Pilot study of spray drift on small organic farms in Switzerland

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1. Background

Spray drift is a major problem for organic farmers, particularly in small fields (Speiser and Kretzschmar, 2021). To support the advocacy work of IFOAM Organics Europe concerning this issue, the present study was carried out.

2. Materials and Methods

2.1 Selection of field sites

A total of five organic winegrowers from five different villages were selected for this study. All vineyards are located in traditional wine-growing areas in the South of Switzerland (cantons Vaud and Valais). To protect the farmers, they remain anonymous in this study. On each farm, one small field was selected which borders directly to a conventional vineyard. Only fields were included that have no directly neighbouring fields treated by helicopter (helicopter application has a different drifting behaviour and would have distorted the pilot study).

The field study was carried out in 2021, which was an extremely wet year, necessitating more frequent use of fungicides than usual.

2.2 Sampling and analysis

Leaf samples were taken on 7 July 2021. This is the peak spraying season, when highest residues can be expected. In total ten samples were collected (two samples per vineyard): One from the first row of vines, bordering directly to the conventional vineyard, another one from the second row of vines.

Fruit samples were taken on 13 September 2021. This is shortly before harvest, where lower residues are expected. Four samples were taken as a rule: the first, second and third row, as well as a row in the field centre. Because one vineyard is only four rows wide, only two samples (first and second row) could be taken there. Thus, 18 fruit samples were collected in total.

All samples were deep-frozen immediately after collection. The samples were sent to Labor Friedle in Germany[1] for analysis. Each sample was subject to a 'multiresidue screening' covering over 800 substances. In addition, all samples for also analysed for the presence of fosetyl and phosphonic acid. These two pesticides are known to occur frequently in wine, but cannot be detected with the multiresidue screening. The limit of quantification was 0.01 mg/kg for all substances except phosphonic acid, for which it was 0.02 mg/kg. Traces below the limit of quantification were also reported by the lab. For determining the 'samples with at least one pesticide detected' and the 'number of substances detected', these traces were included. For calculating the 'median pesticide load per sample', only findings above the limit of quantification were considered.

[1] https://www.labor-friedle.de/home.html

2.3 Cost estimates for establishment of buffer zones

Cost estimates were made for two possible strategies for residue prevention by establishing buffer zones. The first strategy consists of conventional marketing/ processing of the grapes harvested in the *organic border rows*. This strategy is frequently mentioned as a measure to prevent residues in organic wine (Speiser and Kretzschmar, 2021). The second strategy for organic winegrowers to prevent residues from drift is the following agreement between the organic farmer and his neighbour: When the organic winegrower treats his organic grapes, he also treats the *conventional border rows* which are directly bordering to the organic field. In turn, the conventional neighbour abstains from treating his border rows with conventional pesticides. In both cases, the cost estimates were made for border rows of 1, 2 or 3 rows width.

The cost estimates for preventive measures were based on the established calculation model for gross margins (total revenues minus direct costs; no labour costs) in Swiss agriculture. This model is known as 'Deckungsbeiträge' (Agridea, 2021). We used the standard values for organic and conventional viticulture for the variety 'Chasselas', which is frequently grown in the study area. For the first strategy, the gross margin for organic grapes was calculated with the price for conventional grapes. For the second strategy, the costs for plant protection, as shown in the calculation model, were used. Because the study is explicitly focused on small farms, the calculations are based on the sizes of the studied vineyards. For these fields, we determined what proportion of the total vineyard a border of 1, 2 or 3 rows width would make up. To determine the gross margin for the entire field, the gross margin for the field centre and for the border rows under strategy 1 or 2 were calculated separately and then added up.

3. Results

In *every sample* (!), at least one pesticide was detected. A preliminary data inspection showed that phosphonic acid shows a different pattern from the other pesticides. Therefore, phosphonic acid was analysed separately from all other substances (including fosetyl).

3.1 All substances (excluding phosphonic acid)

3.1.1 Substances found, frequency of detection

From the >800 substances detectable with the multiresidue screening, a total of 20 substances were detected. These are given here in order of decreasing frequency (number of detections in brackets): folpet (19); cyflufenamid (10); fosetyl (6); amisulbrom (4); cymoxanil (4); fluxapyroxad (4); mandipropamid (4); myclobutanil (4); quinoxyfen (4); spiroxamin (4); zoxamid (4); 2,6-dichlorbenzamid (3); cyprodinil (2); difenoconazol (2); fenhexamid (2); penconazol (2); trifloxystrobin (2); ametoctradin (1); metalaxyl (1);

metrafenone (1); pyrimethanil (1). All of these substances are either fungicides or fungicide metabolites.

3.1.2 Leaf vs. fruit samples

The results for leaves and fruit are compared in Table 1. The number of pesticides detected ranged from 4 – 9 (average 6.4) on leaves and from 0 – 3 (average 1.1) on fruit. The pesticide load on leaf samples ranged from 0.02 – 33.5 mg/kg (median 0.75 mg/kg). On fruit, it ranged from 0 – 0.09 mg/kg (median 0 mg/kg).

Table 1: Pesticide residues in leaf (N=10) vs. fruit (N=18) samples.

	Leaves	Fruit
Samples with at least one pesticide detected	100 %	56 %
Average number of substances detected per sample	6.4	1.1
Median pesticide load per sample (all substances)	0.75 mg/kg	0 mg/kg

3.1.3 Variability between vineyards

The results for individual vineyards are shown in Table 2. The average number of pesticides found on leaves of an individual vineyard ranged from 4.5 – 8.0 and on fruit, it ranged from 0 – 2.0. The pesticide load showed much greater variability. On leaf samples, it ranged from 0.19 – 19.81 mg/kg (=factor 100). On fruit, it ranged from 0 – 0.05 mg/kg.

The great variability on leaves is due to greatly elevated residues of folpet and of phosphonic acid in vineyard D, which are probably due to a single drift event with a combination product or a tank mix containing these two active ingredients. On fruit, the residue levels were also elevated in vineyard D.

Table 2: pesticide residues for individual vineyards, separately for leaf and fruit samples.

1) Leaves, vineyard…	**A**	**B**	**C**	**D**	**E**
Average number of substances detected per sample	4.5	8.0	6.5	8.0	5.0
Median pesticide load per sample (all substances; mg/kg)	0.19	1.12	0.48	19.81	0.35
2) Fruit, vineyard…					
Average number of substances detected per sample	0.3	1.8	0	2.0	2.0
Median pesticide load per sample (all substances; mg/kg)	0	0.01	0	0.05	0.03

3.1.4 Distance from neighbouring field

The results for rows with a different distance from the neighbouring field are shown in Table 3. The number of pesticides found on leaves slightly declined from row 1 to row 2. On fruit, no clear pattern was observed. The median of pesticide load on leaf samples markedly declined from row 1 to row 2, while on fruit, no clear pattern was obvious.

Table 3: pesticide residues at different distances from the neighbouring field, separately for leaf and fruit samples. Row 1, 2, 3 = first, second and third row from the border. C = field centre.

	Leaves		**Fruit**			
Row	**1**	**2**	**1**	**2**	**3**	**C**
Average number of sub-stances detected per sample	6.8	6.0	1.6	0.6	0.8	1.5
Median pesticide load per sample (all subst.; mg/kg)	0.95	0.14	0	0	0	0.01

3.2 Phosphonic acid

3.2.1 Leaf vs. fruit samples

The results for leaves and fruit are compared in Table 4. Phosphonic acid was found in *all* leaf and fruit samples (!). The median phosphonic acid load on leaf samples ranged from 0.12 – 7.6 mg/kg (median 0.80 mg/kg). On fruit, it ranged from 0.03 – 1.7 mg/kg (median 0.23 mg/kg).

Table 4: residues of phosphonic acid in leaf (N=10) vs. fruit (N=18) samples.

	Leaves	**Fruit**
Samples with phosphonic acid detected	100 %	100 %
Median phosphonic acid load per sample	0.80 mg/kg	0.23 mg/kg

3.2.2 Variability between vineyards

The results for individual vineyards are shown in Table 5. The phosphonic acid load showed great variability. On leaf samples, it ranged from 0.22 – 4.95 mg/kg (=factor 20). On fruit, it ranged from 0.04 – 1.25 mg/kg.

The great variability on leaves is due to greatly elevated residues of folpet and of phosphonic acid in vineyard D, which are probably due to a single drift event with a combination product or a tank mix containing these two active ingredients. On fruit, a different pattern was found. Here, vineyard B showed the highest residue level of phosphonic acid, which contrasts with the pattern for folpet described in chapter 3.1.3.

Table 5: phosphonic acid residues for individual vineyards, separately for leaf and fruit samples.

1) Leaves, vineyard…	**A**	**B**	**C**	**D**	**E**
Median phosphonic acid load per sample	0.22	0.75	0.57	4.95	0.96
2) Fruit, vineyard…					
Median phosphonic acid load per sample	0.04	1.25	0.20	0.35	0.41

3.2.3 Distance from neighbouring field

The results for rows with a different distance from the neighbouring field are shown in Table 6. The phosphonic acid load on leaf and on fruit samples showed no clear pattern.

Table 6: residues of phosphonic acid at different distances from the neighbouring field, separately for leaf and fruit samples. Row 1, 2, 3 = first, second and third row from the border; C = field centre.

	Leaves		**Fruit**			
Row	**1**	**2**	**1**	**2**	**3**	**C**
Median phosphonic acid load per sample	0.79	0.88	0.40	0.25	0.14	0.36

3.3 Cost estimates for preventive measures

3.3.1 Characterisation of the studied vineyards

The vineyards selected for this study ranged from 420 – 4000 m^2, with an average of 2400 m^2 (0.24 ha). The number of rows ranged from 4 – 35, with an average of approximately 23 rows.

3.3.2 Standard organic practices

For viticulture under standard practices, the figures of the 'Deckungsbeitragskatalog' (Agridea, 2021) show a gross margin of 21 926 CHF/ha.

3.3.3 Strategies for establishing buffer zones

Table 7 shows the cost estimates for the two strategies for residue prevention with buffer zones. The estimates were made for three scenarios, where the buffer zone comprises 1, 2 or 3 rows. Because the border rows make up only a minor proportion of the total vineyard, the gross margin for the entire vineyard (including the border row) is only slightly reduced.

Strategy 1: Because the price for conventional grapes is lower, the gross margin for the organic border rows alone is estimated at 14 726 CHF/ha. The gross margin for the entire vineyard ranges from 20 183 – 21 345 CHF/ha.

Strategy 2: In the concerned border row, this practice generates costs for plant protection, but no returns. The estimate reveals that the gross margin for the conventional border rows would be -1 001 CHF/ha, while the gross margin for the organic field remains constant. The gross margin for the entire vineyard ranges from 20 684 – 21 845 CHF/ha.

Table 7: Estimates of the gross margin (in CHF/ha) under standard organic practices and with different strategies for drift prevention with buffer zones.

Width of buffer zone (number of border rows)	1	2	3
Conventional marketing of border rows	21 345	20 764	20 183
Organic plant protection in neighbouring rows	21 845	21 764	21 684

4. Discussion

4.1 Patterns of residues observed

The patterns of residues found in this study are discussed for all substances jointly except phosphonic acid, which is discussed in a separate paragraph (see 4.1.5).

4.1.1 Variability between vineyards

In leaves from field D, high residues of fosetyl and folpet were found. For both substances, the levels strongly declined from row 1 to row 2, thus clearly indicating a drift event. This might likely have taken place with a combination product containing both active substances. This is also reflected in the fruit samples, although less pronounced. In leaves from fields A, B, C and E, residue levels were much lower.

4.1.2 Distance from neighbouring field

This pilot study was designed to investigate *patterns* of residues and does not allow drawing conclusions about the *origins* of residues. As an exception, it does allow preliminary conclusions regarding drift. If residues decline markedly from the margin towards the centre of a field or vineyard, this is generally interpreted as an indication for drift. In 3 out of 5 vineyards (A, C, D), the residue levels for every substance found on leaves declined from the border to the centre, thus indication drift as a likely cause. In the remaining two vineyards, some substances showed this pattern, while other substances showed the opposite pattern. On fruit, no clear pattern was observed.

However, a certain amount of pesticides was detected also in the field centers. This might be caused by drift over longer distances, for example with thermic winds or with helicopter applications. For the small vineyards studied here, distance is thus not enough to protect organic grapes from drift.

4.1.3 Frequency of drift events

As stated in the previous chapter, the occurrence of drift cannot be proven by this study, but it can be identified as a likely reason. Bearing this limitation in mind, it can be concluded that cases of likely drift occurred frequently in the studied vineyards. Since individual leaf samples contained 4 – 9 different substances, it is obvious that each vineyard must have been subject to several drift events before the sampling.

4.1.4 Sampling time

Fewer pesticides were found in fruit than in leaves, and residue levels were generally lower. This is probably due to a combination of factors:

- Many modern pesticides degrade quite fast. The leaf samples were taken in the peak spraying time, when the vineyards were sprayed every couple of days. By contrast, the fruit samples were taken in mid-September. As pesticides may be applied in grapevine only until mid-August, no drift had occurred for one month prior to the fruit sampling.
- Part of the pesticide residues was probably washed away by rain.
- We assume that fruit generally have lower residues than leaves, due to a lower surface/weight ratio.

4.1.5 Deviating pattern of phosphonic acid

Phosphonic acid was found in *all* leaf and fruit samples. In the leaf samples, phosphonic acid was found in levels comparable to or lower than the other pesticides. In the fruit samples, however, phosphonic acid was found at much higher levels than the other pesticides. Residues of phosphonic acid in organic products can have several origins (BioSuisse, 2020). The most likely origins in this context are: heritage of past applications of phosphonic acid or fosetyl in previous years, before the vineyard was converted to organic and drift. The third major origin, undeclared content of phosphonic acid in fertilisers, plant strengtheners or plant protection products, is unlikely, because the Swiss input list[2] closely monitors their inputs to ensure absence of phosphonic acid.

We hypothesize that the presence of phosphonic acid in this study is due to a combination of drift and the high persistence of phosphonic acid in grapevines (Bögli and Speiser, 2019). Grapevines might be subject to multiple drift events over many years, causing the level of phosphonic acid in the grapevines to slowly build up over time. The study design does not allow drawing conclusions on the origins of residues, and more knowledge regarding the long-term behaviour of phosphonic acid in vineyards would be required for an appropriate interpretation of the residues found.

[2] The Swiss Input List is a register of allowed fertilisers and plant protection products. Bio Suisse farmers may only use products which are included in this list. see https://www.betriebsmittelliste.ch

4.2 Possibilities for preventive measures

A recent publication by FiBL gives an overview over the measures to prevent residues on organic products (Speiser and Kretzschmar, 2021). Buffer zones are one tool to reduce drift. For two strategies of residue prevention with buffer zones, as described by Speiser and Kretzschmar (2021), cost estimates were made in this study. These show that preventive measures such as conventional marketing of border rows or organic plant protection in the neighbour's border rows come at relatively low direct costs for organic farmers. Organic plant protection in the neighbour's border rows is economically the more favourable option, but it requires the consent of the neighbour. However, we point out that the two strategies only reduce the likelihood of drift, and do not to completely eliminate this risk. Furthermore, the estimates only consider direct costs and income, while neglecting labour and non-monetary aspects such as reputation damage. Finally, the cost estimates relate only to one border. For an organic vineyard surrounded by conventional vineyards, the costs would thus be higher. Whether one of the two strategies involving buffer zones can be used successfully in a given vineyard must be determined case by case, and the decision cannot be based on these cost estimates alone.

On the other hand, it is also important that non-organic vinegrowers adapt their spraying technique in ways that minimize drift. Drift-reducing measures include choice of an appropriate type of sprayer and nozzles, adaptation of water volume, pressure and driving speed, use of drift-reducing additives and spraying under favourable climatic conditions (Speiser and Kretzschmar, 2021). The effects of such measures were not assessed in this pilot study.

4.3 Comparison with monitoring studies

Pesticides in organic wine are regularly monitored. In a recent study, hardly any residues were found in organic wines (Schildknecht, 2022). This contrasts with the findings of this pilot study. However, this study was limited to organic leaves and grapes, and did not include organic wine, and residues in grapes cannot be compared directly with residues in wine. In addition, we hypothesize that the size of the vineyards might contribute even more to the difference between the two studies. While this pilot study was deliberately carried out in small vineyards, the wines included in the study of Schildknecht (2022) were obtained from supermarkets and must therefore come from much larger vineyards. It is evident that drift affects small vineyards more than larger vineyards.

5. Conclusions

This pilot study has been carried out in a small number of vineyards and therefore does not allow drawing final conclusions on the drift risk for organic vineyards in general. Nevertheless, the results support the following preliminary conclusions:

- On small organic vineyards, drift from conventional neighbours *occurs regularly* and many organic vineyards seem to suffer from multiple drift events every season.
- Leaf samples during the peak spraying season show a substantial level of drift into organic vineyards. Fortunately, the level of pesticide residues greatly declined until mid-September.
- In many cases, residue levels decline markedly from the border row towards the centre of the vineyard. However, the field centres are not completely free of pesticides, which is probably due to a certain extent of drift over longer distances. These residues cannot be prevented by organic winegrowers. In the case of phosphonic acid, storage in the woody parts or carry-over from the time before conversion are also possible explanations.
- In addition, we observed one case of a much stronger drift event, resulting in greatly elevated residue levels. Based on the present data, we cannot estimate the frequency of such events.
- Organic farmers can partially (but not completely) mitigate the effects of spray drift by marketing border rows as conventional, or by applying organic plant protection in the neighbouring conventional rows. Cost estimates show that these strategies come at a relatively low cost for organic winegrowers. However, whether such strategies can be followed must be determined case by case.
- In conclusion, organic winegrowers have the possibility to manage residues due to drift to some extent. However, they cannot completely eliminate drift risks and are therefore dependent on the spraying habits and equipment of the winegrowers in their surroundings. Small fields are more affected than larger fields.

6. Acknowledgement

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Other contributions

7. Literature

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