"Optimisation of downy mildew (*Plasmopara viticola)* control in organic viticulture with low copper doses, new copper formulations and plant strengtheners, results of 20 years of on farm research"

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Key words: viticulture, downy mildew, copper formulations, Myco-Sin VIN, Potassium-Phosphonat (phosphorous acid).

Abstract

Since 20 years in different wine growing regions in Germany, due to weather and infection conditions several fungicide (copper formulations) and plant strengtheners (Myco-Sin VIN®, Ulmasud®, Frutogard®), different plant extracts and compost extracts applications against downy mildew are required in order to obtain satisfactory disease control. Results of the 20 years of on farm trials confirmed good efficacy of the copper based substances like copper hydroxide, partly in combination with two or three applications of Potassium Phosphonat, (Frutogard ®,) new copper-hydroxide formulation or copper oxychloride used in a low doses of copper, copper-octanuat (Cueva®) and alternative products like Myco-Sin-VIN® (sulphuric clay-limestone with high aluminium content).

Introduction

An organic vineyard is a complex living system where the grower actively tries to encourage the self regulation of the ecosystem and the health of this organism. In organic viticulture one of the primary goals is to grow healthy and disease tolerant or resistant plants. With the help of plant strengtheners, which are accepted by organic standards, and with the correct soil- and plant management the regulation of fungal diseases through the induction and enhancement of the plant's own defence mechanisms, can be approached. Only as a last step chemical fungicides (copper and sulphur) are used to manage fungal problems. At the moment, organic viticulture cannot exclude direct plant treatments.

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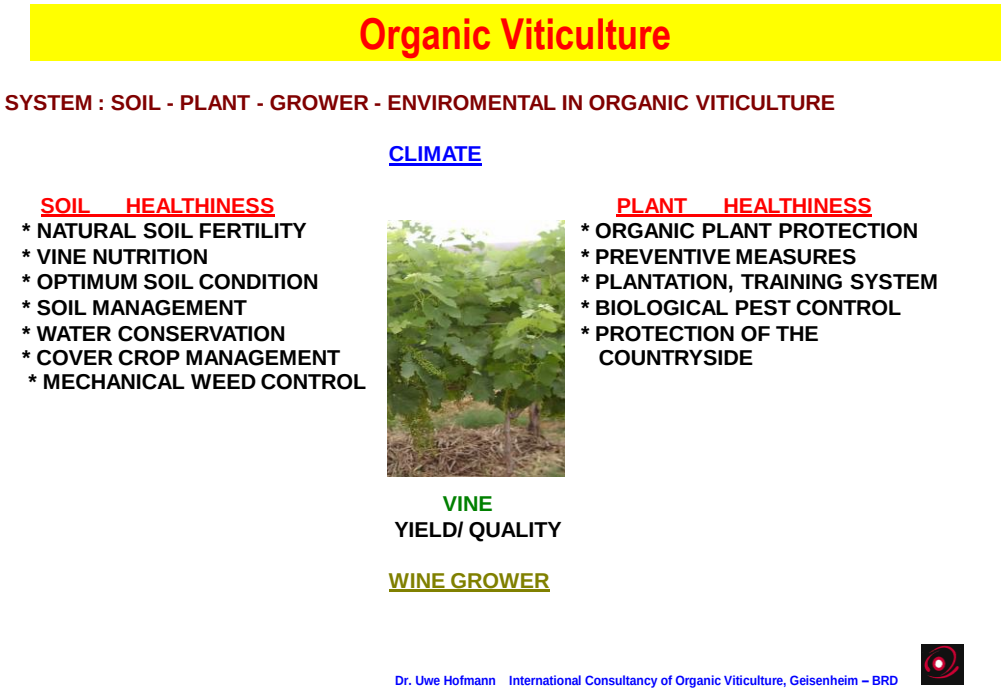
In organic viticulture, there are five main principles of plant protection:

1) fertility and health of the soil
2) viticultural practises, appropriate varieties and training systems
3) timing of the intervention
4) use of plant strengtheners to enhance the natural defence mechanisms
5) biological pest control and habitat management.

The knowledge of the fields and of the soils characteristics, the weather conditions and seasons, which affect the vineyard, are also necessary technical devises.

Graph 1: Organic viticulture a holistic approach.



All the plant growing and plant caring steps with their methods of inter-row –and under vine planting, herbal leys, green manuring, mulching, mowing, soil melioration, compost applications, choice of suitable varieties and rootstocks, training and pruning techniques, try to enhance the health and quality of the vine and its fruit.

Plant resistance can be induced in general and in specific ways. The cuticula and the stomata can be strengthened to create a physical barrier for the fungal spores to enter the inside of the plant cells. Also, the infection pressure can be reduced by applying naturally occurring resistance elicitors (i.e. can trigger a response to plant pathogens). The efficacy of botanical

extracts usually depends not only on one active ingredient but on the diversity and the synergy of the various ingredients.

Downy mildew is one of the most harmful grapevine diseases in every European wine growing zone, the epidemics of which can cause tangible damage both to the leaves and to the bunches. The pathogen can infect all of the vegetative organs of the vine such as leaf, tip, flower, cluster, stalk and young fruit, and can cause numerous infections during the season. Various symptoms can be observed, corresponding to the different stages of the disease cycle: the "oil spots", the whitish mould and the necrotic tissues. The most critical phases for downy mildew infection and yield loss are from beginning of flowering to fruit set.
The greatest damage done by the fungus is the infection of the cluster of young berries and the stalks with an extremely high fruit loss.

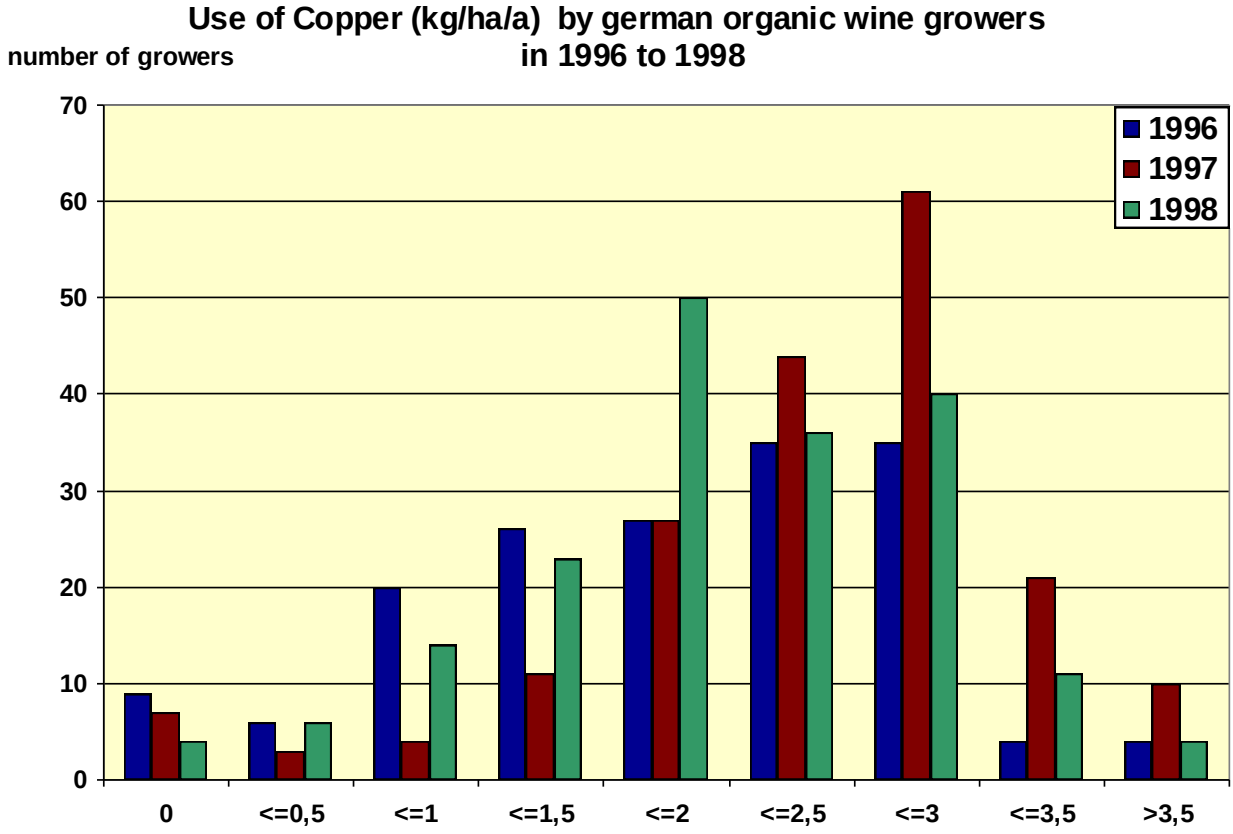
Graph 2: Downy mildew infection on young clusters, Oil-spots and new sporulation on leafs (leaf-borne infection)

The infected and damaged berries are dried out and fall down, there is a influence on wine quality mostly on red grapes, where skin fermentation is recommended. A late downy mildew attack can cause total leaf loss in certain very sensible varieties. Almost all of the *vitis vinifera* varieties are susceptible to downy mildew.

For most winegrowers, whether using organic or integrated methods, downy mildew is one of the major disease problems. Organic winegrowers pay more attention on this disease: they follow official advices and protection methods, conduct field observations and are keen on preventative control strategies. Especially in organic viticulture it is not easy to control this disease as there are only a few products with the desired efficacy are available.

The most common product is copper in different chemical formulations like Bordeaux mixture, Copper-oxychloride, Cupper-hydroxide, tri basic Copper-sulphate, Copper-oxide and Copper octanuat. The copper ion is very immobile in soil, therefore, copper applications result in an accumulation of this element in the soil. That is the reason why organic winegrowers try to reduce its use.

Under the Council Regulation (EEC) 2092/91 Annex II the annual input of copper in organic production is limited to 6 kg / ha (average of 30 kg 5 years/ha), in Germany, Austria and Switzerland not more than 3-4 kg / ha (average of 15 kg 5 years/ha) are allowed.
Graph 3 gives an overview of the copper use in German organic vineyards in the years 1996-1998 (Hofmann, U. 2000).



Between 1988 and 2003 ECO-Consult and the Organic Winegrowers Association of Germany (BÖW) has coordinated a on farm research program concerning copper reduction in organic vine protection.

The following products were tested against downy mildew:

- Copper – oxychloride (Funguran, 450FW)
- Copper-hydroxide (Cuprozin fl.)
- Copper-octanuat (Cueva)
- Myco-Sin, Myco-Sin VIN
- Ulmasud
- Different limestone-products
- Propolis
- Ökofluid, Frutogard (Potassium-Phosphonat)
- Compost extract (horse manure, cow manure)
- Plant extracts (i.e. horse tail-*Equisetum arvense*; golden rod-*Solidago canadensis*; rhubarb-*Rheum rharbarbarum*; willow-*Salix alba*; ivy *Hedera helix*; sage *Salvia officinalis; S. fruticosa;* thyme *Thympra specicata)*
- Microbiological antagonists (i.e. *Erwinia herbicola*)

(Kast, W. 2002; Kauer, R. et al 2002; Schmitt, A. 1998, Vanhaelen, M.& Vanhaelan-Fastre, 1979; Yegen, O. 1992; Häseli, A. 1995; Hofmann, U. 1987, 2000, 2004; Schildknecht, H. 1981; Weltzien, H.C. & Ketterer, N. 1986; Ketterer, N. 1990; Sackenheim, R. et al. 1990; Tilcher, R. 1996; Tilcher, R. et al 2002)

The plant extracts as well as the compost extracts have shown good results under greenhouse-conditions on one year old potted vines. All extracts loose there efficacy under real field-conditions. The only products which had satisfactory results against downy mildew were:

Copper-formulations, Myco-Sin VIN, Ulmasud and the Phosphonat preparations. Tab. 1 shows the disease incidence of downy mildew in the year 1990-2003.

Tab. 1: Disease incidence of Plasmopara viticola infection on clusters in the years 1990 – 2003

(ring trial - on farm research) (Hofmann, U. 2002).

Variants 8 - 12 Treatments	Number of trials	Mean of infection	Maximum infection rate	Minimum infection rate
Copper-oxychlorid Ø < 3 kg Cu / ha	175	28,7	90,5	0
Cueva < 2 kg Cu /ha	5	32,5	70	0
Myco-Sin	27	33,0	89	0
Myco-Sin – VP	32	30,5	89	0
Ulmasud	12	33,5	87	0
Ulmasud 2 X Copper-hydroxide (1,5 –2 kg Cu/ha)	25	26,8	51	0
untreated	50	85	100	10

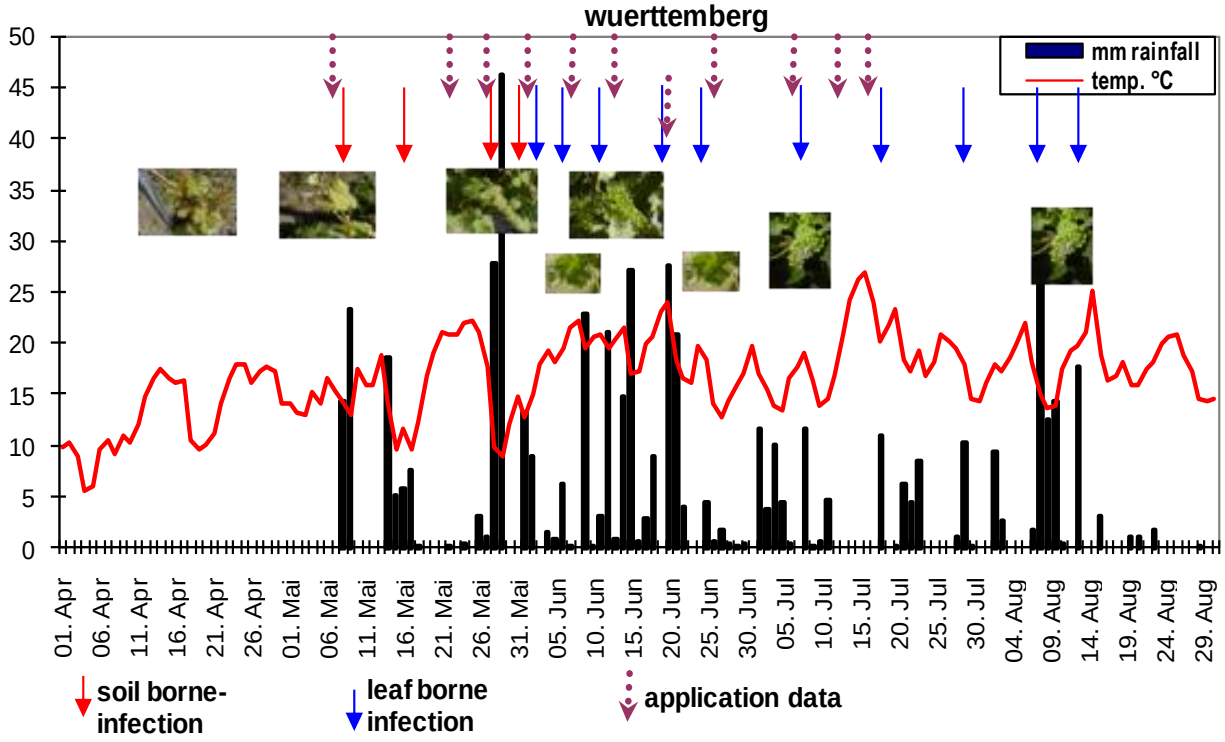
In a second step on farm field trials were engaged during 2004 to 2008 in four organic vineyards under practical conditions with grape varieties Riesling, Müller-Thurgau and Trollinger. These varieties are susceptible for downy mildew. In these three wine growing regions in Germany different climatic and infection conditions for downy mildew are present. The trials were split in two replicates / treatment with two replicates / row (long-plot method). Plot size varied from 900 – 1700 m². Spray volumes ranged from 400 to 1600 l/ ha. 8 – 12 applications were made using the farm vineyard sprayer. The rate of copper was according to the phenological stage between 50 – 400 g/ha and 1,5-3 kg /ha pure Cu in total. Tab. 2. shows the spraying program from 2004 to 2008 for the three different treatments.

Table 2: Experimental program 2oo4 – 2008 for the different treatments.

Year	Treatment 1	Treatment 2	Treatment 3
2004	Cuprozin fl.® (Copper-hydroxide) Frutogard® (Algae extract with Potassium Phosphonat)	Copper 450 FW® (Copper-oxychloride)	Myco-Sin VIN® (clay with Al-sulphate) Cuprozin fl.®
2005	Cuprozin fl.® Algin Biovital® (Algae extract)	New Copper-hydroxide Formulation	Myco-Sin VIN® Cuprozin fl.®
2006	Cuprozin fl.® Algin Biovital®	New Copper-hydroxide Formulation	Myco-Sin VIN ® Kendal® (Plant extract) Cuprozin fl.®
2007/ 2008	Cuprozin fl.® Frutogard®	New Copper-hydroxide Formulation	Myco-Sin VIN ® Kendal® Cuprozin fl.®

The on farm trials were done without an untreated control. The infection conditions were predicted by the use of specific forecast systems like "VitiMeteo Plasmopara" (Bleyer at al 2006) and the information from on farm weather stations. Graph 4 shows the specific weather- and infection conditions for one on farm trial in 2007.

graph. 4: weather - and infection data april - august 2007 location - wuerttemberg



Results of the four years trials

At the start of the project in 2004 there were no **new treatments** for downy mildew from the laboratory and greenhouse trials available, in this case the trials started on the pilot farms with well known and established plant protection strategies against downy mildew with 3-4 kg Cu** in form of copper-oxychloride, copper hydroxide and acidified clay mineral products like Myco-Sin VIN® in combination with 2 copper applications. In 2004 no infection was monitored. From 2005 new copper products with lower copper content and the combination of copper hydroxide with plant strengtheners (algae extracts, plant extracts and Phosphonat) as well as Myco-Sin VIN® in combination with Kendal® were tested.

In the year 2005 a flower cluster infection was occurring in all trials. Based on the appropriate strategy to increase the natural grape defence mechanism against downy mildew by preventative treatments, the disease incidence was lower than 5% with no effect on crop yield. At the same time the infection was significantly higher in conventional neighbouring vineyards and could be controlled only by using systemic fungicides.

The results of the four years trials showed that products like copper hydroxide, new formulated copper hydroxide with low copper content (1,5 – 2 kg/ha/year) or alternative products like Myco-Sin VIN® give good results under medium infection pressure which were present in three of the four farms and locations. The combination of copper hydroxide at low rates with two or three applications of Potassium-Phosphonat (Frutogard®) at pre flowering to fruit set showed a very good control of *P. viticola*. These results compare to some long term on farm (Hofmann, 2003) trials (Kast 1996; Kauer 2003, Tamm, L. et al 2004; Tamm, L. et al 2006). In case of severe infection conditions, which were present on one of the pilot sites (Württemberg-Germany) in most of the years, Myco-Sin VIN® as well as the low copper concentrations were not successful (Tab.2). In 2006 high damage was caused by a severe infection after a longer rainy period on July 8th. The effect of all treatments was very low with a disease incidence of 50%. There was no difference between the treatments. In the year 2007 the high damage was caused also by severe infection after a longer rainy period end of May beginning of June (graph 4). The highest attack was detected in the plots that had been treated with Myco-Sin VIN® in combination with Kendal®. The three applications of Frutogard® from last pre flowering until fruit setting reduced the infection from 76 %to 18%. The new copper- hydroxide formulation with 1,9 kg pure copper/ha reduced the infection from 76 to 47% and was as successful as the combination with Phosphonat (Berkelmann-Löhnertz, B. et al. 2008).

Table 2 : Disease incidence and disease severity (%) of *Plasmopara viticola* infection on clusters of the variety Trollinger in the years 2006 and 2007 at Korb, Württemberg (Germany).

	Treatments	**N°. App.**	**Disease incidence %**	**Disease severity %**	**Cu ++ rate kg/ha**
2006	Cuprozin® fl. 0,05% Algin Biovital® III,	10 10	50,0	15.5	1.8
	new copper-hydroxide formulation 0,1%	10	50.0	15.8	1.2
	Myco-Sin VIN® 0,5% Kendal® 1% Cuprozin® fl.	9 9 1	50.0	15.,8	0.6
2007	Cuprozin fl. 0,05% Frutogard ® 1%	11 3	18.0	11.8	1.9
	new copper-hydroxide formulation 0,1%	11	47.0	16.7	1.9
	Myco-Sin VIN® 0,5% Kendal ® 1%	11 11	76.0	24.3	0.0

Conclusions

In three of four on farm trials with low or medium infection pressure in the years 2004 to 2007 the application for downy mildew control with low copper content < 2 kg/ha and with plant strengtheners like Myco-Sin VIN® were successful. Only on one vineyard with higher infection pressure depend on the specific weather conditions (higher rainfall) downy mildew could infect clusters and leaves with no different disease incidence between the treatments. Only the combination of low rate copper formulation in combination with K-Phosphonat until fruit set reduced the infection. As of today, it is not possible under high infection pressure of downy mildew (*P. viticola*) to reduce the copper level lower than 3 kg.

PLANT PROTECTION STRATEGY AGAINST *PLASMOPARA VITICOLA*

DOWNY MILDEW

<table>
<tr><th colspan="3">Plant Protection strategies</th></tr>
<tr><td colspan="3">Downy mildew</td></tr>
<tr><td>- no risk

Planting of high resistant and tolerant grape varieties (PIWI) reduce the use of specific plant treatments.

Two plant treatments with low copper content or plant strengtheners before and after blooming

Well structured canopy</td><td>- low infection pressure

Dry weather conditions, low rainfall, no dew,
low humidity < 40%
late primary infection (after blooming)
day temperature > 30°
night temperature < 10°

Weather forecasting system
Well structured canopy
Application methods, timing of the treatments

Spraying every second row
Treatments with low copper content (100 – 500 g Cu/ha per spray) or plant strengthener</td><td>- high infection pressure

Wet and warm weather conditions, high or permanent rainfall, dew,
high humidity >95%
early primary infection
day temperature < 30°
night temperature > 20°

Weather forecasting system
Well structured canopy
Application methods, timing of the treatments

Spraying every row, weekly treatments with high copper content (500 – 1000 g Cu/ha per spray),
maximum use of Copper: 6kg Cu/ha (30 kg in the average of 5 years)</td></tr>
<tr><td colspan="3">Regulatory framework:
Regulation (EC) No 834/2007: Article 12: (g) the prevention of damage caused by pests, diseases and weeds shall rely primarily on the protection by natural enemies, the choice of species and varieties, crop rotation, cultivation techniques and thermal processes;
(h) in the case of an established threat to a crop, plant protection products may only be used if they have been authorized for use in organic production
Authorized organic plant treatments included in Annex IIB,
National regulations of plant protection</td></tr>
<tr><td colspan="3">Additional comments: infected berries are dried out and fallen down (yield loss),
Selective harvesting, sorting and destemming are necessary, infected berries can influence the quality of the wine (mush-fermentation by red wine)
Copper has a negative role on the expression of sulphuric aromas such as the « thiols ».
Copper treatments increase the skin thickness, This thickening favours a better resistance to the end of the cycle diseases: grey rotting and acid rotting.</td></tr>
<tr><td colspan="3">Environmental impact: copper is a heavy metal and a very persistent fungicide, which are accumulate in the soil and be toxic for some microorganisms, long term strategies to reduce the amount of copper are necessary</td></tr>
</table>

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