with high wind velocities.

Conclusions

First analyses of deposit formation in crop protection of minimum pruning system vines allow only hypotheses, not conclusive results. Only between a half to a third of the under surfaces of leaves in minimum pruning systems had deposits, compared with the results in espalier systems. In particular, the foliage roof level proved difficult for the active ingredient to reach. The deposit variability found in spot samples was, however, too high on the leaf under surfaces and the procentual proportion of leaf surfaces insufficiently covered, or not covered at all, was also markedly increased compared to results with the espalier growing system. Subsequent trials should, therefore, definitely increase the number of spot samples to at least 360 leaves per trial. On the other hand, as method for spot sampling in minimum pruning systems a three-part zoning of the foliage wall, with separate sampling of the horizontal foliage roof level, proves practical and sensible.

The assumption in practical viticulture that powerful radial fan sprayers are more suitable for application in minimum pruning vineyards could be neither confirmed nor denied in the trial design presented here. This was because the KMS Rinklin radial fan applied is, with its lower air velocity, not representative of this type of fan and therefore the results are not generally transferable to radial fan sprayers. The Rinklin sprayer is a special model designed for steep vineyards and the consequent lightweight construction of its blower fan means it cannot produce the highest wind velocities. Therefore further investigations aim at using a radial fan with higher wind velocities, which has already become established in practical viticulture. The SZA 24 fan, too, that originally was not conceived for widely-spaced rows, should also be replaced in further investigations by a design with more powerful fan potential, for instance the fruit and vineyard fan sprayer SZA 28. This sprayer would more suitably represent the axial fan design for application in minimum pruning in that it is more suitable for application in the vineyard-specific characteristics of this growing form. Whether the factor wind velocity has the greatest significance in minimum pruning, or that of air volume, must be tested once again with the proposed machines.

Additionally, in particular trials with over-the-row sprayers should be done, because these could offer further exploitation of minimum pruning system efficiencies while still achieving satisfactory deposit results. These trials are being planned.

From the very low leaf deposit found in the foliage roof level, with axial as well as with radial fan sprayers, first conclusions can include the necessity for development of a special sprayer concept for minimum pruning vineyards. A possible approach might be an additional sprayer arm applying spray from above and onto the targeted foliage roof.

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